The effect of volatility and market cap on cryptocurrency portfolio's

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Abstract

I study the influence of two factors which have proven to influence the stock market. Applying the knowledge to the cryptocurrency market. 50 of the largest cryptocurrencies are studied over a 2,5-year period from December 2018 to June 2021. Both for the volatility anomaly, and the size effect presence no significant evidence was found. The cryptocurrency market behaved against expectations.

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1. Introduction

It all started on the 3rd of January 2009. The birth of Bitcoin. Providing a currency that was not dependent on financial institutes and gave the users privacy (Nakamoto, 2008). This was the beginning of the cryptocurrency market. Over the years Bitcoin has seen massive growth, but massive crashes too. Characterized by its high volatility and high returns the coin has grown to a multibillion market cap currency. With the current state of Bitcoin approaching the 1 trillion mark and the entirety of the market already surpassing it, it is no longer something that can be ignored. Over the years interest has grown. Not just by investors, but by researchers as well. With the market being very young, there is still a lot left undiscovered. This paper will try to shed some light on not just Bitcoin, but on 50 cryptocurrencies who are among the largest in the market. The paper is inspired by Fama & French and their paper titled: Common risk factors (1993). The second main paper which is discussed is the volatility effect by Blitz & van Vliet (2007). These two papers will form the fundamentals for this research. Their key findings will be tested on the cryptocurrency market to see whether there are similarities or if they are fundamentally different. With the two papers in mind, we derive two main questions this paper will try to answer:

1. Is there a volatility effect in the cryptocurrency market?
2. Is there a size effect in the cryptocurrency market?

To answer this question, we will start with a literature review. First, I will dive into the volatility anomaly. Next, I characterize the cryptocurrency market by its key differences to the stock market, as well as highlight already published research including the size effect. After the literature review, I will describe the data as accurately as possible and follow this with a description of the methodology. Here I will describe formulas used and their function. Following up is the result section where I will discuss the findings of this study and explain their meaning. To finish I will write my conclusions and give a discussion on improvements of this paper as well as suggestions for further research.

2. Literature review

2.a Volatility Anomaly

In 1964 the CAPM model arose (Sharpe, 1964). Theorized by William Sharpe about stock returns under risk. With its main insight the positive correlation between stock returns and risk. Stating that investors who undergo a higher risk should demand a higher return to compensate for said risk. This was a revolutionary finding that got rewarded in 1990 with the Nobel prize.

The CAPM model has been tested numerous times, and already in the early 70's it was researched by Fama and Macbeth (1973) with the result that they could not find a significant influence of risk on the returns of stock. Later the Fama and French three factor model was proposed to add two variables in explaining returns (1993). Firstly, the size of the firm based on its market cap. This variable is named Small Minus Big (SMB), which refers to the returns of large cap stocks minus the returns of small cap stocks. Secondly the characteristic of a company's book to market ratio was added as variable. This variable is named High Minus Low (HML) which refers to high book to market ratios minus low book to market ratios. Adding these 2 variables improved predicting a stock's returns from 70% by Sharpe to 90% accuracy (Fama & French, 1998).

Various other attempts have been done to improve the forecasting of returns. There remains a volatility anomaly, where low volatility stocks outperform high volatility stocks. The volatility effect is described by Blitz and van Vliet (2007) where, even after adjusting for various factors, low volatility stocks still outperform high volatility stocks based on returns, Sharpe ratio and alpha. This finding is in

contradiction with the efficient market hypothesis and suggests that investors are overpaying for riskier investments.

Over time this theory has been tested on various markets. The first research was done over the largest 2000 companies in the research of Blitz and van Vliet. In 2013 the same research was done on the emerging markets (Blitz, Pang, & van Vliet). In emerging markets, the same volatility anomaly was found. On average there were 1000 stocks in the market sample, with very similar results as the first paper. Now with the Chinese economy becoming larger and larger the same study was performed on the Chinese market where there are a lot more private investors active, as well as more government influence (Blitz, Hanauser, & van Vliet, The Volatility Effect in China, 2021). Even though the market is characterized by key differences the volatility effect remained statistically significant. I conclude that the volatility effect is prevalent in various markets. This anomaly is however not yet tested in all markets. In this paper I will focus on whether the volatility effect is present in the cryptocurrency market.

2.b Cryptocurrency market

In 2009 the first cryptocurrency emerged: The Bitcoin. Developed by the anonymous programmer (or programmers) that goes by the pseudonym Satoshi Nakamoto. The cryptocurrency came with a new technology named Blockchain. The main purpose was to generate a system for electronic transactions without relying on trust on a third party (such as banks), instead using the protection of mathematical formulas (Nakamoto, 2008). Because of its transparency, efficiency, and anonymous character of ownership, Bitcoin has experienced rapid growth over the past decade.

As the popularity of Bitcoin increased, other cryptocurrencies emerged. As of 2021 over 5000 cryptocurrencies are listed on databases such as Coingecko.com and Coinmarketcap.com. The total market cap of cryptocurrency has surpassed the 1 trillion USD (see appendix b). The market has evolved rapidly and can be seen as a market on its own. The cryptocurrency market has various similarities to the stock market. Traders can trade on the market. Open, High, Low and Closing prices are reported. Market capitalisation can be calculated. Indices are present on the market. Even though there are similarities, there are some major differences between the stock market and cryptocurrency market that can influence the volatility effect discussed in this paper.

2.b.I Bubble dynamics

‘A bubble is an economic cycle that is characterized by the rapid escalation of market value, particularly in the price of assets. This fast inflation is followed by a quick decrease in value, or a contraction, that is sometimes referred to as a "crash" or a "bubble burst."’ (Investopedia). Cryptocurrencies are well known for their rapid growth. The most researched coin on the crypto market is Bitcoin by a large margin. Research has shown that bitcoin prices are prone to speculative bubbles (Cheah & Fry, 2015). There has been a bubble burst in 2018, with an 80% plunge (Patterson, 2018). The high volatility of cryptocurrencies makes it very susceptible to bubbles which drastically increases risk. Recently there has been another major sell-off in cryptocurrencies. Reason being the growing regulation from governments.

