Evaluation of Investment Strategies for Cryptocurrencies
How to get Rich Quick with this one Weird Trick (?)

Johannes Herrmann

August 27, 2020
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2. The Solution: Deploy a Trading Bot using a popular Trading Strategy
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The Problem: Investing in Bitcoin for Fun and Profit

The Solution: Deploy a Trading Bot using a popular Trading Strategy

The Evaluation: Are we rich yet?
Introduction

Problem: Given the price history of Bitcoin, decide whether to
- Buy
- Sell
- Do nothing
The Problem

Introduction

**Problem:** Given the price history of Bitcoin, decide whether to
- Buy
- Sell
- Do nothing

**Objective:** Maximum profit
Measuring Profit: The ROI

**ROI** Return on Investment:
Percentage of funds gained/lost

\[
ROI = \frac{\text{Net Profit}}{\text{Investment}}
\]

Example:
Assume we have 200$
Buy 2 BTC for 100$ each
BTC price increases by 10%
Sell 2 BTC for 110$ each
ROI:

\[
\frac{220 - 200}{200} = 0.1 = +10\%
\]
Measuring Profit: The ROI

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Another way to calculate:

- ROI: \( \frac{110}{100} - 1 = +10\% \)
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Another way to calculate:

- ROI: $\frac{110}{100} - 1 = +10\%$
- This works because:

$$\text{ROI} = \frac{F_s - F_b}{F_b}, F_s = \frac{F_b}{p_b}p_s$$
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Another way to calculate:
- ROI: \( \frac{110}{100} - 1 = +10\% \)
- This works because:

\[
\text{ROI} = \frac{F_s - F_b}{F_b}, \quad F_s = \frac{F_b}{p_b} p_s
\]

\[
\Rightarrow \text{ROI} = \frac{F_b p_s - F_b}{F_b} = \frac{p_s}{p_b} - 1
\]
Given:
- Current point in time $t$
- Prices $p = p_0, p_1, p_2, \ldots, p_t$
- Trades $T = \{(b_1, s_1), (b_2, s_2), \ldots\}$
Formal Problem Definition

Given:
- Current point in time $t$
- Prices $p = p_0, p_1, p_2, \ldots, p_t$
- Trades $T = \{(b_1, s_1), (b_2, s_2), \ldots\}$

The strategy which generated $T$ is called optimal, if there exists no set $T'$, such that:

\[
\left( \prod_{(b,s) \in T} \frac{p_s}{p_b} \right) - 1 < \left( \prod_{(b',s') \in T'} \frac{p_{s'}}{p_{b'}} \right) - 1
\]

(Without cost)
Formal Problem Definition

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The strategy which generated $T$ is called optimal, if there exists no set $T'$, such that:

$$\left( \prod_{(b', s') \in T'} \frac{p_{s'} \cdot (1 - c)}{p_{b'} \cdot (1 + c)} \right) - 1 < \left( \prod_{(b, s) \in T} \frac{p_s \cdot (1 - c)}{p_b \cdot (1 + c)} \right) - 1$$

(With cost)
Formal Problem Definition

Given:

- Current point in time \( t \)
- Prices \( p = p_0, p_1, p_2, \ldots, p_t \)
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\]

(With cost)

Why the brackets?
The Problem

The Baseline: HODL

- The Buy and Hold strategy (a.k.a. HODLing)
The Problem

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- Arguably one of the most common strategies
- Buy at the first (possible) point in time and sell at the last
- Set of trades $T = \{(0, t)\}$

ROI: \[ p_t = p_0 - 1 \]
The Baseline: HODL

- The Buy and Hold strategy (a.k.a. HODLing)
- Arguably one of the most common strategies
- Buy at the first (possible) point in time and sell at the last
- Set of trades $T = \{(0, t)\}$
- ROI: $\frac{p_t}{p_0} - 1$
The Baseline: HODL

The Buy and Hold strategy (a.k.a. HODLing)
Arguably one of the most common strategies
Buy at the first (possible) point in time and sell at the last
Set of trades \( T = \{(0, t)\} \)
ROI: \( \frac{p_t}{p_0} - 1 \)

