**FE670: Project Report**

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# 1. Instrument and Strategy

The instrument I have chosen is BIO, a stock from Bio-Rad Laboratories, Inc. I used a 5-year timeframe, from 01-01-2017 to 12-31-2021. It contains the financial crisis of 2018 as well as impact of Covid pandemic after that, which provides a unique opportunity to test how stationary the strategy is.

The trading strategy is based on the idea of Simple moving average strategy (SMA):

Chart

Description automatically generated

I have chosen 20 days for short lookback window and 100 days for long lookback window and calculated respective simple moving averages as the trading signal. If is higher than , I buy and via versa.

# 2. Strategy results

The cumulative P/L of the SMA strategy is as the following:

Chart

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The black line is the cumulative PnL of the Buy & Hold strategy. The red line is the cumulative Pnl of the SMA strategy. During the period, SMA underperformed B&H in terms of returns. The problem may come from the choice of trading signal (threshold, short or long SMA window)

# 3. Bootstrap results

After implementing the trading strategy, it comes to the part of back testing. In this part, I have used a R package called “boot” to do the bootstrap framework.

For simplicity, I choose the AR(1) model to describe distribution of daily log returns .

I have done 150 times of bootstrap and the result is as the following:

Chart, line chart, histogram

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|  | **# of round-trip trades** | **Total return, %** | **B&H return, %** | **Winning trades, %** | **Max drawdown, %** | **Sharpe ratio, %** |
| --- | --- | --- | --- | --- | --- | --- |
| **Historical** | 30 | 90.93% | 142.25% | 43.33% | 22.80% | 69.74% |
| **Average** | 27.9 | 102.46% | 140.25% | 38.15% | 32.25% | 76.15% |

In empirical, the total return rate is 90.93% with maximum drawdown of 22.80%. Compared to the historical results, the resampled data, on average, has the total return rate increased to 102.46% but the max drawdown also increased up to 32.25%. The Sharpe ratio of the bootstrap resampling also higher than the empirical. This confirms the profitability of the strategy.

I used t.test function in R to check if average total return differs from zero:

Text, letter

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Although the strategy performed extremely well in terms of returns and Sharpe ratio, in general, it still underperformed the B&H.

# 4. SMA strategy statistics

If we look at the density of daily PnL as well their statistics, it looks like that they are not normally distributed, instead, it is more likely a left skewed distribution.

Chart, histogram

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| **Mean** | **Sigma** | **Skew** | **Kurtosis** |
| --- | --- | --- | --- |
| 0.0007228461 | 0.01645409 | 0.352348 | 11.55361 |

# 5. Time series momentum strategy

The performance of TSM compared to B&H is as the following

| **Sample** | **Annual return** | | | **Sharpe** | |
| --- | --- | --- | --- | --- | --- |
| TSM | B&H | p-value | TSM | B&H |
| 21-day | 23.88% | 28.96% | 0.00 | 0.87 | 1.03 |

TSM underperformed B&H in terms of both returns and Sharpe ratio. The reason is that TSM misses some price growth opportunities that exist in the case when the 12-month lookback returns are negative.

# 6. ARMA+GARCH (1,1)

Before running ARMA+GARCH(1,1) estimation model, I tested the stationarity of the new time series. The Augmented Dickey-Fuller test gives a p-value less than 0.01, which means the times series is stationary. Then, I used auto.arima function in R, which gives me the best ARIMA model based on AIC criteria (Akaike Information Criterion) and get estimated (p, q) = (1, 1).

| Coefficients | **AR1** | **MA1** |  |
| --- | --- | --- | --- |
| 0.8941 | -0.9392 | 7e-04 |

ARMA (1,1) + GARCH (1,1)

| Coefficients |  | **AR1** | **MA1** |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 0.001535 | 0.429134 | -0.506002 | 7e-04 | 0.145076 | 0.475353 |

# 7. Possible ways for improving PnL

According to the discuss above, there are some ways to improve this strategy. Firstly, using another trading signal may make a difference to the PnL. Secondly, instead of using only trend indicator, we can combine momentum indicator and trend indicator together. Finally, finding a better model for the time series will give us a more accurate bootstrap result compared to the AR(1) model.