2.b.II Regulation

Since 2019 trading cryptocurrencies has been illegal in China. Nevertheless, people continued trading online. In May 2021 three major organizations in China issued warnings to costumers that there was no protection to their losses (BBC, 2021). The cryptocurrency market is new and knows little regulations, but China is not alone in banning cryptocurrencies. There are already 12 countries with bans on bitcoins, from religious, to controlling reasons (Stein, 2021). More moderate governments are debating which regulations should be applied to cryptocurrencies. Such as the USA, struggling taxwise

whether to classify cryptocurrencies such as Bitcoin as an asset or a currency (Marian, 2013). The cryptocurrency market has gotten more regulated over the years and this trend will most likely continue.

2.b.III Diversification

Prior research states that there is an association between a diversification strategy and profitability (Rumelt, 1982). It reduces risk and is something investors look for to obtain a safer portfolio. Therefore, new investments that can reduce risk and hedge against other investments are of interest for investors. A study performed by Brière, Oosterlinck and Szafarz (2015) has shown that Bitcoin shows significant benefits in portfolio diversification. However, the researchers warn for the early stage of the currency. Nevertheless, the risk-return trade-off of studied portfolios improved substantially. Since the cryptocurrency market is highly correlated between the cryptocurrencies, this paper will provide insights which might help investors choose which cryptocurrency is best for diversification in their portfolio. Helping them choose between high and low volatility stocks as well as large and small caps.

2.b.IV Market efficiency

We have seen in the volatility anomaly section that the stock market tends to be inefficient when it comes to risk return equilibria. However, it is difficult to give a solid definition of when the market is efficient. Richard Thaler, specialized in market efficiency, says in an interview to the Chicago booth that the market is efficient under two criteria: “first is can you beat the market, second whether prices are correct” (2016). Since the market of cryptocurrency is new, widespread research is not readily available. In 2016 the first study showed up on the (in)efficiency of bitcoin (Urquhart, 2016). Five empirical different tests were performed over the 2010-2016 period and proving that Bitcoin showed ‘quite strong’ inefficiency. Newer research however on the five largest cryptocurrencies see that up to 2018 the market was inefficient, but the following six quarters became efficient (Tran & Leivrik, 2020). In the paper they mention rapid improvement of price-return volatility, liquidity, and the relationship to other assets. Since this paper examines the period between December 2018 and June 2021, the hypothesis is that the cryptocurrency market will be efficient for the larger stocks (in this study). The smaller stocks and their efficiency however have not been studied enough to give a clear hypothesis.

2.b.V Large vs small cap

Research shows that in the cryptocurrency market there is a strong correlation between the liquidity of a coin and its efficiency (Wei, 2018). Suggesting that large cap stocks show a better price efficiency than small cap stocks. This suggests that the Fama and French three factor model might help explain the returns in cryptocurrency. However, this would only add the factor of SMB since the book to market value is not present in cryptocurrencies. There is however a problem with large cap cryptocurrencies data: it is for assets with a market cap larger than $10 billion. As of writing there are only 13 cryptocurrencies that fall into this group. Of which some do not have sufficient data available, making the group very small. To still examine this problem this study will divide portfolios in quintile groups based on their market cap.

2.b.VI Volatility anomaly

The low volatility anomaly has been studied by Burggraf and Rudolf (2021), they did however not find a low volatility effect. This research however varies from the original research by Blitz and van Vliet in a couple of ways. Both Alpha and Beta are not included, and the three-factor model is not applied. This paper will incorporate these factors.

2.b.VII Stocks vs Cryptocurrencies

In the above section various key differences between the stock market and cryptocurrencies are described. Where the stock market usually does not see a huge crash unless there are major macroeconomic factors at play such as the financial crisis and the corona crisis, the cryptocurrency market is characterized by bubble dynamics. Where the stock market is already heavily regulated, governments are figuring out which regulations on the cryptocurrency markets are deemed fit. The new diversification possibilities given by the cryptocurrency market have taken interest of investors and is becoming more popular over the years. Market efficiency study is currently mainly focussed on the 5 largest cryptocurrencies. This study will try to shed some light on other cryptocurrencies as well. Large and small cap cryptocurrencies are difficult to define and study since the market is so young and stocks are growing rapidly. This study will incorporate this topic. And lastly, the volatility effect is researched on a large sample. Given the young state of the market this paper will focus on a smaller sample to get more mature cryptocurrencies.

3. Data

For the data I use historical data obtained from CoinGecko. CoinGecko is a cryptocurrency database that was founded in 2014 (CoinGecko, 2021). It averages 10 million monthly users and is, together with Coinmarketcap, widely used as the primary database for research (Alexander & Dakos, 2019). As of 2020 Coinmarketcap became a paid service and CoinGecko became the largest provider of free historical data.

From CoinGecko cryptocurrencies are selected based on two criteria: firstly, they must have at least 2.5-years of data available. Secondly, the cryptocurrency cannot be based on another coin. There are various coins that are either equivalent to one Bitcoin or to one US dollar. Since these would not represent an individual coin, they add weight to for example Bitcoin which is unpreferable. Hence, they are left out.

The usual market index for stocks is the S&P500. For the cryptocurrency, this index is not representative. Mainly because of the different characteristics of the cryptocurrency market such as it being always open. There is not yet a clearly defined market standard for the cryptocurrency market. For this research was chosen for the Crescent Crypto Market Index (CCMIX). This index includes the largest cryptocurrencies and has a market coverage of 90% (Crescent, 2021). This index rebalances every month based on the trailing 90-day average market cap. As of writing the 18 largest crypto currencies are included (appendix 3). There might however be some included that are not included in our sample, due to a lack of historical data, e.g., Polygon (MATIC).

Both the cryptocurrency data obtained from CoinGecko, and the market data range from the 3rd of December 2018 onwards to the 6Th of June 2021. This is exactly 131 weeks which translates to 2.5 years of data. The data downloaded was daily data which is transformed to weekly data by looking solely at the first day of the week, Monday. Since the cryptocurrency market is open 24 hours a day 7 days a week, the time of reporting is 00:00:00 UTC.

The main variables are the time it was snapped at as described above. The price at given time and lastly the corresponding market cap. From this data new variables will be calculated: return and volatility. This will be explained in methodology.

