The Chinese University of Hong Kong

FTEC 5530 Project Report

Quantitative and Algorithmic Trading

Effectiveness of Technical Analysis Indicators in Cryptocurrencies

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Abstract

In this project, we conduct empirical studies on the effectiveness of technical analysis indicators in cryptocurrencies using two contract pairs BTC/USDT and ETH/USDT. The goal is to construct rigorous backtesting pipelines based on the typical Exponential Moving Average (EMA) and Moving Average Convergence and Divergence (MACD) trading signals.

We have applied grid search algorithm to search for the best possible parameters. For EMA, the long moving average is tuned in a range from 5 to 50, while the short moving average is tuned from 1 to the long moving average. For MACD, the long-short moving average search takes the same approach as the EMA, while the moving average of DIF is tuned in a range from 5 to 25 with a step size equaling to 1.

The backtesting results reveal several performance metrics of different parameters. The performance metrics include average return per trade, duration, win ratio, maximum profit and loss per trade. The final chosen suitable parameter sets all achieve decent cumulative return, relatively low maximum loss in history, and relatively large win ratio through the given period.

We then compare the performance of EMA and MACD. It turns out that in terms of cumulative return, EMA outperforms MACD for the daily bitcoin and hourly ethereum, but underperforms MACD for the hourly bitcoin and daily ethereum. We also discover that though the win ratios between EMA and MACD performance are similar, the MACD strategy has a shorter holding period and changes the position more frequently.

Finally, we analyze the effectiveness for EMA and MACD in the time horizon of a yearly basis. Typical technical signals such as EMA and MACD were able to effectively capture the price movement and obtain many correct predictions in the past, but the effectiveness decreases sharply in recent periods when the market becomes more and more efficient. The average returns per trade for both indicators in 2022 are even negative.

Keywords: *technical analysis, EMA, MACD, backtesting, suitable parameters, performance comparison, market efficiency*

Contents

1 Introduction

A commonly type of market timing is conducted according to well-designed trading signals. Many trading signals are developed by conducting technical analysis on the historical microstructure information. The n-day SMA assigns equal weight to the past n day price information, while the n-day EMA signal assigns a higher weight to recent prices and therefore is more sensitive and reactive to the price changes [3]. It is defined recursively:

$$EMA_{n,t} = \frac{n-1}{n+1} \times EMA_{n,t-1} + \frac{2}{n+1} \times Price_t \tag{1}$$

The moving average convergence and divergence (MACD) is built based on EMA:

$$MACD_t = DIF_t - SIG_t \tag{2}$$

where

$$DIF_t = EMA_{n_1,t} - EMA_{n_2,t} \tag{3}$$

and

$$SIG_t = EMA^d_{n_3,t} \tag{4}$$

Here EMA^d denotes that the moving average is calculated using DIF series instead of the original close price series. There are two parameters which need tuning in EMA signal (long and short) while MACD signal has three parameters [2]:

- n_1: The short-term exponential moving average period, default to be 12
- n_2: The long-term exponential moving average period, default to be 26
- n_3: The exponential moving average period of the DIF, default to be 9

