W U T I S

Crypto Asset Dynamics

Algorithmic Trading

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Our Team

Kirill **Gusev**

Associate

- Concept
- ARMA-GARCH model

Raiffeisen Bank International
Member of RBI Group

- MSc B&F (Uni Wien)
- BSc Business and Administration (Uni Wien)

Karina **Pekarek-Kostka**

Analyst

- Naive Approach
- Portfolio optimization

- BSc Business and Economics (WU)

David **Hirnschall**

Head of Department

- Support

Raiffeisen Bank International
VIG VIENNA INSURANCE GROUP
GENERALI

- PhD Fin. Math (WU)
- MSc Fin. Math (TU)
- BSc Fin. Math (TU)

Agenda

Introduction

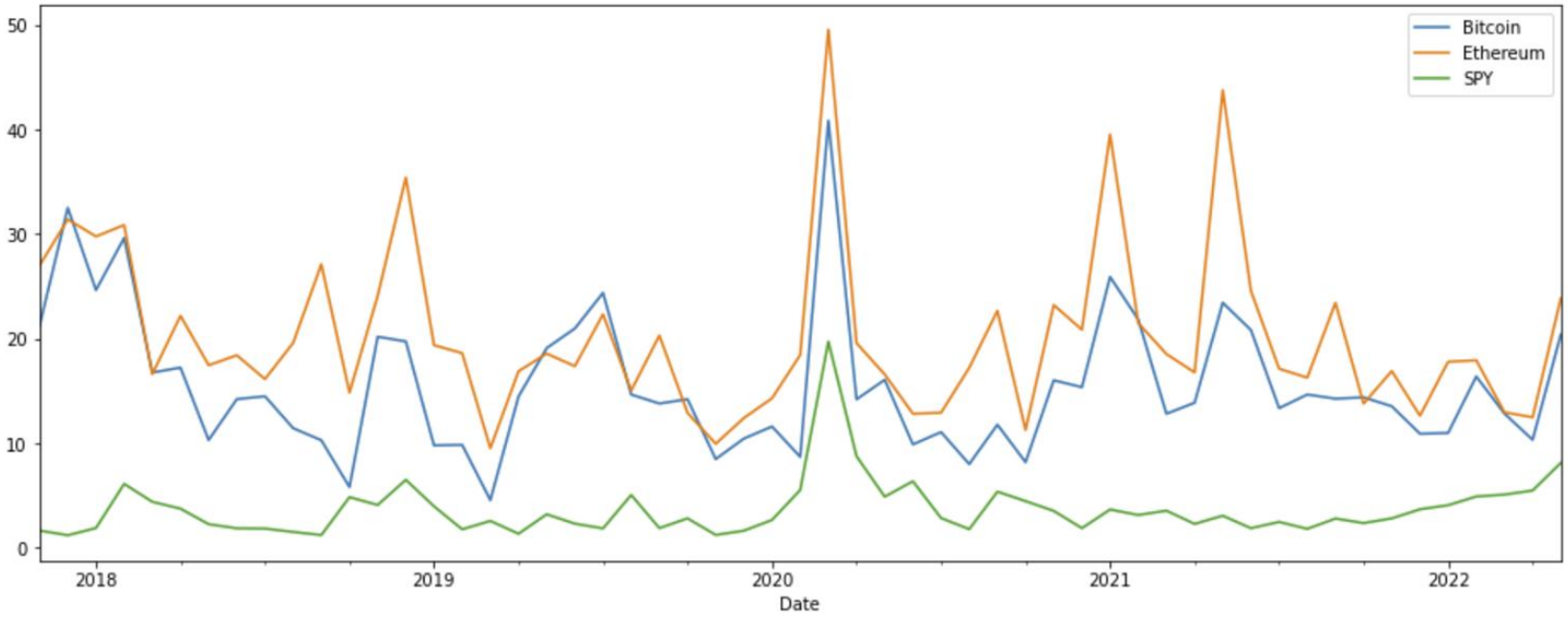
- Crypto currencies incorporate certain asset's properties and could be characterized as crypto assets.
- Extremely profitable at a cost of high volatility.
- Is modern portfolio theory appropriate for the risk diversification in case of crypto assets?
  - Which risk measure to choose?
- Proper model for investigating dynamics of crypto asset returns .
  - ARMA + GARCH and Sample Innovation

"Despite being described as a medium of exchange, cryptocurrencies do not have the typical attributes of a medium of exchange. Consequently, cryptocurrencies are more appropriately described as crypto assets. A common investment attribute shared by the more than 2,500 crypto assets is that they are highly volatile. An investor interested in reducing price volatility of a portfolio of crypto assets can do so by constructing an optimal portfolio through standard optimization techniques that minimize tail risk."

Hu, Yuan & Rachev, Svetlozar & Fabozzi, Frank. (2019)

Describing the (extreme) Volatility of Crypto Assets.