4. Methodology

The methodology used for this paper consists of two parts. First equally weighted quintile portfolios are created based on their volatility. The volatility will be measured over a half year period. This consists of 26 weeks of returns. The average volatility will determine the composition of the portfolios over the following 26 weeks. The portfolios will be reweighted four times. With 26 weeks of each portfolio. In total the portfolios will have 2 years of data with 4 different compositions of assets weighted based on their historical 26-week volatility. This is a relatively short period, but since the cryptocurrency market is a very fast paced market this captures the most influential data.

Secondly, I create new groups of cryptocurrencies based on their market cap. When creating the portfolios, the market cap of the week prior to the creation date is used. This means that from the period of t_1 up to t_{26}, where t is the week of the portfolio, and 26 is the end of the period for the composed portfolio, the market cap of t_0 is used. The portfolio is reweighted 5 times over the course of a 2.5-year period. The reason that the market cap-based portfolio is weighted one time more than the volatility-based portfolio is that the volatility portfolio uses the first 26 weeks to determine the volatility whereas the market cap is already available.

Both groups of portfolios are taken the same actions. First de returns of the cryptocurrencies are calculated. Using the formula:

$$return = \ln\left(\frac{P_{new}}{P_{old}}\right)$$

Using Logarithmic returns has an important benefit. It deals better with outliers by using a normal distribution in calculating the returns. This shrinks outliers.

With this data the return of the portfolio can be calculated by taking the weight of the cryptocurrency multiplied by its return. Since all are weighted equally, this is the same as taking the average of the returns in said portfolio. With this return the standard deviation of the weekly returns can be calculated. In addition to the volatility, I consider alternative risk measures. The alternative risk measures used are the Sharpe ratio, Beta of the cryptocurrency to the market, and its corresponding Alpha.

For the Sharpe ratio the following formula is used:

$$Sharpe\ Ratio = \frac{r_i - r_f}{\sigma_i}$$

There is a study by Liu, Tsyvinski & Wu (2019) where the risk-free rate is measured as the one-month treasury bill of the United States. Since March 2020 however with the pandemic hitting this rate has plummeted to 0,01% (FRED, 2021). As opposed to 2,5% at its peak in 2019. This would give a very low risk-free rate in 2020 and 2021. During my corporate finance class, I was taught to use a different risk-free rate in such cases. With the advice provided by professor Dwarkasing being 2,00% annual return. Therefore, for calculating the Sharpe ratio a risk-free rate of 2,00% annually will be used. This annual risk-free rate will be transformed into weekly risk-free rate by dividing by 52. All returns have the risk-free rate already subtracted. For the Return and standard deviation, the weekly returns and deviation are annualised.

To obtain beta and alpha of the portfolios a regression is performed. Regressing the returns of the stock to the market with the risk-free rate subtracted. Giving the following equation.

$$R_{p,t} - R_{f,t} = \alpha_p + \beta_{p,M} * \left(R_{M,t} - R_{f,t}\right) + \varepsilon_{p,t}$$

Where $R_{p,t}$ is the return on portfolio p in period t. The risk-free rate is described as $R_{f,t}$, α_p is the alpha of portfolio p and $\beta_{p,M}$ is the beta of portfolio p to the market m. $R_{M,t}$ is the return of the market M in period t. Lastly $\varepsilon_{p,t}$ is the idiosyncratic return on portfolio p in period t. The risk-free rate is calculated by taking the annual risk-free rate of 2,00 percent with the reasons described above and turning it into weekly data by taking the root to the power of 52. With the resulting alpha and beta, the T-statistic is determined to see whether the variable is statistically significant.

5. Results

In the following section the results of the empirical findings are presented. First, I start with the results of the portfolios assembled based on their volatility. Starting with a summary of the statistics followed by the results. The findings will be studied and explained. With the explanation I will interpret the results and conclude their meaning. Secondly, I will examine the portfolios that are assembled based on their market cap. With another summary of the statistics, explanation, and an interpretation of the results.

Volatility based portfolios

Table 1:

This table shows the summary statistics of the portfolios sorted on their past volatility. With Low being the portfolio with the least volatile cryptocurrencies of the past 26 weeks increasing to High being the portfolio with the most volatile cryptocurrencies.

	Low	P2	P3	P4	High	Market
Observations	104	104	104	104	104	104
Mean (log)	1.66%	1.85%	1.16%	1.46%	1.52%	1.48%
Std. Dev.	0.142	0.149	0.152	0.138	0.145	0.1
Min	-66.12%	-69.10%	-69.23%	-62.75%	-65.41%	-47.11%
max	47.53%	45.00%	39.47%	36.89%	40.43%	27.02%

We see in table 1 that there are 104 observations. One observation represents one week of returns. Where 26 weeks is a half year. 104 weeks is exactly 4x26, what means that 104 weeks equals 2 years of data. The means of the portfolio are the average weekly returns. Meaning that the market portfolio of the cryptocurrencies had an average weekly return of 1.48%. When comparing this to for example the S&P500 which has an average yearly return of 10%, 1.48% weekly is incredibly high. The means of the portfolios do not show a clear upwards pattern. The low volatility portfolio does outperform the high volatility portfolio. This is not in line with the EMH and would suggest choosing a less volatile portfolio could reward higher returns. This does hint towards the volatility anomaly as previously discussed where low volatility assets outperform high volatility assets.

Table 2:

*This table show the statistical significance of the average returns of the volatility sorted portfolios. The t-statistic tests the chance of the mean being non-zero. The P-value is the chance of the mean being larger than zero. *, ** or *** determining their significance level on the 10%, 5% and 1% level.*

	Low	P2	P3	P4	High	market
Mean (log)	1.66%	1.85%	1.16%	1.46%	1.52%	1.48%
t-statistic	1.192	1.267	0.78	1.084	1.071	1.505
P (μ > 0)	0.882	0.896	0.781	0.863	0.857	0.932*

When we see whether the means are statistically significantly larger than 0, we see that only the market mean is significant at 10%, as shown in table 2. All the portfolios are not statistically significant from zero, which means that we cannot say that the portfolios grand an average net positive return at the common 5% significance level. This can mainly be contributed to their high volatility. Another important factor is that 2 years of data is relatively small compared to equal studies performed on the stock market. This is due to the cryptocurrency market being a new market with less data available on this date. A smaller sample size, combined with high volatility results in non-significant results. This is like the commodity futures market, where there are on average positive returns, but due to their high volatility, average returns are often non-significant (Szymanowska, 2020). We find a characteristic that is similar to the commodity futures market but different to the stock market.