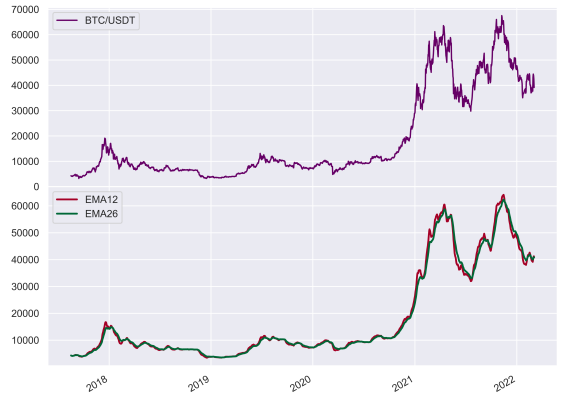

Figure 1: EMA of BTC/USDT daily price

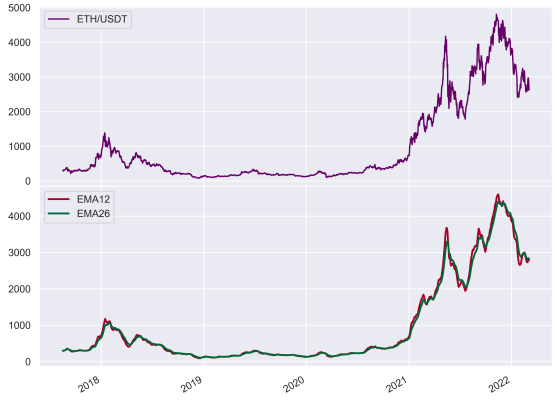

Figure 2: EMA of ETH/USDT daily price

Two figures above depict the short and long EMA line compared to the original close price series with default parameters (12 and 26 respectively). The EMA curve is much smoother than the orignal price. The long and short curve closely tracks each other while the short EMA reacts to price changes more sensitively. The trading signal gives the trader the timing to long when the short-term moving average curve crosses the long-term curve upward and gives the timing to short otherwise. We assume in the following analysis that the trader will always take a full long position when the signal is 1 and take a full short position when the signal is -1.

2 Data Manipulations

2.1 Data Description

The assets to be tested are two cryptocurrency pairs: BTC/USDT and ETH/USDT, including both daily data and hourly data. The period of the price and volume information are listed in the table. The data obtained only contain basic price and volume information.

Pair Name	Frequency	Period Begin	Period End
BTC/USDT	Daily	2017.08.17	2022.03.04
BTC/USDT	Hourly	2021.01.01	2022.03.04
ETH/USDT	Daily	2017.08.17	2022.03.04
ETH/USDT	Hourly	2021.01.01	2022.03.04

Table 1: Period range of the data used

2.2 Data Processing

Time Format Since the data are obtained using the API provided by binance, the time is in Greenwich Mean Time (GMT) format, which is 8 hours ahead of the Beijing time. Therefore we adjust the time format of the hourly data to Beijing time by adding 8 hours.

Signal Design For EMA indicator, when the short-term moving average crosses the long-term moving average upward, the price is still considered to have the momentum to go up, and therefore we set the trading signal to be 1. If the crossing direction is downward, however, the trading signal is set to be -1. For MACD indicator, we set the signal to be 1 when a "golden cross" occurs, namely, MACD changes from negative to positive, and set the signal to be -1 otherwise.

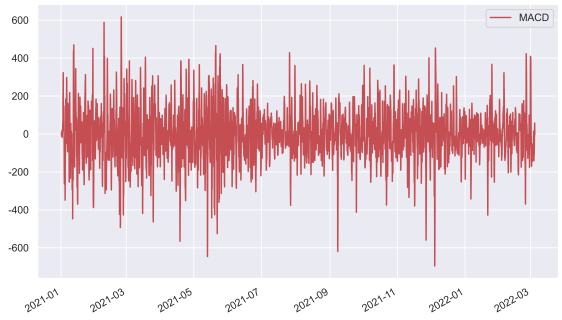

Figure 3: MACD of BTC/USDT hourly price

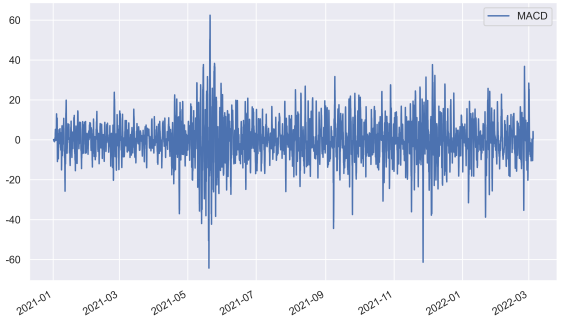

Figure 4: MACD of ETH/USDT hourly price

As seen from the two MACD plots under the default parameters, the indicator value of bitcoin is more volatile and has a wider range in absolute value than that ethereum.

Basic Return Analysis We first get some insights about the percentage of trading days in a year in which the daily return is positive about the daily price data. This gives us an overview about how the cryptocurrencies perform in the given period. We would also expect the MACD signal for bitcoin will lead to a more frequent change in the holding position due to the high volatility. From the table we can see the cryptocurrencies on average earns a positive return. However, bitcoin and ethereum both went through a hugh bear market in 2018, making the return slumps.