Mean Monthly Volatilities (2017-11-09 to 2022-05-19)		
Asset	Stdev. returns*	Stdev. prices*
Bitcoin	15.55%	6099.06
Ethereum	20.24%	390.85
XRP	23.24%	0.2987
Litecoin	21.25%	49.50
EOS	24.30%	2.37
BNB	22.16%	51.63
SPY	3.67%	21.11



- Crypto currencies are drastically more volatile than say the S&P500 (ETF)
- Bitcoin has the lowest volatility from the listed crypto-assets: 15.55%
- Graph depicts the monthly volatilities of three crypto-assets over a span of 4-years
  - Bitcoin fluctuated between ~5% and ~40% monthly volatilities
  - Ethereum fluctuated between ~10% and ~50% monthly volatilities
  - SPY fluctuated between ~3% and ~18% monthly volatilities

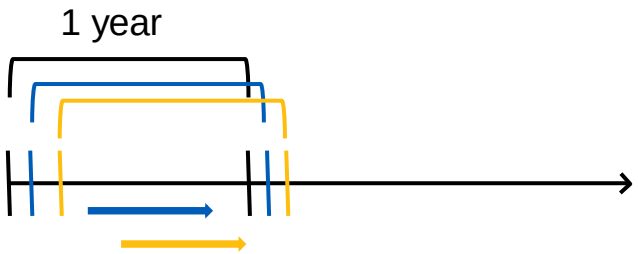
*Annualized

Naive Approach (Historical Data): Method.

Three optimization approaches.

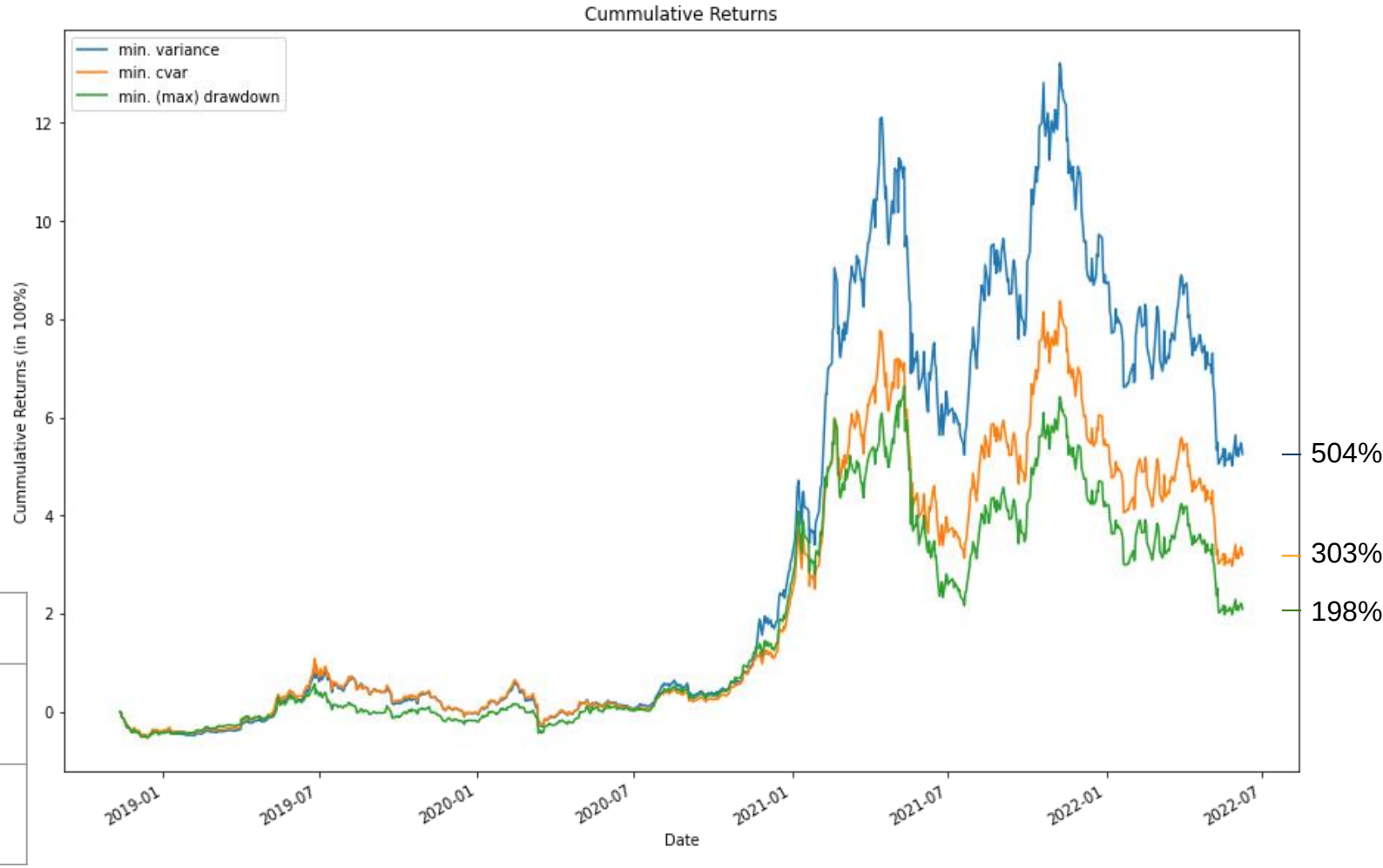
- Minimum Variance portfolio
- Minimum CVaR portfolio
- Minimum Drawdown portfolio