Can we do better?
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The Basic Idea

- Deploy a bot that can buy/sell when signal is given
- The signal is produced by another popular strategy:

  The SMAC
The SMA: Simple Moving Average

- For each data point, calculate the average of last n data points
The SMA: Simple Moving Average

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Figure: Black line: Price over Time, Blue Line: SMA with a window of 10
The SMA

Formula for SMA $s_t$ with window $n$:

$$s_t = \frac{1}{n} \cdot \sum_{i=0}^{n-1} p_{t-i}$$
The SMAC Strategy

**SMAC** Simple Moving Average Crossover

- For each data point, calculate two SMAs with different windows
- If the difference between the SMAs changes sign, buy/sell
The SMAC Strategy: Example

Figure: Red SMA window: 6, Blue SMA window: 10
The SMAC Strategy: Example

Figure: Red SMA window: 6, Blue SMA window: 10
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Figure: Red SMA window: 6, Blue SMA window: 10
The SMAC Strategy

- Let the window values be $m, n$ with $m < n$
- Fast SMA: $f_t = \frac{1}{m} \cdot \sum_{i=0}^{m-1} p_{t-i}$
- Slow SMA: $s_t = \frac{1}{n} \cdot \sum_{i=0}^{n-1} p_{t-i}$
- Difference: $d_t = f_t - s_t$
- Strategy:

\[
\begin{align*}
  d_{t-1} < 0 \text{ and } d_t \geq 0 & \Rightarrow \text{Buy} \\
  d_{t-1} > 0 \text{ and } d_t \leq 0 & \Rightarrow \text{Sell}
\end{align*}
\]
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Theory: An Optimal Model

- Assume price decreases linearly
  \[ p_t = p_0 - t \cdot k \]

Figure: \( k = 5 \), Red SMA window: 2, Blue SMA window: 4
Assume price decreases linearly

\[ p_t = p_0 - t \cdot k \]

Buy signal is only triggered by a change

\[ \geq k \left( \frac{n \cdot m}{2} - 1 \right) \]

**Figure:** \( k = 5 \), Red SMA window: 2, Blue SMA window: 4
The Evaluation

Theory: An Optimal Model

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We can trigger a sell signal in a similar fashion.

Figure: $k = 5$, Red SMA window: 2, Blue SMA window: 4
We can trigger a sell signal in a similar fashion. Here: change $\leq -k\left(\frac{n \cdot m}{2} - 1\right)$.
The Evaluation

Theory: An Optimal Model

And so on...

Figure: $k = 5$, Red SMA window: 2, Blue SMA window: 4
Bitcoins Next Top Model?

- $p_0 \geq \frac{n \cdot m}{2} \cdot k$
- ROI: $\frac{p_0}{p_0 - k} - 1$
- Length: $n \cdot m + 2$
The Evaluation

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- \( p_0 \geq \frac{n \cdot m}{2} \cdot k \)
- ROI: \( \frac{p_0}{p_0 - k} - 1 \)
- Length: \( n \cdot m + 2 \)
- For \( k = 5, m = 2, n = 4 \):
  - \( p_0 = 50 \geq 20 \)

Figure: \( k = 5, m = 2, n = 4 \)
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For $k = 5$, $m = 2$, $n = 4$:
- $p_0 = 50 \geq 20$
- ROI: $\frac{50}{50 - 5} - 1 = +11.1111\%$

Figure: $k = 5$, $m = 2$, $n = 4$
The Evaluation

**Bitcoins Next Top Model?**

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For $k = 5, m = 2, n = 4$:

- $p_0 = 50 \geq 20$
- ROI: $\frac{50}{50 - 5} - 1 = +11.1111\%$
- Length: $2 \cdot 4 + 2 = 10$

Seems reasonable

*Figure: $k = 5, m = 2, n = 4$*
Bitcoins Next Top Model?