# Appendix

| Sample | # of round-trip trades | Total return, % | B&H return, % | Winning trades, % | Max drawdown, % | Sharpe ratio, % |
| --- | --- | --- | --- | --- | --- | --- |
| Historical | 30 | 90.93% | 142.25% | 43.33% | 22.80% | 69.74% |
| B1 | 40 | 12.71% | 86.75% | 35.00% | 50.56% | 10.30% |
| B2 | 32 | 95.06% | 126.97% | 28.13% | 26.19% | 78.54% |
| B3 | 16 | 163.02% | 198.80% | 37.50% | 22.25% | 109.28% |
| B4 | 31 | 79.39% | 121.66% | 45.16% | 40.87% | 59.72% |
| B5 | 22 | 168.62% | 207.75% | 50.00% | 25.44% | 119.25% |
| B6 | 28 | 173.29% | 197.96% | 50.00% | 22.18% | 145.67% |
| B7 | 18 | 194.60% | 202.16% | 38.89% | 19.84% | 140.25% |
| B8 | 27 | 65.18% | 54.91% | 48.15% | 44.27% | 51.69% |
| B9 | 26 | 110.45% | 173.09% | 34.62% | 38.10% | 80.66% |
| B10 | 22 | 148.69% | 191.99% | 50.00% | 26.92% | 108.08% |
| B11 | 28 | 135.92% | 198.74% | 46.43% | 31.77% | 112.75% |
| B12 | 32 | 157.98% | 238.42% | 43.75% | 30.51% | 117.61% |
| B13 | 11 | 193.06% | 185.20% | 36.36% | 18.73% | 131.94% |
| B14 | 20 | 107.95% | 129.02% | 40.00% | 38.19% | 86.13% |
| B15 | 32 | 118.73% | 168.05% | 40.63% | 24.75% | 91.31% |
| B16 | 40 | -11.57% | 79.44% | 42.50% | 37.19% | -10.15% |
| B17 | 40 | 59.49% | 130.70% | 35.00% | 44.28% | 49.25% |
| B18 | 32 | 90.91% | 111.37% | 31.25% | 37.01% | 66.48% |
| B19 | 15 | 284.19% | 301.28% | 60.00% | 17.63% | 207.62% |
| B20 | 39 | 25.37% | 32.23% | 35.90% | 36.51% | 20.83% |
| B21 | 31 | 91.18% | 107.49% | 29.03% | 21.96% | 66.95% |
| B22 | 32 | 71.11% | 109.66% | 40.63% | 29.70% | 60.50% |
| B23 | 33 | 66.83% | 86.66% | 36.36% | 32.47% | 53.67% |
| B24 | 20 | 202.11% | 252.02% | 45.00% | 24.60% | 151.06% |
| B25 | 34 | 63.98% | 122.53% | 35.29% | 32.47% | 48.11% |
| B26 | 28 | 54.03% | 86.65% | 42.86% | 25.19% | 46.03% |
| B27 | 28 | 68.35% | 81.98% | 28.57% | 32.58% | 48.36% |
| B28 | 24 | 156.13% | 218.62% | 50.00% | 35.86% | 104.56% |
| B29 | 26 | 133.70% | 177.84% | 30.77% | 25.70% | 105.59% |
| B30 | 26 | 172.60% | 229.52% | 30.77% | 33.19% | 118.05% |
| B31 | 18 | 138.90% | 187.13% | 38.89% | 24.75% | 107.34% |
| B32 | 28 | 92.62% | 153.78% | 25.00% | 32.06% | 80.26% |
| B33 | 18 | 180.16% | 209.99% | 44.44% | 24.63% | 117.65% |
| B34 | 42 | 7.83% | 53.02% | 21.43% | 48.49% | 6.95% |
| B35 | 26 | 59.11% | 72.02% | 50.00% | 33.59% | 46.96% |
| B36 | 22 | 168.67% | 199.56% | 50.00% | 26.55% | 124.92% |