Rolling-window approach.



- weights are optimized for each window (w) and applied to the day directly following the window (w + 1).

Optimal portfolio optimization approaches (timeframes)		
2019-01 to 2019-06	2019-07 to 2020-08	2020-09 to 2022-07
min. drawdown	min. cVaR and min. variance	min. variance



Naive Approach (Historical Data): Performance Comparison.

Evaluating rolling-window optimization approaches			
	min. Variance portfolio	min. CVaR portfolio	min. Drawdown portfolio
Ann. Returns	**65.4%**	47.7%	35.8%
Ann. Volatility	98.1%	**96.5%**	108.4%
Sharpe Ratio*	**0.643**	0.47	0.308
max. Drawdown	-64.5%	-65.6%	**-64.3%**

Setting.

- Rolling-window algorithm applied to the aforementioned crypto-currencies from **2017-11-09 to 2022-05-19**. (omit first-year for the window)

Results.

- The min. Variance portfolio performs the best for an investor who would like to optimize their sharpe ratio or returns.
- The min. CVaR portfolio has the overall least volatility and is suitable for an investor who would like to prioritize risk over return.
- The min. Drawdown portfolio has the smallest drawdown and is fitting for an investor who would like to minimize downside volatility.

*used 3-Month T-bill rate on Jan 2. 2019 (2.37%)

ARMA(1,1) GARCH(1,1) Model: Checking the Accuracy of (model) Predicted Returns.

Accuracy of Return Predictions							
Crypto A.	Bitcoin	Ethereum	XRP	Litecoin	BTC Cash	EOS	BNB*
M.A.E.*	2.62	3.44	3.63	3.71	3.88	3.90	3.68

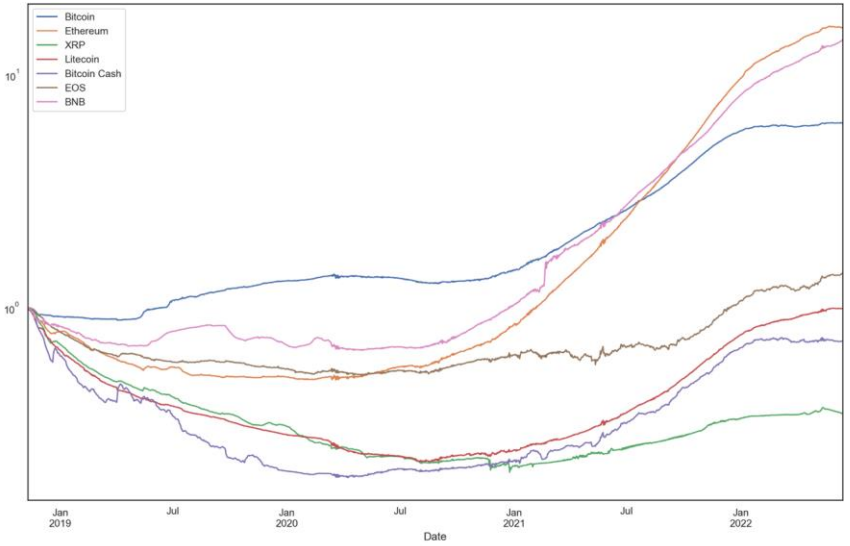
- Modeling the returns with ARMA(1,1) GARCH (1,1) processes