Table 3:

*This table captures the risk factors measured on the portfolios sorted by their volatility. Sharpe being the Sharpe ratio capturing the return-risk ratio. Beta and alpha are the components of the regression of the market being the independent variable and the portfolio being the dependent variable. Beta describes the relationship of the cryptocurrency to the market and alpha captures the portfolios abnormal returns. *, ** or *** determining their significance level on the 10%, 5% and 1% level.*

	Low	P2	P3	P4	High	Market
Mean (log)	1.66%	1.85%	1.16%	1.46%	1.52%	1.48%
Standard deviation	0.142	0.149	0.152	0.138	0.145	0.1
Sharpe	0.12	0.12	0.08	0.11	0.10	0.15
Beta	0.915***	0.962***	1.040***	0.960***	0.962***	.
(t-value)	8.59	8.6	9.58	9.93	9.09	.
Alpha	0.003	0.004	-0.004	0.000	0.001	.
(t-value)	0.28	0.38	-0.35	0.04	0.08	.

Lastly, we look at the risk factors in table 3. The Sharpe ratio for the portfolios is lower than the market Sharpe ratio. This is different than the results for the stock market as Blitz & van Vliet discovered, where the lower volatility portfolios outperformed the market based on Sharpe ratio. We do see that the lower volatility portfolio outperforms the high volatility portfolio. This is the result of a combination of higher average return and lower volatility. What is noteworthy is that the volatility of the portfolios is almost equal. This suggest that the past 6-month volatility does not predict the future 6-month volatility. When looking at beta, P2, P4 and the high volatility portfolio, they share an almost identical beta. This can be explained by the high correlation over the cryptocurrency market. As discussed, the market tends to move, when times are bad the entire cryptocurrency market is doing poorly and vice versa. This explains why the betas are very close to 1, which would mean a portfolio moved similar to the market. Lastly Alpha, there is no significant alpha found in the portfolios, meaning the portfolios failed to deliver statistically significant abnormal returns compared to the market. This does not immediately mean that investing in one of the portfolios is a bad investment, as there can still be diversification benefits.

The results in summary are as follows: the Low portfolio outperformed the high portfolio on average, had a higher Sharpe ratio and lower volatility. However, over the quintile portfolios we see that there is no trend that can be spotted in either decreasing or increasing performance, suggesting that the results are random. This means that without further research no hard evidence can be given on whether the volatility anomaly exists in cryptocurrencies.

Market cap-based portfolios

Table 4:

This table shows the summary statistics of the portfolios sorted on their market cap. With large being the portfolio with cryptocurrencies with the largest market cap, decreasing to Small being the portfolio consisting of the smallest market cap cryptocurrencies.

	Large	P2	P3	P4	Small	Market
Observations	130	130	130	130	130	130
Mean (log)	1.60%	1.46%	1.55%	1.40%	2.37%	1.75%
Std. Dev.	0.136	0.139	0.137	0.142	0.152	0.100
Min	-60.82%	-69.70%	-63.58%	-68.67%	-69.67%	-47.05%
Max	37.24%	49.33%	37.96%	43.42%	40.71%	26.97%

Continuing with the portfolios sorted on their market cap. First thing what is different is that the period of the market cap-based portfolios. Since there was 2,5 years of data the first half year of data that was used in the volatility portfolios to determine average portfolios, is included. Reason is that the market cap at the start of a measuring period was taken, instead of taking the average, since the market cap reflects all previously known information. Therefore the 6-month period already gives results. This makes comparing to the volatility-based portfolios impossible, but provides more data and does not matter when comparing between the portfolios based on market cap. Therefore, I have chosen to give more priority to more data and focusing more on the individual variables instead of comparing volatility-based portfolios with market cap-based portfolios. This way the risk factors captured give a better result.

We start with noticing that the average market mean has gone up. This means that the first 26 weeks were on average better than the following 2 years over the entire market. However, there is only one portfolio with a higher mean than the market, the small market cap portfolio. In line with the Fama-French 3 factor model, small cap stocks outperform the large cap stocks. What is also as expected is that the small cap stocks experience a higher volatility on average, meaning that they are riskier. This is in line with expectations. What however is not as expected is the random pattern across portfolios. Similarly, to the volatility portfolios, there is no strong increasing or decreasing trend. Meaning that there is no straight correlation between size and return.

Table 5:

*This table show the statistical significance of the average returns of the market cap sorted portfolios. The t-statistic tests the chance of the mean being non-zero. The P-value is the chance of the mean being larger than zero. *, ** or *** determining their significance level on the 10%, 5% and 1% level.*

	Large	P2	P3	P4	Small	Market
Mean (log)	1.60%	1.46%	1.55%	1.40%	2.37%	1.75%
t-statistic	1.35	1.20	1.29	1.12	1.71	1.9893
P ($\mu > 0$)	0.910*	0.884	0.900*	0.868	0.961**	0.976**

We continue at looking whether the means are positive on average. We see that both the market and small market cap are statistically significant at 5%. The Large cap portfolio and portfolio 3 are statistically significant at 10%. We see that the other 2 portfolios are not statistically significant. Compared to the volatility-based portfolios this is a better result, which is attributed to the more

positive period that is included with the market cap-based portfolios. Hence the increase in t-statistic is expected.

Table 6:
*This table captures the risk factors measured on the portfolios. Sharpe being the Sharpe ratio capturing the return-risk ratio. Beta and alpha are the components of the regression of the market being the independent variable and the portfolio being the dependent variable. Beta describes the relationship of the cryptocurrency to the market and alpha captures the portfolios abnormal returns. *, ** or *** determining their significance level on the 10%, 5% and 1% level.*

	Large	P2	P3	P4	Small	Market
Mean (log)	1.60%	1.46%	1.55%	1.40%	2.37%	1.75%
Standard deviation	0.136	0.139	0.137	0.142	0.152	0.100
Sharpe	0.12	0.11	0.11	0.10	0.16	0.18
Beta	0.982***	0.889***	0.907***	0.917***	0.938***	.
(t-Value)	11.95	9.49	10.02	9.66	8.97	.
Alpha	-0.001	-0.001	0.000	-0.002	0.007	.
(t-Value)	-0.14	-0.10	-0.04	-0.22	0.68	.