Year	Number	BTC/USDT	ETH/USDT
2017	137	0.56204	0.51094
2018	365	0.50136	0.47123
2019	365	0.51780	0.48767
2020	365	0.57650	0.55737
2021	365	0.50410	0.55616
2022	63	0.47619	0.49206

Table 2: Percentage of positive returns on a yearly basis

Backtesting Criterion The trader can only trade according to historical information. Suppose a trader stands at 2020.01.01 and he uses the historical daily data to perform actions. After getting the new **close** price on 2020.01.01, the trader updates his calculation on MACD signal and finds that MACD turns from negative to positive, indicating a long position. However, the trader can only trade on 2020.01.02, and hold a long position at the **open** price of 2020.01.02. After performing the buying action, the first return the trade gets should be determined by the open price on 2020.01.02 and 2020.01.03.

```
# backtesting in KDB
btc: update signalside   :?[signal > 0;1i;-1i], j: sums 1^i - prev i from btc;
btc: update signalidx    :fills ?[0 = deltas signalside; 0N; j] from btc;
btc: update n            :sums abs signalside,
            signaltime   :first time,
            signalprice  :first close by signalidx from btc;
# generate signal
btc: select from btc where n = 1, 1 = abs signalside;
btc: btc upsert 0!select from btc;
# use the next open price to calculate return
btc: update bps          :10000*signalside*-1 + next next open%next pxenter,
            nholds       :(next j)-j from update
            pxexit       :next pxenter from `time xasc btc;
# move empty signal
delete from btc where null signalside
```

The core code for backtesting using KDB is listed. From the reasoning above, when doing the backtesting, we should calculate the profit and loss (pnl) using the forward open price (denoted as "next open" by KDB) instead of the current close price.

3 Parameter Tuning and Performance Analysis

In this section, we conduct backtesting using EMA and MACD towards bitcoin and ethereum. We use grid search to run possible and reasonable combinations of signal parameters. Performance among different sets of parameters will be compared, including average return per trade, accumulated return, win ratio, maximum win/loss percentage, etc.

3.1 EMA Performance

3.1.1 Grid Search Algorithm

We first conduct grid search for the two parameters in the EMA signal. We first search for the parameters that can give the cumulative return. The grid search algorithm in KDB is as follows:

```
# iterating for the best parameters in EMA according to culumative return
backtest: {[nFast;nSlow;btc_d] btc_d   :update emaS:EMA[close;nFast],
```

```
                                    emaL    :EMA[close;nSlow] from btc_d;
                                    result  :cross_signal_bench[update time:date,
                                    signal  :emaS-emaL, pxenter:next open from btc_d];
                                    -1+prd 1+result[;`bps]%10000}
# iterate for fast moving average
para1: {[nSlow; btc_d] nFast:1+til nSlow-1; max backtest[;nSlow;btc_d] each nFast}
# iterate for slow moving average
para2: {[nSlow; btc_d] maxs para1[;btc_d] each nSlow}
output: para2[5+til 46; btc_d]
```

We iterate the long moving average from 5 to 50, with step size to be 1. The short moving average iterates from 1 to long moving average with step size also equaling to 1. In addition to using cumulative return as the selection metric, we can also use other metrics including win ratio, maximum profit divided by maximum loss, etc. The algorithm applied for these metrics is similar.