$$r_t^{(i)} = \mu_t^{(i)} + a_t^{(i)},$$

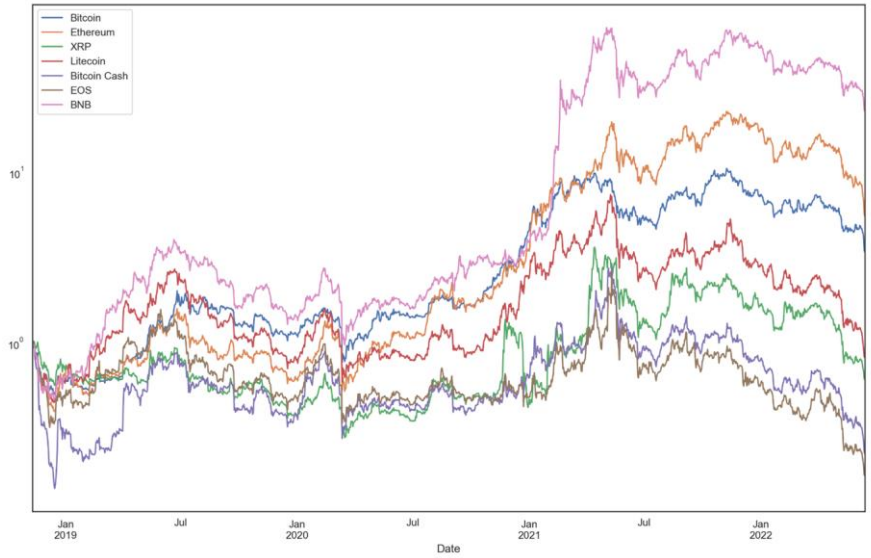
- The modeled outcome resembles the general long term tendency but not the short term trends
- Improvement - sample innovation