Lastly, we examine the risk factors. The smaller the average market cap of the portfolio gets, the riskier it becomes, except for portfolio 2. What is remarkable is that none of the portfolios outperforms the market based on their Sharpe ratio. Making investing in the market index the best investment based on Sharpe ratio. Looking at the 5 portfolios, the small market cap portfolio performs best. Meaning that the portfolio sorted on the smallest market caps out of the sample has the highest return-risk ratio. We again see that the Betas of all portfolios are relatively close to 1. The portfolio with the beta closest to 1 is the Large portfolio. This is logical as the market is value based on market cap. This results in the market consisting mostly of the largest cryptocurrencies. Difference being that the market is value weighted and the portfolios are equally weighted. All the betas of the portfolios are statistically significant meaning that the market partly explains the portfolios. Looking at alpha I did not find any significant alpha, meaning that the way the portfolios are constructed they were not able to achieve statistically significant abnormal returns. Remarkable is that four of the alphas are even negative, portfolio 3 rounding to zero on the negative side. Again, we see the small market portfolio outperformed the other portfolios over the sample based on abnormal returns. Overall, the market with the smallest cap cryptocurrencies out of the sample has performed best, in line with the theoretical literature, however there is no linear connection that can be seen in sample between size and performance.

6. Conclusion & Discussion

This study tries to capture two important factors that have been proven to effect returns of assets in other markets. Creating equally weighted quintile portfolios based on volatility and market cap size. I examined their means, standard deviation, Sharpe ratio, Beta and Alpha. This provides various conclusions which I will discuss here. After this I will address limitations to this study and recommendations for future research.

First thing that is very prevalent in the results is that the market tends to move as a whole. The different cryptocurrencies are highly correlated to each other. Resulting in means and standard deviations that are relatively close across all portfolios. The volatility-based portfolios showed results not in line with the efficient market hypothesis, portfolios sorted on risk did not deliver higher returns

while having higher risk than portfolios sorted on lower volatility. This was reflected by the two portfolios sorted by the lowest volatility achieving the highest Sharpe ratio. Unlike the stock market, no statistically significant positive alphas were found for the lower volatile portfolios. I conclude that there are imperfections in the market and investing in lower volatility cryptocurrencies can improve your risk-return ratio.

Secondly, the portfolios sorted on market cap. While the smallest market cap portfolio had the highest return, no linear relation between market cap and expected returns was found. The Sharpe ratios also are very close, except for the smallest cap portfolio, which can be attributed to its exceptionally high return. For the other portfolios suggesting that their risk/return ratio is in proportion to each other. However, no strong evidence for the average size of the market cap and predictability of returns in the cryptocurrency market.

I will now discuss imperfections to my study. To my research are various major limitations. First and most important is the availability of data. Where research on the stock market has enormous amounts of data reaching back decades ago, the cryptocurrency market is merely a decade old. With the market still in its developing stage, for a lot of cryptocurrencies only a few years of data is available. I expect this to rapidly increase with its popularity still growing. A similar study in the future could be performed including more data and a longer period.

This study reweighted the portfolios, however less than other similar studies have done. This was mainly due to personal skill in coding and time. A following study could reweigh the portfolios more often and decrease the measuring time afterwards. For example: instead of 26 weeks measuring and 26 reweighing, reweighing every month and only capture the following month. This would allow to capture both the size effect and volatility effect more accurately and might deliver more statistically significant results.

Another limitation is the dependence of the cryptocurrency market on Bitcoin. This can be seen by the betas all being close to 1 and the market portfolio consisting of over 50% of Bitcoin. The cryptocurrency tends to move the same direction as bitcoin. In a future study, this can be fixed by replacing the USD as the currency with Bitcoin. Expressing cryptocurrencies in the amount of Bitcoin they are worth. This terminates their dependence on Bitcoin and could show better how their individual performance is.

As the cryptocurrency market is a very young market research could also develop over time. The market can become more mature and stabilize. Volatility might decrease and the market could evolve to a market that is more alike the stock market. Only time and further research will tell.

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8. Appendices

Appendix a: Portfolios sorted by volatility.

Showing the volatility portfolios with 1 being the least volatile increasing to the most volatile portfolio 5. The st.dev no. is the number they placed in the sample based on their standard deviation. The symbols are as provided by CoinGecko with corresponding names. The volatility is calculated by taking a 26-week period. Appendix I to IV are representing four different time series measuring volatility over this 26-week period.

I, Time series 1 = 12/03/2018 until 03/06/2019

II, Time series 2 = 03/06/2019, 02/12/2019

III, Time series 3 = 02/12/2019, 01/06/2020

IV, Time series 4 = 01/06/2020, 30/11/2020

Appendix a.I Portfolios sorted on volatility, time series 1

Portfolio	Symbol	Average Std. Dev.
Low	BTC	0.096767153
Low	DCR	0.104047785
Low	XRP	0.109314858
Low	HT	0.115433890
Low	CHSB	0.117842627
Low	ZRX	0.118450361
Low	MANA	0.121123444
Low	ZEC	0.123723989
Low	SC	0.126608238
Low	NANO	0.127624773
2	MKR	0.129016545
2	XMR	0.131846269
2	NEO	0.132018695
2	VET	0.132928383
2	BNT	0.136456707
2	BNB	0.137936775
2	OKB	0.138578592
2	NEXO	0.142588670
2	DGB	0.143289094
2	ZEN	0.143676648
3	DOGE	0.146870934
3	DASH	0.150275315
3	XLM	0.152377829
3	ZIL	0.153082460
3	EOS	0.153354275
3	ICX	0.153780386
3	TRX	0.154701623
3	BAT	0.157978397
3	OMG	0.159165118
3	ADA	0.159890320
4	WAVES	0.160071175
4	ETH	0.160547365
4	BTG	0.162230984
4	QTUM	0.167719403
4	LTC	0.171013128
4	MIOTA	0.175775352
4	ETC	0.175971277
4	XEM	0.180991628
4	LINK	0.181833245
4	XTZ	0.196653317
High	ONT	0.203187227
High	THETA	0.221244440
High	BSV	0.238335103
High	HOT	0.249835811
High	SNX	0.255470826
High	FTM	0.272082680
High	RVN	0.338345882
High	BCH	0.357821842
High	ENJ	0.375922414
High	TEL	0.397144601