3.1.2 Daily BTC

We apply the above algorithm into the daily price for bitcoin. Assume we have 1 dollar at the beginning, we conduct the backtesting regardless of commission fees. From the grid search, the best set of parameter that gives the maximum cumulative return is [10, 30]. The performance statistics are summarized below. From the table, if holding 1 dollar at the beginning in 2017,

Parameters	**Avg (bps)**	**Cumulative**	**Benchmark**
[10,30]	1977.137	68.3356	8.136039
Duration	**Win Ratio**	**Max Win**	**Max Loss**
38.558	0.40909	3.67764	-0.14343

Table 3: Performance sheet for the best cumulative return parameter

we can achieve 69 dollars at the period end compared to 9.14 dollars by holding the bitcoin through the whole period. The average holding period is roughly 38 days, with a total number of changing positions to be 44. We can check the performance when holding a long position or a short position respectively. We see the strategy gains most of its cumulative return when

Signal	**Avg(bps)**	**Cumulative**	**Duration**	**Win Ratio**	**Max Win**	**Max Loss**
1	3616.931	34.2219	41.571	0.40909	3.67764	-0.13571
-1	411.879	0.96853	35.682	0.40909	0.44726	-0.14344

Table 4: Performance sheet for long and short position

holding a long position. However, we see the win ratio under this parameter set is relatively low. We try to iterate again for another set of parameters that gives the best win ratio.

Parameters	**Avg (bps)**	**Cumulative**	**Benchmark**
[24,42]	2796.637	27.16772	8.136039
Duration	**Win Ratio**	**Max Win**	**Max Loss**
65.3333	0.56	3.369059	-0.20378

Table 5: Performance sheet for the best win ratio parameter

The iterating result shows when the parameter set is [24,42], we can reach the best win ratio of 56%, which is considerably higher than that of the previous parameter set. Its average holding period is 65.3 days, with a total number of changing positions to be 25. This implies that the strategy does not change positions frequently, and thus reaches a higher average return per trade (2800 bps). However, the cumulative return is much lower than the previous strategy, and it suffers from the infrequent signals. As seen from the table, the maximum loss is higher and the maximum profit is lower than the previous strategy. This may happen due to the high volatility nature that the cryptocurrencies have.

3.1.3 Hourly BTC

We now repeat the above grid search algorithm for a more frequent hourly bitcoin data. Again we search based on the best cumulative return and the best win ratio separately. We can see

Parameter	Avg(bps)	Cumulative	Duration	Win Ratio	Max Win	Max Loss
[11,36]	42.24884	1.524408	35.2344	0.3402	0.25632	-0.0926
[18,28]	33.22859	0.730191	40.2283	0.3607	0.25663	-0.11787

Table 6: Parameters that maximize the cumulative return and win ratio

that the parameter which gives the best win ratio ([18,28]) is not significantly different from that which gives the best cumulative return. However, the cumulative return for the first set of parameter is two times larger than that of the second set. Except for the cumulative return, the performance on other metrics such as the average return per trade is similar. Therefore we consider the first set of parameter is better. We can also list the performance when the position is long or short separately.

Signal	Avg(bps)	Cumulative	Duration	Win Ratio	Max Win	Max Loss
1	67.2220	1.2317	37.1862	0.35862	0.256327	-0.07009
-1	17.2756	0.1311	33.2827	0.32191	0.254103	-0.09268

Table 7: Long-short performance under parameter [11,36]

Signal	Avg(bps)	Cumulative	Duration	Win Ratio	Max Win	Max Loss
1	61.4978	0.83476	42.456	0.34375	0.25663	-0.11787
-1	4.95935	-0.05699	38.00	0.37795	0.24798	-0.08564

Table 8: Long-short performance under parameter [18,26]

Indeed, if we hold the bitcoin throughout the whole period, the cumulative return is 0.403488. Although the best parameter we determine ([11,36]) can bring a cumulative return of 152%, the number is much lower than the previous daily bitcoin price. This phenomenon possibly occurs for two reasons:

- The time range for the hourly data is much shorter than the daily data. Bitcoin went through a huge bull market in 2017 and 2020 while encountered a huge bear market in the late 2021.
- The effectiveness of the technical indicators is decreasing in recent years.

We shall discuss more on whether the effectiveness is decreasing through years in the last section.