| B37 | 26 | 102.44% | 172.03% | 30.77% | 32.27% | 74.78% |
| B38 | 26 | 71.91% | 48.20% | 46.15% | 27.98% | 59.11% |
| B39 | 32 | 29.99% | 94.00% | 28.13% | 36.62% | 27.34% |
| B40 | 28 | 91.74% | 132.41% | 28.57% | 49.39% | 71.51% |
| B41 | 20 | 98.92% | 132.96% | 45.00% | 27.42% | 67.85% |
| B42 | 44 | 38.85% | 150.12% | 34.09% | 41.17% | 31.10% |
| B43 | 26 | 169.62% | 192.80% | 50.00% | 26.60% | 141.91% |
| B44 | 26 | 134.37% | 185.93% | 34.62% | 28.95% | 95.12% |
| B45 | 34 | 69.64% | 93.34% | 38.24% | 28.09% | 62.50% |
| B46 | 32 | 93.95% | 147.04% | 50.00% | 35.01% | 66.00% |
| B47 | 16 | 231.10% | 270.54% | 31.25% | 28.47% | 163.76% |
| B48 | 26 | 125.18% | 175.70% | 38.46% | 26.14% | 94.46% |
| B49 | 17 | 178.41% | 211.13% | 41.18% | 21.15% | 127.79% |
| B50 | 23 | 126.47% | 188.46% | 47.83% | 24.63% | 81.93% |
| B51 | 36 | 75.95% | 106.16% | 27.78% | 50.45% | 64.03% |
| B52 | 18 | 111.18% | 118.77% | 38.89% | 30.90% | 82.66% |
| B53 | 28 | 128.45% | 173.67% | 46.43% | 29.38% | 95.56% |
| B54 | 16 | 243.31% | 272.35% | 43.75% | 21.14% | 162.76% |
| B55 | 47 | 48.91% | 140.60% | 25.53% | 42.17% | 39.57% |
| B56 | 28 | -19.16% | 58.84% | 28.57% | 57.92% | -13.18% |
| B57 | 40 | 44.46% | 91.11% | 45.00% | 45.20% | 33.74% |
| B58 | 34 | -55.36% | -10.81% | 35.29% | 55.17% | -47.13% |
| B59 | 38 | -11.56% | 38.71% | 36.84% | 34.48% | -10.49% |
| B60 | 26 | 131.18% | 163.87% | 34.62% | 23.25% | 98.14% |
| B61 | 24 | 144.99% | 233.15% | 33.33% | 26.17% | 95.49% |
| B62 | 24 | 113.54% | 184.62% | 33.33% | 40.41% | 81.60% |
| B63 | 40 | 33.01% | 86.74% | 30.00% | 31.57% | 26.51% |
| B64 | 24 | 130.18% | 153.12% | 33.33% | 32.76% | 100.80% |
| B65 | 20 | 89.60% | 72.30% | 35.00% | 29.31% | 71.33% |
| B66 | 32 | 79.23% | 109.05% | 37.50% | 25.08% | 70.29% |
| B67 | 28 | 73.97% | 80.53% | 46.43% | 32.16% | 67.22% |
| B68 | 34 | 96.76% | 146.07% | 38.24% | 30.30% | 73.17% |
| B69 | 18 | 147.59% | 171.91% | 50.00% | 24.22% | 117.07% |
| B70 | 23 | 140.86% | 177.68% | 52.17% | 30.18% | 96.84% |
| B71 | 25 | 85.05% | 96.37% | 40.00% | 29.29% | 67.90% |
| B72 | 31 | 119.72% | 153.02% | 45.16% | 21.30% | 88.07% |
| B73 | 36 | 61.49% | 105.81% | 33.33% | 30.64% | 49.28% |
| B74 | 26 | 136.94% | 156.75% | 34.62% | 26.70% | 105.81% |
| B75 | 32 | 52.89% | 49.15% | 34.38% | 40.66% | 43.40% |
| B76 | 20 | 133.77% | 133.42% | 40.00% | 35.92% | 102.72% |