Appendix a.II Portfolios sorted on volatility, time series 2

Portfolio	Symbol	Average Std. Dev.
Low	XEM	0.080436
Low	DOGE	0.082895
Low	MIOTA	0.087414
Low	XRP	0.088203
Low	THETA	0.092821
Low	MANA	0.095699
Low	DASH	0.097103
Low	XLM	0.099491
Low	WAVES	0.100218
Low	ICX	0.100482
2	BNT	0.100893
2	ZEC	0.102882
2	BTC	0.103076
2	RVN	0.104266
2	BAT	0.106935
2	ETH	0.107176
2	ADA	0.107783
2	BTG	0.109130
2	XMR	0.109133
2	ENJ	0.110248
3	BNB	0.112252
3	HOT	0.112682
3	LTC	0.113088
3	MKR	0.116614
3	SC	0.119420
3	HT	0.119869
3	ETC	0.122389
3	NEXO	0.123892
3	ZEN	0.124785
3	NANO	0.126860
4	BCH	0.127769
4	OMG	0.128118
4	ZIL	0.130918
4	TEL	0.132966
4	EOS	0.135306
4	DCR	0.139070
4	OKB	0.139582
4	DGB	0.140551
4	TRX	0.143960
4	FTM	0.153023
High	QTUM	0.153507
High	ZRX	0.155524
High	VET	0.160653
High	XTZ	0.167338
High	NEO	0.169174
High	BSV	0.176266
High	ONT	0.186145
High	SNX	0.190571
High	CHSB	0.205558
High	LINK	0.232051

Appendix a.III Portfolios sorted on volatility, time series 3

Portfolio	Symbol	Average Std. Dev.
Low	XRP	0.092984
Low	BTC	0.100419
Low	DOGE	0.100754
Low	HT	0.102143
Low	QTUM	0.111093
Low	DCR	0.112513
Low	TRX	0.114356
Low	XEM	0.115170
Low	BAT	0.116657
Low	LTC	0.117696
2	EOS	0.118009
2	NEO	0.119911
2	XLM	0.126442
2	BNB	0.126848
2	ETH	0.126851
2	WAVES	0.127264
2	BCH	0.127552
2	XMR	0.130861
2	ONT	0.132071
2	ZEN	0.139070
3	MIOTA	0.139105
3	SNX	0.143811
3	HOT	0.145361
3	NEXO	0.152915
3	VET	0.153738
3	ETC	0.154375
3	ADA	0.154561
3	NANO	0.156062
3	RVN	0.157585
3	SC	0.157609
4	MKR	0.167120
4	ZEC	0.168092
4	OKB	0.170465
4	LINK	0.173201
4	DASH	0.180855
4	BTG	0.182429
4	MANA	0.182662
4	FTM	0.183906
4	OMG	0.185360
4	CHSB	0.187188
High	ENJ	0.195202
High	BNT	0.201724
High	ZIL	0.201884
High	BSV	0.214741
High	ZRX	0.214787
High	DGB	0.223388
High	ICX	0.224373
High	THETA	0.224400
High	TEL	0.282879
High	XTZ	0.339178

Appendix a.IV Portfolios sorted on volatility, time series 4

Portfolio	Symbol	Average Std. Dev.
Low	HT	0.054119
Low	BTC	0.060656
Low	XMR	0.071448
Low	BCH	0.079544
Low	ETC	0.083320
Low	RVN	0.084141
Low	MKR	0.089534
Low	EOS	0.090890
Low	DASH	0.091659
Low	BNB	0.093574
2	BSV	0.093606
2	BTG	0.095828
2	HOT	0.097929
2	ETH	0.101834
2	ONT	0.103190
2	ENJ	0.103821
2	TRX	0.104473
2	NEO	0.104474
2	BAT	0.107767
2	ZEC	0.107805
3	OKB	0.109350
3	LTC	0.110880
3	ICX	0.112718
3	MIOTA	0.112754
3	XTZ	0.114862
3	DCR	0.116047
3	SC	0.123498
3	QTUM	0.124152
3	NANO	0.125712
3	DOGE	0.129175
4	ZRX	0.134977
4	THETA	0.138225
4	ADA	0.143691
4	XEM	0.150786
4	DGB	0.158157
4	NEXO	0.160146
4	XRP	0.162830
4	ZEN	0.181662
4	VET	0.186183
4	ZIL	0.186553
High	TEL	0.197933
High	XLM	0.205164
High	LINK	0.207142
High	BNT	0.217513
High	SNX	0.229859
High	FTM	0.246617
High	MANA	0.263492
High	CHSB	0.264169
High	WAVES	0.266407
High	OMG	0.299352

Appendix b: Portfolios sorted by market cap.

Showing the market cap portfolios with Large being the largest average market cap decreasing to the smallest average market cap Small. The symbols are as provided by CoinGecko with corresponding names. The market cap is based on historical data provided by CoinGecko. The market cap is the market cap of the cryptocurrencies at their corresponding dates. With appendix I to V having the following dates in chronological order: 12/03/2018, 03/06/2019, 02/12/2019, 01/06/2020, 30/11/2020. The percentage of total SUM represents their value weighted in the total sample. The portfolios are however equally weighted.