3.1.4 Daily ETH

Following the same logic, we directly apply the grid search for the ethereum data. Ethereum wents through its maximum drawdown ever in history in 2018, causing huge loss to traders who held a long position during that time. However, such "huge loss" may become huge benefits if the trading signal switches to a short position rapidly. We direct list the performance metrics under the iterated best parameters which give the best cumulative return and win ratio respectively. The result is quite astonishing. Even if we only slightly change the parameters, the final

Parameters	**Avg (bps)**	**Cumulative**	**Benchmark**
[12,18]	2048.935	212.7128	7.68245
Duration	**Win Ratio**	**Max Win**	**Max Loss**
37.4318	0.46666	2.86070	-0.26905

Table 9: Performance sheet for the best cumulative return parameter

cumulative return can be dramatically different. Compared to the benchmark, namely, holding ethereum for the whole period, the EMA signal proves to be extremely effective in generating excess return. It switches the position from long to short quickly once identifying the occurrence

Parameters	**Avg (bps)**	**Cumulative**	**Benchmark**
[21,25]	3827.374	93.4115	7.68245
Duration	**Win Ratio**	**Max Win**	**Max Loss**
60.6153	0.481481	5.99231	-0.246708

Table 10: Performance sheet for the best win ratio parameter

of a possible bear market. While the win ratio between the two sets of parameters are similar, the cumulative return of the first parameters set is more than doubled. It changes the position more frequently to cope with the high volatility of ethereum.

3.1.5 Hourly ETH

We repeat the search algorithm for hourly ethereum data and obtain the performance below.

Parameters	**Avg (bps)**	**Cumulative**	**Benchmark**
[4,18]	33.2335	4.84705	2.639598
Duration	**Win Ratio**	**Max Win**	**Max Loss**
14.9604	0.31478	0.31567	-0.08963

Table 11: Performance sheet for the best win ratio parameter

From the table, the parameter set that maximizes the win ratio has much longer average holding period, which is beneficial since the more frequent the position changes, the higher commission fee the trader will pay. However, the cumulative return is much lower than the first set of parameter and even fails to catch up with the benchmark. Therefore, we would choose the first set of parameter as the candidate.

Parameters	Avg (bps)	Cumulative	Benchmark
[15,22]	44.3825	1.38828	2.639598
Duration	**Win Ratio**	**Max Win**	**Max Loss**
31.91562	0.342679	0.528595	-0.10811

Table 12: Performance sheet for the best win ratio parameter

3.2 MACD Performance

3.2.1 Grid Search Algorithm

There are in total three parameters to be tuned for MACD signal. The requirement is the short-term moving average parameter should be smaller than the long-term moving average parameter. Considering a reasonable parameter range, we iterate the long moving average from 5 to 50, with step size to be 1. The short moving average iterates from 1 to the long moving average with step size also equaling to 1. Besides, the third parameter, namely, the moving period of DIF, iterates from 5 to 25, with step size equaling to 1. The code in KDB is as follows.

```
# iterating for the best parameters in MACD according to culumative return
backtest: {[nFast;nSlow;nSig;btc_d] btc_d    :update macd:MACD[close;nFast
                                              ;nSlow;nSig] from btc_d;
                                    result   :cross_signal_bench[update
                                    time     :date, signal: macd,
                                    pxenter  :next open from btc_d];
                                    -1+prd 1+result[;`bps]%10000}
# iterate for nFast
para1 :{[nSlow;nSig;btc_d] nFast:1+til nSlow-1;
max backtest[;nSlow;nSig;btc_d] each nFast}
# iterate for nSlow
para2 :{[nSlow;nSig;btc_d] max para1[;nSig;btc_d] each nSlow}
# iterate for nSig
para3 :{[nSlow;nSig;btc_d] maxs para2[nSlow;;btc_d] each nSig}
nSlow :5+til 46; nSig:  5+til 21
output:para3[nSlow; nSig; btc_d]
```

The cumulative return is chosen to be the metric for determining the best parameter. Performance will be compared between the best parameter and the traditional default parameter ([12,26,9]).