| B77 | 27 | 153.21% | 193.72% | 29.63% | 19.59% | 117.60% |
| B78 | 30 | 49.63% | 100.13% | 40.00% | 41.93% | 38.25% |
| B79 | 16 | 197.91% | 213.94% | 25.00% | 29.47% | 137.79% |
| B80 | 32 | 108.66% | 154.14% | 43.75% | 24.53% | 80.07% |
| B81 | 30 | 128.67% | 168.07% | 50.00% | 30.33% | 89.26% |
| B82 | 10 | 334.01% | 321.27% | 30.00% | 21.09% | 206.28% |
| B83 | 35 | 46.12% | 85.22% | 45.71% | 29.34% | 34.12% |
| B84 | 26 | 128.70% | 159.72% | 34.62% | 29.98% | 97.04% |
| B85 | 31 | 167.31% | 201.99% | 38.71% | 33.35% | 124.99% |
| B86 | 12 | 210.75% | 226.36% | 41.67% | 18.52% | 158.43% |
| B87 | 32 | 72.81% | 143.19% | 34.38% | 43.21% | 55.47% |
| B88 | 28 | 98.04% | 139.89% | 46.43% | 29.82% | 66.67% |
| B89 | 24 | 75.40% | 114.29% | 41.67% | 31.54% | 56.83% |
| B90 | 34 | 117.09% | 175.43% | 35.29% | 32.16% | 83.41% |
| B91 | 32 | 94.91% | 139.33% | 43.75% | 29.96% | 75.71% |
| B92 | 26 | 69.88% | 140.82% | 42.31% | 31.86% | 53.82% |
| B93 | 14 | 308.56% | 320.45% | 42.86% | 28.69% | 196.42% |
| B94 | 24 | 41.42% | 67.92% | 37.50% | 31.80% | 31.31% |
| B95 | 16 | 119.27% | 83.63% | 43.75% | 20.72% | 102.41% |
| B96 | 26 | 73.82% | 106.94% | 34.62% | 33.44% | 66.27% |
| B97 | 26 | 85.31% | 128.33% | 42.31% | 28.98% | 61.91% |
| B98 | 36 | 35.49% | 98.07% | 36.11% | 39.86% | 28.51% |
| B99 | 49 | 15.23% | 90.06% | 28.57% | 35.30% | 11.67% |
| B100 | 30 | 85.28% | 129.21% | 30.00% | 38.07% | 62.24% |
| B101 | 26 | 120.57% | 186.84% | 23.08% | 46.45% | 91.36% |
| B102 | 34 | -16.38% | -16.52% | 41.18% | 56.20% | -14.55% |
| B103 | 44 | 82.20% | 170.20% | 27.27% | 29.54% | 67.78% |
| B104 | 21 | 44.35% | 36.60% | 33.33% | 34.93% | 37.64% |
| B105 | 44 | -7.81% | 59.59% | 31.82% | 45.26% | -5.79% |
| B106 | 30 | 49.67% | 50.09% | 46.67% | 32.82% | 44.95% |
| B107 | 32 | 47.31% | 69.82% | 40.63% | 39.25% | 44.57% |
| B108 | 32 | 66.63% | 100.35% | 28.13% | 26.05% | 56.19% |
| B109 | 34 | 59.96% | 64.77% | 41.18% | 27.06% | 46.22% |
| B110 | 26 | 35.10% | 86.28% | 23.08% | 40.08% | 29.00% |
| B111 | 23 | 161.59% | 171.97% | 30.43% | 24.03% | 115.13% |
| B112 | 40 | 19.86% | 59.99% | 32.50% | 36.82% | 14.87% |
| B113 | 40 | -63.06% | -26.09% | 32.50% | 56.53% | -58.19% |
| B114 | 28 | 100.43% | 162.04% | 46.43% | 23.49% | 75.54% |
| B115 | 22 | 108.25% | 90.61% | 31.82% | 28.15% | 85.65% |
| B116 | 42 | -49.15% | -19.25% | 21.43% | 54.95% | -41.74% |