Appendix b.I: Market cap of cryptocurrencies at 12/03/2018

Portfolio	Symbol	Market cap	Percentage of total sum
Large	BTC	7.18E+10	58.01%
Large	XRP	1.47E+10	11.90%
Large	ETH	1.20E+10	9.70%
Large	XLM	3.06E+09	2.48%
Large	BCH	2.99E+09	2.42%
Large	EOS	2.89E+09	2.33%
Large	LTC	1.99E+09	1.61%
Large	BSV	1.75E+09	1.41%
Large	ADA	1.29E+09	1.04%
Large	XMR	9.93E+08	0.80%
2	TRX	9.74E+08	0.79%
2	MIOTA	8.21E+08	0.66%
2	DASH	7.88E+08	0.64%
2	BNB	7.55E+08	0.61%
2	XEM	6.98E+08	0.56%
2	ETC	5.46E+08	0.44%
2	NEO	5.14E+08	0.42%
2	ONT	4.90E+08	0.40%
2	ZEC	4.23E+08	0.34%
2	XTZ	3.81E+08	0.31%
3	BTG	3.21E+08	0.26%
3	MKR	2.88E+08	0.23%
3	VET	2.72E+08	0.22%
3	DOGE	2.59E+08	0.21%
3	OKB	2.54E+08	0.20%
3	ZRX	2.33E+08	0.19%
3	OMG	2.28E+08	0.18%
3	BAT	2.14E+08	0.17%
3	DCR	1.83E+08	0.15%
3	QTUM	1.71E+08	0.14%
4	WAVES	1.57E+08	0.13%
4	DGB	1.46E+08	0.12%
4	ZIL	1.42E+08	0.12%
4	NANO	1.39E+08	0.11%
4	ICX	1.28E+08	0.10%
4	SC	1.16E+08	0.09%
4	LINK	1.08E+08	0.09%
4	HOT	9.63E+07	0.08%
4	MANA	7.80E+07	0.06%
4	NEXO	5.79E+07	0.05%
Small	HT	4.85E+07	0.04%
Small	THETA	4.74E+07	0.04%
Small	RVN	4.50E+07	0.04%
Small	BNT	4.08E+07	0.03%
Small	ZEN	3.56E+07	0.03%
Small	TEL	3.22E+07	0.03%
Small	ENJ	2.44E+07	0.02%
Small	FTM	9.65E+06	0.01%
Small	CHSB	3.87E+06	0.00%
Small	SNX	3.83E+06	0.00%
	Total	1.24E+11	100.00%

Appendix b.II: Market cap of cryptocurrencies at 03/06/2019

Portfolio	Symbol	Market cap	Percentage of total sum
Large	BTC	1.55E+11	59.81%
Large	ETH	2.87E+10	11.07%
Large	XRP	1.88E+10	7.26%
Large	EOS	8.09E+09	3.12%
Large	BCH	7.90E+09	3.05%
Large	LTC	7.12E+09	2.75%
Large	BNB	4.80E+09	1.85%
Large	BSV	3.37E+09	1.30%
Large	ADA	2.99E+09	1.16%
Large	XLM	2.65E+09	1.02%
2	TRX	2.55E+09	0.99%
2	XMR	1.52E+09	0.59%
2	DASH	1.46E+09	0.56%
2	MIOTA	1.36E+09	0.53%
2	XTZ	1.21E+09	0.47%
2	ETC	1.06E+09	0.41%
2	NEO	9.95E+08	0.38%
2	ONT	9.23E+08	0.36%
2	XEM	8.58E+08	0.33%
2	MKR	7.32E+08	0.28%
3	ZEC	5.92E+08	0.23%
3	BTG	5.08E+08	0.20%
3	OKB	4.55E+08	0.18%
3	BAT	4.54E+08	0.18%
3	VET	4.33E+08	0.17%
3	HOT	4.09E+08	0.16%
3	DOGE	4.08E+08	0.16%
3	LINK	3.73E+08	0.14%
3	QTUM	3.44E+08	0.13%
3	OMG	3.31E+08	0.13%
4	DCR	2.87E+08	0.11%
4	WAVES	2.65E+08	0.10%
4	RVN	2.62E+08	0.10%
4	NANO	2.37E+08	0.09%
4	ZRX	2.05E+08	0.08%
4	ICX	2.04E+08	0.08%
4	DGB	1.96E+08	0.08%
4	ZIL	1.95E+08	0.08%
4	SC	1.47E+08	0.06%
4	ENJ	1.46E+08	0.06%
Small	HT	1.31E+08	0.05%
Small	THETA	1.04E+08	0.04%
Small	MANA	7.73E+07	0.03%
Small	ZEN	7.47E+07	0.03%
Small	NEXO	5.89E+07	0.02%
Small	BNT	4.93E+07	0.02%
Small	FTM	4.37E+07	0.02%
Small	SNX	2.81E+07	0.01%
Small	TEL	1.98E+07	0.01%
Small	CHSB	5.08E+06	0.00%
	Total	2.59E+11	100.00%

Appendix b.III: Market cap of cryptocurrencies at 02/12/2019

Portfolio	Symbol	Market cap	Percentage of total sum
Large	BTC	1.34E+11	71.33%
Large	ETH	1.64E+10	8.75%
Large	XRP	9.72E+09	5.18%
Large	BCH	3.90E+09	2.08%
Large	LTC	3.03E+09	1.62%
Large	EOS	2.64E+09	1.41%
Large	BNB	2.37E+09	1.26%
Large	BSV	1.89E+09	1.01%
Large	ADA	1.23E+09	0.66%
Large	XLM	1.16E+09	0.62%
2	TRX	1.06E+09	0.56%
2	XMR	9.36E+08	0.50%
2	XTZ	8.71E+08	0.46%
2	LINK	7.89E+08	0.42%
2	OKB	7.26E+08	0.39%
2	HT	6.74E+08	0.36%
2	NEO	6.53E+08	0.35%
2	MIOTA	5.72E+08	0.30%
2	DASH	4.84E+08	0.26%
2	ETC	4.55E+08	0.24%
3	VET	4.39E+08	0.23%
3	ONT	4.05E+08	0.22%
3	MKR	3.83E+08	0.20%
3	XEM	3.27E+08	0.17%
3	DOGE	2.79E+08	0.15%
3	BAT	2.67E+08	0.14%
3	ZEC	2.23E+08	0.12%
3	DCR	2.07E+08	0.11%
3	QTUM	1.72E+08	0.09%
3	ZRX	1.55E+08	0.08%
4	HOT	1.41E+08	0.08%
4	NANO	1.18E+08	0.06%
4	BTG	1.12E+08	0.06%
4	RVN	1.12E+08	0.06%
4	SNX	1.11E+08	0.06%
4	OMG	1.05E+08	0.06%
4	DGB	8.24E+07	0.04%
4	THETA	7.79E+07	0.04%
4	ICX	6.79E+07	0.04%
4	SC	6.40E+07	0.03%
Small	WAVES	6.07E+07	0.03%
Small	ENJ	5.49E+07	0.03%
Small	NEXO	5.46E+07	0.03%
Small	ZIL	4.82E+07	0.03%
Small	ZEN	4.35E+07	0.02%
Small	MANA	3.30E+07	0.02%
Small	FTM	2.66E+07	0.01%
Small	BNT	1.88E+07	0.01%
Small	TEL	1.04E+07	0.01%
Small	CHSB	4.54E+06	0.00%
	Total	1.88E+11	100.00%