$$a_t^{(i)} = \sigma_t^{(i)} \epsilon_t^{(i)}$$

Crypto assets' returns simulation

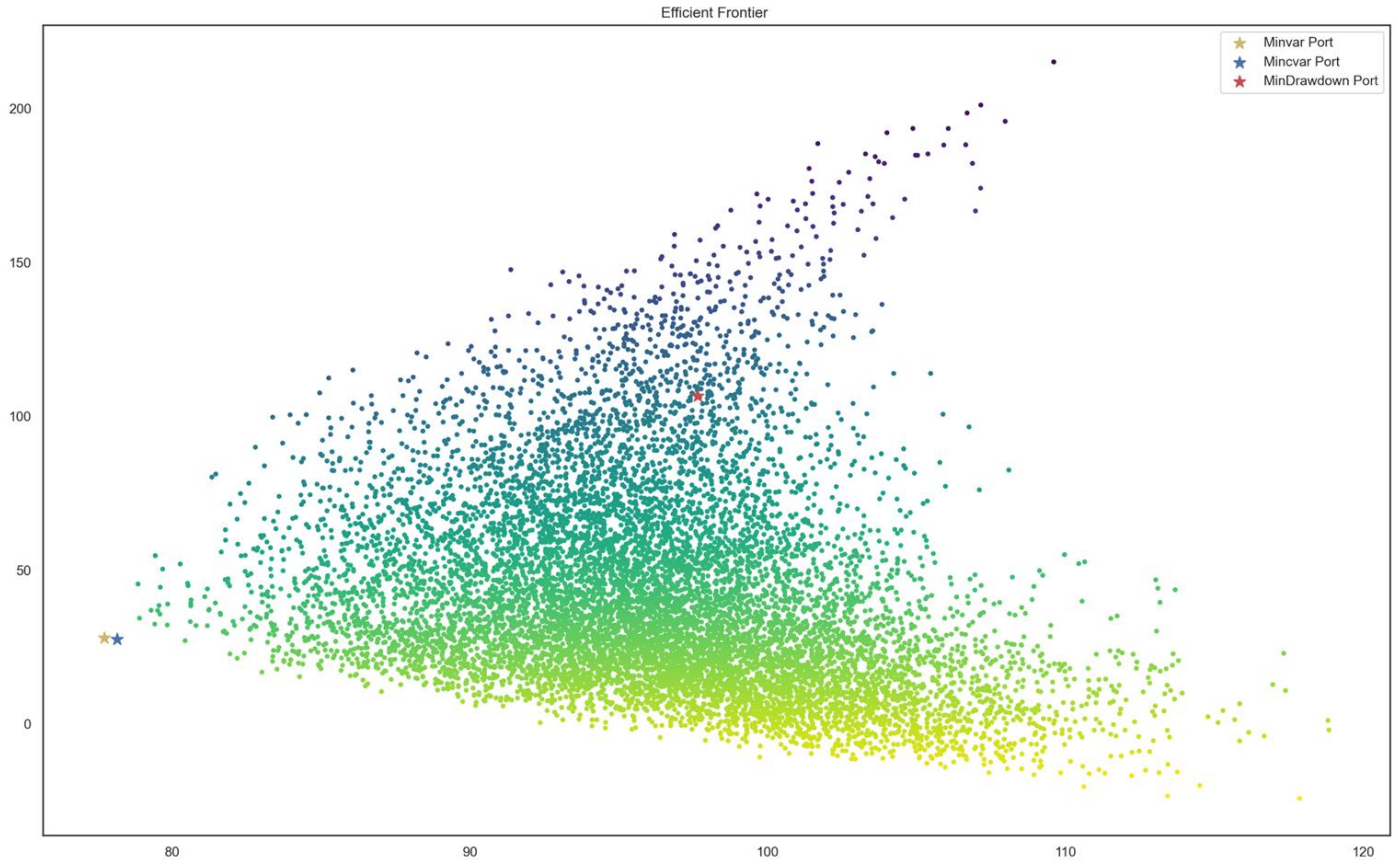


Crypto assets' returns actual



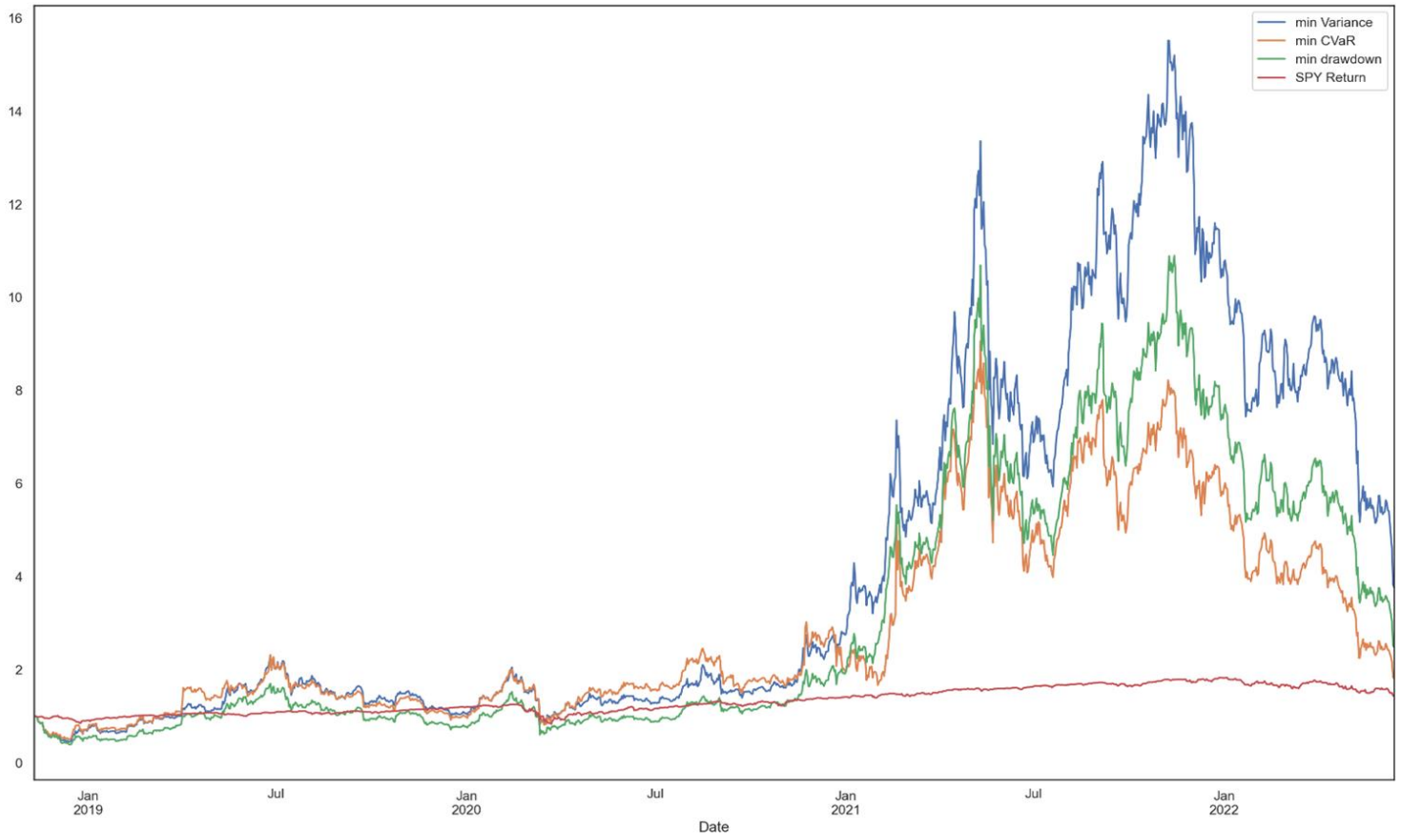
*M.A.E. - Mean Absolute Error

ARMA(1,1) GARCH(1,1) Model: Modeling the Efficient Frontier and Sample Innovation.



- Sample innovation and portfolio optimization
  - 10000 possible portfolios
  - T-distributed sample innovation with 5 degrees of freedom and unit variance
- Three optimization portfolios:
  - Minimum Variance portfolio
  - Minimum CVaR portfolio
  - Minimum Drawdown portfolio

Cumulative Returns



Three types of ARMA GARCH portfolios and S&P 500 ETF

- Minimum Variance portfolio
- Minimum CVaR portfolio
- Minimum Drawdown portfolio
- Market portfolio (SPY)

Comparison: Performance of the Naive vs. GARCH Approach.