3.2.2 Daily BTC

We directly apply the above algorithm into the daily price for bitcoin. The two tables summarize the performance under the default parameter and the parameter that gives the highest cumulative return. It can be seen that the default parameter set changes positions too often, resulting in an average holding period of only 14 days. The cumulative return is even lower than holding bitcoin through the period. Besides, the maximum loss, the win ratio, and the average

Parameters	Avg (bps)	Cumulative	Benchmark
[48,49,5]	879.8202	49.2646	8.136039
Duration	**Win Ratio**	**Max Win**	**Max Loss**
26.2539	0.4375	1.10027	-0.2397

Table 13: Performance sheet for the best cumulative return parameter

Parameters	Avg (bps)	Cumulative	Benchmark
[12,26,9]	307.058	5.361635	8.136039
Duration	**Win Ratio**	**Max Win**	**Max Loss**
14.4	0.396551	1.14589	-0.24409

Table 14: Performance sheet for the default MACD parameter

return per trade are all worse than the first set of parameters. In this case, we regard [48,49,5] as a suitable parameter set for daily bitcoin price.

3.2.3 Hourly BTC

We then apply the grid search algorithm into the daily price for bitcoin. From the table, the

Parameters	Avg (bps)	Cumulative	Benchmark
[4,48,26]	23.4960	2.60552	0.4034881
Duration	**Win Ratio**	**Max Win**	**Max Loss**
14.5	0.32574	0.189124	-0.11511

Table 15: Performance sheet for the best cumulative return parameter

performance of MACD indicator for hourly data outperforms that of the EMA indicator. With similar duration, win ratio, maximum profit and maximum loss, the grid search parameter performs much better in terms of cumulative return and average return per trade. Therefore we

Parameters	Avg (bps)	Cumulative	Benchmark
[12,26,9]	6.219698	0.1069264	0.4034881
Duration	**Win Ratio**	**Max Win**	**Max Loss**
13.0739	0.33121	0.19600	-0.09832

Table 16: Performance sheet for the default MACD parameter

regard [4,48,26] as a suitable parameter set for hourly bitcoin price. The maximum cumulative return is 260%, much higher than the benchmark and the result that is obtained in EMA signal.

3.2.4 Daily ETH

Previously, we backtest the EMA on daily ethereum price and discover a huge amount of profit. Proper parameters can switch the positions timely, effectively cutting off the loss when the bear market occurs. Improper parameters, however, misjudge the timing to short or long and can bring huge drawdown to the trader. The results show that the MACD signal is even more powerful than EMA in the daily price. The best parameter ([35,38,8]) reaches a cumulative return hundred times higher than the benchmark. The default parameter however, performs even much worse than the benchmark and has the maximum loss to be -0.5 on a single day, which is pretty large on a daily basis.

Parameters	Avg (bps)	Cumulative	Benchmark
[35,38,8]	1171.159	222.0644	7.68245
Duration	**Win Ratio**	**Max Win**	**Max Loss**
23.28169	0.40277	2.11868	-0.27162

Table 17: Performance sheet for the best cumulative return parameter

Parameters	Avg (bps)	Cumulative	Benchmark
[12,26,9]	226.0808	0.3895699	7.68245
Duration	**Win Ratio**	**Max Win**	**Max Loss**
13.46341	0.379032	0.792190	-0.49703

Table 18: Performance sheet for the default MACD parameter

3.2.5 Hourly ETH

Lastly, we apply the grid search on the hourly ethereum price. The result, however, is quite disappointing. From the two tables, even the best set of parameter ([15,29,10]) which maxi-

Parameters	Avg (bps)	Cumulative	Benchmark
[15,29,10]	23.77477	1.769157	2.639598
Duration	**Win Ratio**	**Max Win**	**Max Loss**
15.1627	0.36927	0.32507	-0.14899

Table 19: Performance sheet for the best cumulative return parameter

mizes the historical cumulative return fails to outperform the benchmark. Ethereum grows by two times from 2021 till now, while the MACD signal even fails to catch up with its original return. On the other hand, the default parameter underperforms the benchmark as well. This

Parameters	Avg (bps)	Cumulative	Benchmark
[12,26,9]	10.06179	0.269945	2.639598
Duration	**Win Ratio**	**Max Win**	**Max Loss**
12.3869	0.35628	0.35628	-0.14899

Table 20: Performance sheet for the default MACD parameter

phenomenon seems to suggest that the MACD signal is losing its power in recent years and fails to cope with the extreme volatile hourly ethereum data.