- $p_0 \geq \frac{n \cdot m}{2} \cdot k$
- ROI: $\frac{p_0}{p_0 - k} - 1$
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For a realistic setting:
- $k = 5$, $m = 50$, $n = 100$:
- $p_0 \geq 12500$
**The Evaluation**

**Bitcoins Next Top Model?**

- \( p_0 \geq \frac{n \cdot m}{2} \cdot k \)
- ROI: \( \frac{p_0}{p_0 - k} - 1 \)
- Length: \( n \cdot m + 2 \)

For a realistic setting:
- \( k = 5, m = 50, n = 100: \)
- \( p_0 \geq 12500 \)
- ROI:
  \[
  \frac{12500}{12500 - 5} - 1 = +0.04\%
  \]

![Graph](image.png)

*Figure: k = 5, m = 50, n = 100*
The Evaluation

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- \( p_0 \geq 12500 \)
- ROI: \( \frac{12500}{12500 - 5} - 1 = +0.04\% \)
- Length: \( 50 \cdot 100 + 2 = 5002 \)

Figure: \( k = 5, m = 50, n = 100 \)
The Evaluation

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For a realistic setting:
- \( k = 5, m = 50, n = 100: \)
- \( p_0 \geq 12500 \)
- ROI: \( \frac{12500}{12500 - 5} - 1 = +0.04\% \)
- Length:
  - \( 50 \cdot 100 + 2 = 5002 \)
- Does not seem reasonable

Figure: \( k = 5, m = 50, n = 100 \)

Johannes Herrmann

August 27, 2020 18 / 23
Empirical Test: The Setting

- Assume we want to invest in some asset (like BTC)
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- Time period $\geq$ 3 months
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- And if it is the SMAC: For what window setting?
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Optional: Formal definition of the binomial test setting
SMAC: The Strategy Settings

- If we consider window sizes up to 300 reasonable:
- **44850** possible settings (Proof)
SMAC: The Strategy Settings

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- 10, 20, 50, 100, 200 (10 different settings in total)
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- Settings used by R+V Insurance (Volksbank):
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SMAC: The Strategy Settings

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SMAC: The Strategy Settings

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- Total number of recommended settings:
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- What gives a higher chance of success:
  Choosing a recommended setting or one at random?
# Test Results

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Most other day trading strategies lack a mathematical justification
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**Day trading strategies are basically astrology for Millennials**
Thank you!
Cost

- How do cryptocurrency exchanges earn money?
Cost

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- With the spread
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- With the **spread**
- **Spread**: Difference between buying and selling price
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- How do cryptocurrency exchanges earn money?
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  - “Regular” BTC price is 100$
  - Exchange will sell BTC for 101$
  - Exchange will buy BTC for 99$
How do cryptocurrency exchanges earn money?

With the **spread**

**Spread**: Difference between buying and selling price

Example, where spread is 2%:

“Regular” BTC price is 100$

Exchange will sell BTC for 101$

Exchange will buy BTC for 99$

Note: This is more complex in a real setting

(Based on price movement, amount of customers, trading volume, etc.)
Compounded ROI

- For $T = \{(b_1, s_1), \ldots, (b_n, s_n)\}$
Compounded ROI

- For $T = \{(b_1, s_1), \ldots, (b_n, s_n)\}$
- $\text{ROI} = \frac{F_{s_n} - F_{b_1}}{F_{b_1}}$
Compounded ROI

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- Remember: \( F_{s_i} = \frac{p_{s_i}}{p_{b_i}} F_{b_i} \)
Compounded ROI

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Remember: $F_{s_i} = \frac{p_{s_i}}{p_{b_i}} F_{b_i}$

If we do not change the funds in between trades:

$F_{b_i} = F_{s_{i-1}}$

$\Rightarrow F_{s_i} = \frac{p_{s_i}}{p_{b_i}} F_{s_{i-1}}$
Compounded ROI

For $T = \{(b_1, s_1), \ldots, (b_n, s_n)\}$

$\text{ROI} = \frac{F_{sn} - F_{b1}}{F_{b1}}$

Remember: $F_{si} = \frac{p_{si}}{p_{bi}} F_{bi}$

If we do not change the funds in between trades:

$F_{bi} = F_{si-1}$

$\Rightarrow F_{si} = \frac{p_{si}}{p_{bi}} F_{si-1}$

Solving the recursion:

$F_{sn} = \left(\prod_{i=1}^{n} \frac{p_{si}}{p_{bi}}\right) \cdot F_{b1}$
Compounded ROI

- For $T = \{(b_1, s_1), \ldots, (b_n, s_n)\}$
- $\text{ROI} = \frac{F_{s_n} - F_{b_1}}{F_{b_1}}$
- Remember: $F_{s_i} = \frac{p_{s_i}}{p_{b_i}} F_{b_i}$
- If we do not change the funds in between trades:
  - $F_{b_i} = F_{s_{i-1}}$
  - $\Rightarrow F_{s_i} = \frac{p_{s_i}}{p_{b_i}} F_{s_{i-1}}$
- Solving the recursion:
  - $F_{s_n} = \left( \prod_{i=1}^{n} \frac{p_{s_i}}{p_{b_i}} \right) \cdot F_{b_1}$
  - $\Rightarrow \text{ROI} = \left( F_{b_1} \cdot \prod_{i=1}^{n} \frac{p_{s_i}}{p_{b_i}} - F_{b_1} \right) \cdot \frac{1}{F_{b_1}}$
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- $\text{ROI} = \frac{F_{s_n} - F_{b_1}}{F_{b_1}}$
- Remember: $F_{s_i} = \frac{p_{s_i}}{p_{b_i}} F_{b_i}$
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  - $= \left(\prod_{(b,s) \in T} \frac{p_s}{p_b}\right) - 1$
Number of SMAC strategies

- Example: For slow window of 4, there are 3 possible settings
  - (4, 3), (4, 2), (4, 1)
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- Total number of settings, up to a slow window of $n$: 
  \[
  \frac{n(n-1)}{2}
  \]
Number of SMAC strategies

- Example: For slow window of 4, there are 3 possible settings
  - (4, 3), (4, 2), (4, 1)
- For a slow window of $i$, there are $i - 1$ possible settings
- Total number of settings, up to a slow window of $n$:
  $$\sum_{i=2}^{n} i - 1 = \sum_{i=1}^{n-1} i = \frac{n(n - 1)}{2}$$
Binomial Test

- Null hypothesis: SMAC has a greater ROI than the BnH with probability at most $\frac{1}{2}$
- $H_0 : \theta \in \left[0, \frac{1}{2}\right]$, $H_1 : \theta \in \left(\frac{1}{2}, 1\right]$
Binomial Test

- Null hypothesis: SMAC has a greater ROI than the BnH with probability at most \( \frac{1}{2} \)
- \( H_0 : \theta \in \left[ 0, \frac{1}{2} \right], \quad H_1 : \theta \in \left( \frac{1}{2}, 1 \right) \)
- Each SMAC setting is tested on 100 random samples
Binomial Test

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- We reject $H_0$, if SMAC succeeds in more than 62 out of 100 trials
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  - $X \sim B(100, 0.5)$, $\mathbb{P}(X \leq 62) = 0.994$
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  \[ H_0 : \theta \in \left[0, \frac{1}{2}\right], \quad H_1 : \theta \in \left(\frac{1}{2}, 1\right) \]

- Each SMAC setting is tested on 100 random samples

- For a significance level $\alpha = 0.01$:
  - We reject $H_0$, if SMAC succeeds in more than 62 out of 100 trials
  - $X \sim B(100, 0.5), \quad P(X \leq 62) = 0.994$
  - Assume we commit a type II error, if $\theta \geq 0.7$
  - $Y \sim B(100, 0.7), \quad P(Y \leq 62) = 0.053$
Binomial Test

- Null hypothesis: SMAC has a greater ROI than the BnH with probability at most $\frac{1}{2}$
  
  $H_0 : \theta \in [0, \frac{1}{2}], \ H_1 : \theta \in (\frac{1}{2}, 1]$

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- For a significance level $\alpha = 0.01$:
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  Assume we commit a type II error, if $\theta \geq 0.7$

  $Y \sim B(100, 0.7), \ P(Y \leq 62) = 0.053$

  Then we get type II error probability $\beta = 0.053$

  And power $(1 - \beta) = 0.947$
Bitcoin Price Data
Microsoft Price Data
EUR/USD Price Data