Optimization Portfolios Comparison Table							
	min. Variance portfolio		min. CVaR portfolio		min. Drawdown portfolio		S&P 500 ETF
(Approach)	Naive	ARMA-GARCH	Naive	ARMA-GARCH	Naive	ARMA-GARCH	Market Portfolio
Ann. Returns	**65.4%**	60.6%	**47.7%**	45.4%	35.8%	35.9%	9.33%
Ann. Volatility	98.1%	**89.4%**	96.5%	**90.1%**	108.4%	**103.0%**	**21.22%**
Sharpe Ratio*	0.643	0.645	0.47	0.47	0.308	**0.371**	**0.311**
max. Drawdown	**-64.5%**	-67.0%	-65.6%	-65.6%	**-64.3%**	-74.4%	-4.61%

Results.

- The ARMA-GARCH model offers reduced volatility and equal - if not higher - Sharpe ratio for all portfolios calculated in comparison to the naive approach.
- The naive approach, in contrast, offers higher (or equal) returns, and a reduced drawdown in comparison to the ARMA-GARCH approach.
- The best portfolio option for the ARMA-GARCH approach would be the minimum-variance if the sole goal is to minimize volatility or maximize the Sharpe ratio. In terms of minimizing downside volatility, the CVaR portfolio would be better suited.

Generally, the approach and portfolio-optimization type chosen, heavily depend on the goals of the individual investor.

*used 3-Month T-bill rate on Jan 2. 2019 (2.37%)

Appendix

Appendix

References

Hu, Yuan & Rachev, Svetlozar & Fabozzi, Frank. (2019). Modelling Crypto Asset Price Dynamics, Optimal Crypto Portfolio, and Crypto Option Valuation.

Appendix

Further strategy improvement

- Mitigating the huge drops in returns
- Predict returns' decreases with ARMA GARCH
- Switch to the safer crypto assets such as stable coin

Appendix

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

- Returns

$$r_t^{(i)} = \mu_t^{(i)} + a_t^{(i)}, i = 1, \dots, d, t = 0, \dots T$$

- ARMA(1,1)

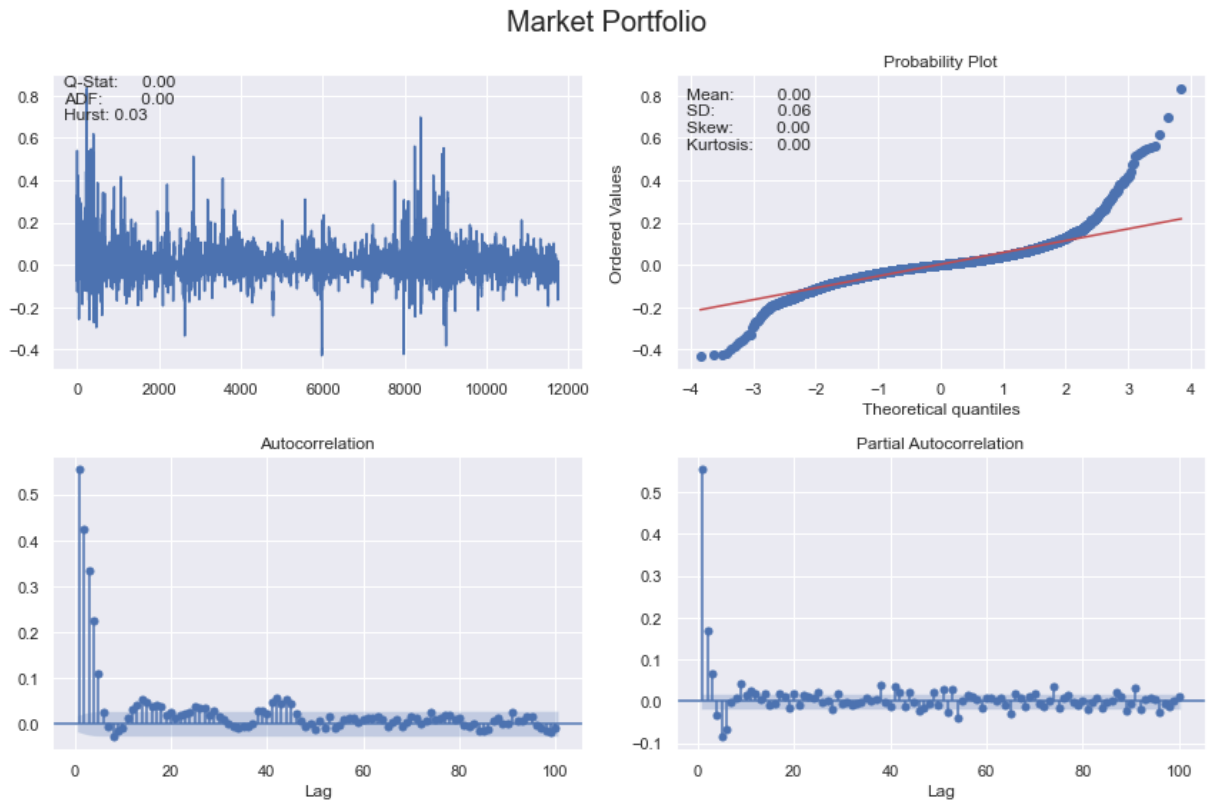
$$\mu_t^{(i)} = \varphi_0^{(i)} + \varphi_1^{(i)} r_{t-1}^{(i)} + \theta_1^{(i)} a_{t-1}^{(i)}$$