3.3 Best Parameter Conclusion

In the table summary of section 3.1 and 3.2, we use grid search algorithm to go through a wide range of parameter combinations to compare their performance metrics. We have calculated the performance of the default parameter and the best parameters that give the optimal cumulative return and win ratio respectively. We summarize the suitable parameters as follows.

The performance metrics including average return per trade, duration, win ratio, maximum

	Parameters	
Indicator	**EMA**	**MACD**
Daily BTC	[10,30]	[48,45,5]
Daily ETH	[12,18]	[35,38,8]
Hourly BTC	[11,36]	[4,48,26]
Hourly ETH	[4,18]	[15,19,10]

Table 21: A Set of suitable parameters

profit and loss per trade are compared to determine the suitable parameter. These suitable parameter sets all achieve decent cumulative return, relatively low maximum loss in history, and relatively large win ratio through the given period compared with other sets of parameters.

4 Indicator Comparison

We can now compare the performance between EMA and MACD. The following figure displays the percentage of the total cumulative return each signal occupies. It shows that MACD out-

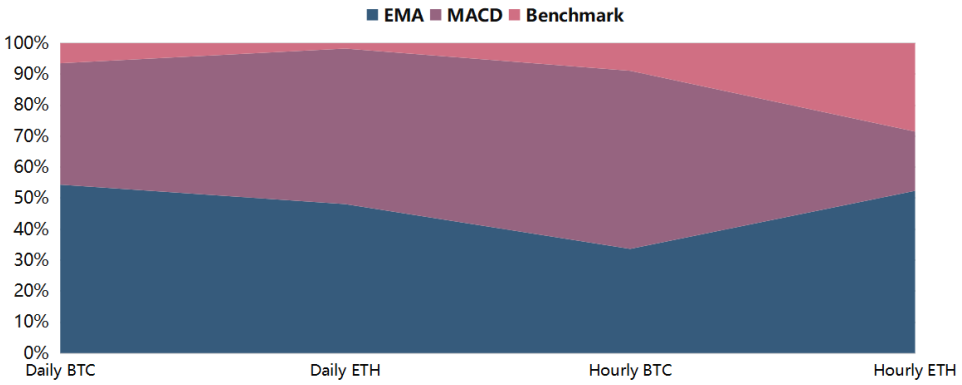

Figure 5: Cumulative return comparison between EMA, MACD, and benchmark

performs EMA in terms of cumulative return for hourly bitcoin and daily ethereum. For hourly ethereum and daily bitcoin, the EMA signal outperforms. While the best parameter of EMA always earn cumulative return far more than the benchmark, we see that MACD signal underperforms the benchmark in hourly ethereum. This may indicates that the MACD signal is losing its effectiveness over time, since the daily price has a wider historical time range than the hourly price.

We can further compare for the win ratio and the holding period. The bar charts illustrate the average win ratio and holding period comparison with different datasets. Although the win ratios between EMA and MACD are similar, MACD strategy has a much lower average holding period compared to that of the EMA. This indicates that MACD signal changes its sign and position frequently. The benefit is that MACD reacts to the sudden rise or drop in the cryptocurrencies more sensitively. Also it may suffer from the facts that: 1) the fast reaction could be misleading; 2) the transaction cost is high. In summary, we obtain the conclusions:

- In terms of cumulative return, EMA outperforms MACD for the daily bitcoin and hourly ethereum, but underperforms MACD for the hourly bitcoin and daily ethereum.