| B117 | 25 | 126.82% | 150.28% | 32.00% | 25.25% | 96.11% |
| B118 | 26 | 113.40% | 142.21% | 50.00% | 26.50% | 92.03% |
| B119 | 20 | 163.87% | 179.21% | 35.00% | 28.06% | 118.30% |
| B120 | 24 | 121.42% | 181.32% | 41.67% | 32.11% | 93.06% |
| B121 | 42 | 53.69% | 99.53% | 38.10% | 34.15% | 42.68% |
| B122 | 31 | 128.10% | 161.60% | 48.39% | 25.15% | 106.99% |
| B123 | 26 | 119.52% | 149.26% | 38.46% | 26.27% | 87.82% |
| B124 | 26 | 130.68% | 138.33% | 38.46% | 25.73% | 93.81% |
| B125 | 36 | -0.27% | 67.01% | 22.22% | 53.06% | -0.23% |
| B126 | 20 | 199.01% | 248.96% | 40.00% | 32.96% | 125.77% |
| B127 | 20 | 124.77% | 137.82% | 45.00% | 20.48% | 96.80% |
| B128 | 14 | 130.04% | 96.42% | 42.86% | 27.58% | 88.06% |
| B129 | 22 | 149.78% | 183.77% | 31.82% | 27.14% | 109.23% |
| B130 | 30 | 1.34% | 59.90% | 46.67% | 53.55% | 1.03% |
| B131 | 36 | 10.11% | 91.66% | 27.78% | 41.36% | 8.93% |
| B132 | 30 | 27.04% | 70.32% | 40.00% | 39.33% | 21.51% |
| B133 | 20 | 140.37% | 179.27% | 30.00% | 39.65% | 107.73% |
| B134 | 24 | 148.21% | 172.06% | 41.67% | 23.89% | 117.42% |
| B135 | 28 | 101.30% | 175.16% | 42.86% | 33.77% | 77.14% |
| B136 | 24 | 148.36% | 208.04% | 41.67% | 23.57% | 127.24% |
| B137 | 34 | 61.08% | 127.67% | 44.12% | 37.39% | 43.86% |
| B138 | 32 | 71.24% | 146.06% | 28.13% | 23.94% | 56.46% |
| B139 | 24 | 248.04% | 286.28% | 20.83% | 25.85% | 147.99% |
| B140 | 26 | 61.50% | 90.26% | 42.31% | 28.24% | 51.40% |
| B141 | 34 | 89.94% | 188.59% | 32.35% | 41.15% | 68.47% |
| B142 | 26 | 174.45% | 242.00% | 50.00% | 36.65% | 123.56% |
| B143 | 39 | -15.43% | 72.21% | 35.90% | 52.97% | -12.61% |
| B144 | 15 | 263.80% | 274.52% | 40.00% | 20.79% | 169.58% |
| B145 | 16 | 122.76% | 116.40% | 50.00% | 29.63% | 99.48% |
| B146 | 24 | 158.03% | 179.53% | 45.83% | 22.04% | 124.61% |
| B147 | 26 | 143.41% | 139.90% | 46.15% | 21.30% | 99.68% |
| B148 | 28 | 88.95% | 105.47% | 35.71% | 38.82% | 76.71% |
| B149 | 36 | 57.71% | 82.28% | 36.11% | 25.15% | 51.40% |
| B150 | 26 | 129.27% | 202.60% | 38.46% | 31.23% | 93.53% |
| Average | 27.9 | 102.46% | 140.25% | 38.15% | 32.25% | 76.15% |

Table 1: Resampled data set

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figure 1: Augmented Dickey-Fuller Test of BIO time series

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figure 2: Augmented Dickey-Fuller Test of SMA time series