- GARCH(1,1)

$$a_t^{(i)} = \sigma_t^{(i)} \epsilon_t^{(i)}$$

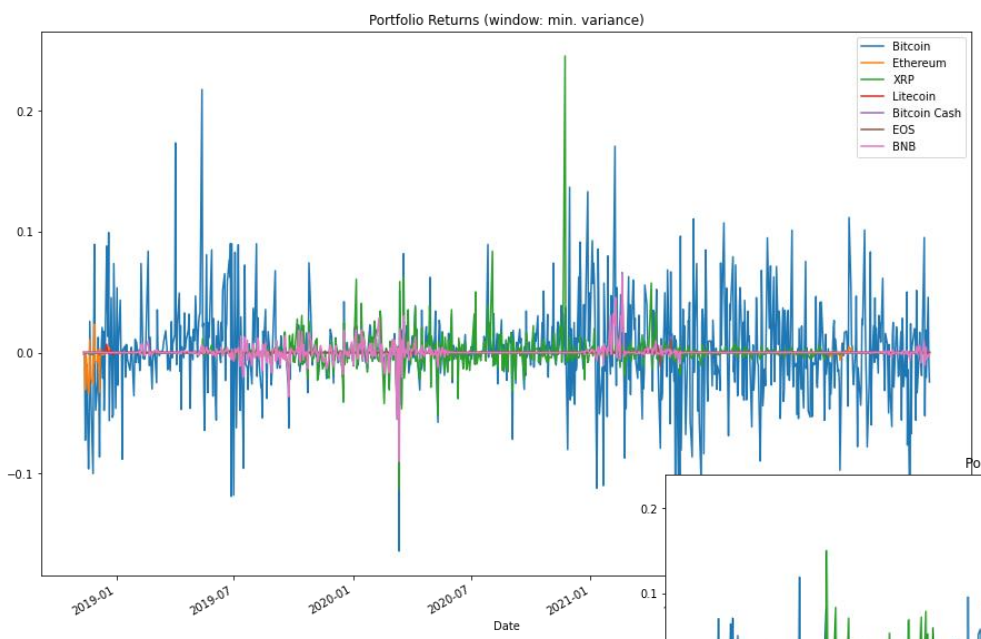
$$(\sigma_t^{(i)})^2 = \alpha_0^{(i)} + \alpha_1^{(i)} (a_{t-1}^{(i)})^2 + \beta_1^{(i)} (\sigma_{t-1}^{(i)})^2$$

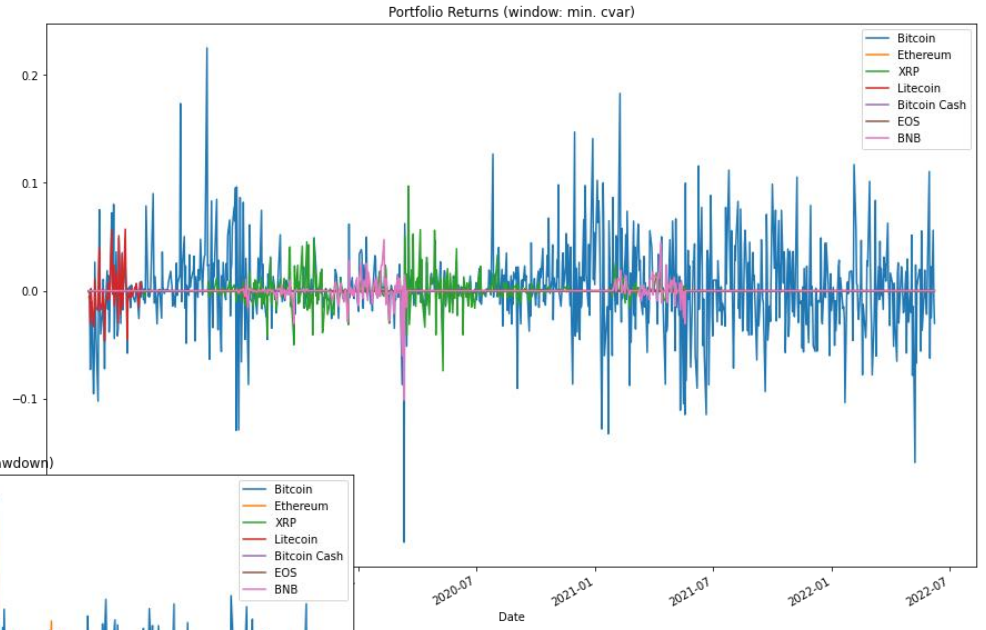
  - $\epsilon_t^{(i)}$ - sample innovation