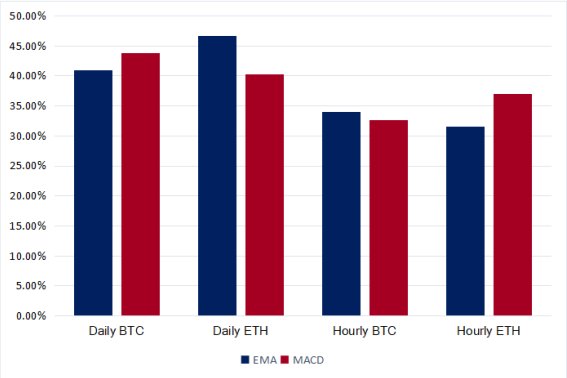

Figure 6: Win ratio comparison

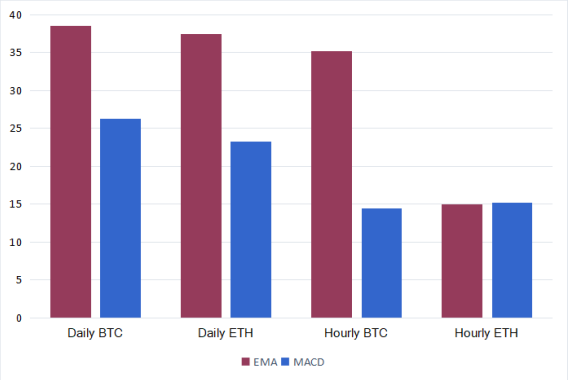

Figure 7: Holding period comparison

- The technical signals may be losing their effectiveness with time going by.
- The win ratios between EMA and MACD performance are similar, while MACD strategy has a shorter holding period and changes the position more frequently.

5 Discussion and Conclusion

In this project, two typical technical indicators EMA and MACD are tested for effectiveness on bitcoin and ethereum. We apply the grid search algorithm to find the best set of parameters that gives an overall satisfactory performance metrics. We propose a set of suitable parameters and also compare the effectiveness between EMA and MACD.

However, the cryptocurrency market is becoming more and more efficient through years. In previous sections, we raise the doubt that whether the indicators are performing worse in recent years, since the MACD signal underperforms the benchmark in 2022. We can list the performance of the indicators on a yearly basis as below.

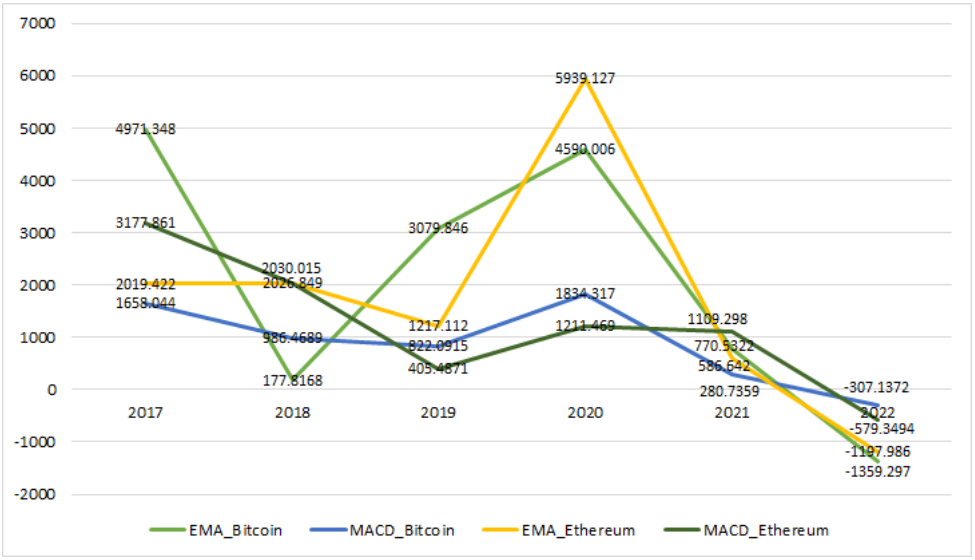

Figure 8: Average return per trade by year

The line chart displays the average return per trade (in bps) on a yearly basis with respect to the daily bitcoin price and ethereum price. The charts clearly depicts a decreasing trend in the

average return. Despite the rising up in 2020 (because of a bull market), the average return keeps decreasing, which even becomes negative at 2022 regardless of EMA or MACD strategy.

Hence it is not weird that in our backtesting, the performance for the daily data is much better than the hourly data. The hourly data are taken from year 2021 till now, in which the technical indicators all perform much worse than in other historical periods.

In conclusion, the technical indicators are powerful and effective and can help earn lots of excess return in the history. However, the effectiveness decreases sharply in recent years due to the increase in market efficiency [1].

References

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