Appendix b.IV: Market cap of cryptocurrencies at 01/06/2020

Portfolio	Symbol	Market cap	Percentage of total sum
Large	BTC	1.74E+11	71.10%
Large	ETH	2.57E+10	10.48%
Large	XRP	8.97E+09	3.66%
Large	BCH	4.39E+09	1.79%
Large	BSV	3.54E+09	1.45%
Large	LTC	2.97E+09	1.21%
Large	EOS	2.51E+09	1.03%
Large	BNB	2.51E+09	1.02%
Large	ADA	2.29E+09	0.94%
Large	XTZ	1.98E+09	0.81%
2	LINK	1.57E+09	0.64%
2	OKB	1.46E+09	0.60%
2	XLM	1.42E+09	0.58%
2	XMR	1.15E+09	0.47%
2	TRX	1.04E+09	0.43%
2	HT	9.44E+08	0.39%
2	ETC	8.03E+08	0.33%
2	NEO	7.66E+08	0.31%
2	DASH	7.25E+08	0.30%
2	MIOTA	6.08E+08	0.25%
3	ZEC	4.79E+08	0.20%
3	MKR	4.08E+08	0.17%
3	VET	3.96E+08	0.16%
3	XEM	3.78E+08	0.15%
3	ONT	3.49E+08	0.14%
3	DOGE	3.19E+08	0.13%
3	BAT	3.08E+08	0.13%
3	THETA	2.48E+08	0.10%
3	DGB	2.26E+08	0.09%
3	OMG	2.11E+08	0.09%
4	ZRX	2.07E+08	0.08%
4	ENJ	1.88E+08	0.08%
4	ICX	1.79E+08	0.07%
4	QTUM	1.68E+08	0.07%
4	DCR	1.68E+08	0.07%
4	BTG	1.59E+08	0.07%
4	ZIL	1.53E+08	0.06%
4	RVN	1.23E+08	0.05%
4	NANO	1.16E+08	0.05%
4	WAVES	1.09E+08	0.04%
Small	HOT	1.09E+08	0.04%
Small	SC	1.01E+08	0.04%
Small	SNX	8.23E+07	0.03%
Small	NEXO	7.14E+07	0.03%
Small	ZEN	5.78E+07	0.02%
Small	MANA	5.33E+07	0.02%
Small	BNT	4.24E+07	0.02%
Small	CHSB	2.06E+07	0.01%
Small	TEL	1.39E+07	0.01%
Small	FTM	1.20E+07	0.00%
	Total	2.45E+11	100.00%

Appendix b.V: Market cap of cryptocurrencies at 30/11/2020

Portfolio	Symbol	Market cap	Percentage of total sum
Large	BTC	3.36E+11	68.97%
Large	ETH	6.51E+10	13.35%
Large	BNB	2.74E+10	5.61%
Large	ADA	5.29E+09	1.08%
Large	DOGE	5.23E+09	1.07%
Large	XRP	5.19E+09	1.06%
Large	BCH	5.14E+09	1.05%
Large	LINK	4.45E+09	0.91%
Large	LTC	4.19E+09	0.86%
Large	XLM	3.13E+09	0.64%
2	ETC	2.87E+09	0.59%
2	VET	2.20E+09	0.45%
2	THETA	2.19E+09	0.45%
2	EOS	1.77E+09	0.36%
2	TRX	1.60E+09	0.33%
2	XMR	1.47E+09	0.30%
2	OKB	1.25E+09	0.26%
2	NEO	1.06E+09	0.22%
2	MIOTA	9.86E+08	0.20%
2	BSV	9.49E+08	0.19%
3	MKR	9.45E+08	0.19%
3	XTZ	7.89E+08	0.16%
3	HT	7.40E+08	0.15%
3	DCR	7.01E+08	0.14%
3	DASH	6.19E+08	0.13%
3	SNX	6.11E+08	0.13%
3	ZEC	5.27E+08	0.11%
3	TEL	4.94E+08	0.10%
3	XEM	4.64E+08	0.10%
3	HOT	4.34E+08	0.09%
4	ZIL	3.46E+08	0.07%
4	ENJ	3.33E+08	0.07%
4	WAVES	3.29E+08	0.07%
4	QTUM	3.09E+08	0.06%
4	ZEN	2.87E+08	0.06%
4	BAT	2.80E+08	0.06%
4	NEXO	2.33E+08	0.05%
4	MANA	1.74E+08	0.04%
4	DGB	1.63E+08	0.03%
4	BTG	1.56E+08	0.03%
Small	ONT	1.45E+08	0.03%
Small	NANO	1.45E+08	0.03%
Small	ZRX	1.32E+08	0.03%
Small	BNT	1.09E+08	0.02%
Small	OMG	1.06E+08	0.02%
Small	FTM	1.05E+08	0.02%
Small	SC	9.50E+07	0.02%
Small	CHSB	8.36E+07	0.02%
Small	ICX	4.86E+07	0.01%
Small	RVN	8.72E+06	0.00%
	Total	4.88E+11	100.00%

Appendix c: Market index composition as of 10/06/2021

This appendix shows the market index composition on June the 10th, 2021. The market index composition changes over time and is value weighted. Giving a representation of the market. 10/06/2021, there are 18 cryptocurrencies in this index and the appendix shows their name with corresponding symbols. The weight is their weight in the market index.

Symbol	Name	Weight
BTC	Bitcoin	69.73%
ETH	Ethereum	18.66%
ADA	Cardano	3.07%
DOGE	Dogecoin	1.90%
LTC	Litecoin	1.07%
BCH	Bitcoin Cash	0.89%
Link	Chainlink	0.90%
XLM	Stellar	0.63%
VET	VeChain	0.62%
TRX	TRON	0.47%
EOS	EOS	0.38%
NEO	NEO	0.31%
ATOM	Cosmos	0.29%
XTZ	Tezos	0.25%
MKR	Maker	0.19%
ALGO	Algorand	0.23%
DASH	Dash	0.17%
ZEC	Zcash	0.15%