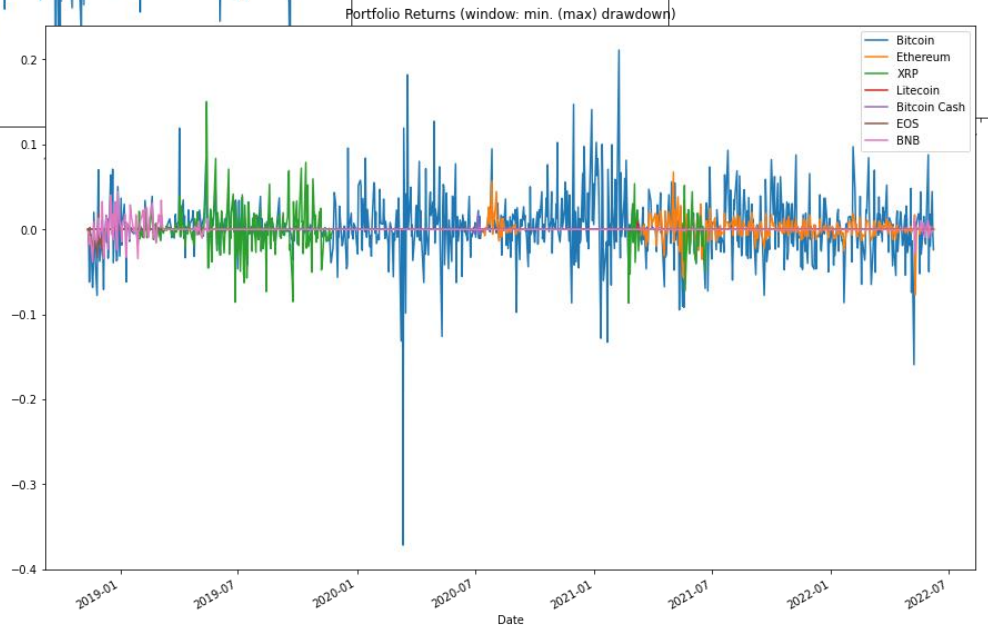


Appendix

Portfolio Returns Composition (Rolling window + no-limit).







Appendix

Naive Approach (Historical Data): Further Information.

Further experimentation.
Optimized portfolios (min. var, min. cvar, and min. drawdown) over a three-year period (without a rolling-window) yielding the following results.

Evaluating 3-year portfolio approaches			
	min. Variance portfolio	min. CVaR portfolio	min. Drawdown portfolio
Ann. Returns	34.7%	36.5%	**86.6%**
Ann. Volatility	**75.7%**	76.3%	81.9%
Sharpe Ratio*	0.427	0.448	**1.029**
max. Drawdown	-81.9%	-82.9%	**-76.1%**

*used 3-Month T-bill rate on Jan 2. 2019 (2.37%)

Appendix

Naive Approach (Historical Data): Further Information.

Further experimentation.
Optimized portfolios (min. var, min. cvar, and min. drawdown) over a three-year period (without a rolling-window) with a **75% weight limit for BTC**.

Evaluating 3-year portfolio approaches (+ BTC limit)			
	min. Variance portfolio	min. CVaR portfolio	min. Drawdown portfolio
Ann. Returns	40.8%	56.1%	**86.6%**
Ann. Volatility	**76.4%**	77.0%	81.9%
Sharpe Ratio*	0.504	0.698	**1.029**
max. Drawdown	-82.7%	-80.3%	**-76.1%**

*used 3-Month T-bill rate on Jan 2. 2019 (2.37%)

Appendix

Naive Approach (Historical Data): Further Information.

Further experimentation.
Optimized portfolios (min. var, min. cvar, and min. drawdown) over a three-year period (**WITH a rolling-window**) with a **75% weight limit for BTC**.

Evaluating 3-year portfolio approaches (+ rolling-window, + BTC limit)			
	min. Variance portfolio	min. CVaR portfolio	min. Drawdown portfolio
Ann. Returns	**75.9%**	48.7%	32.9%
Ann. Volatility	**104.8%**	106.7%	109.2%
Sharpe Ratio*	**0.702**	0.434	0.28
max. Drawdown	**-64.3%**	-64.7%	-65.2%

*used 3-Month T-bill rate on Jan 2. 2019 (2.37%)