VaR in financial risk management

GARCH MODELS IN PYTHON

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Risk management mindset

Rule No.1: Never lose money

Rule No.2 Never forget Rule No.1

-- Warren Buffett

What is VaR

- VaR stands for Value at Risk
- Three ingredients:
  1. portfolio
  2. time horizon
  3. probability

VaR examples

_1-day 5% VaR of $1 million _

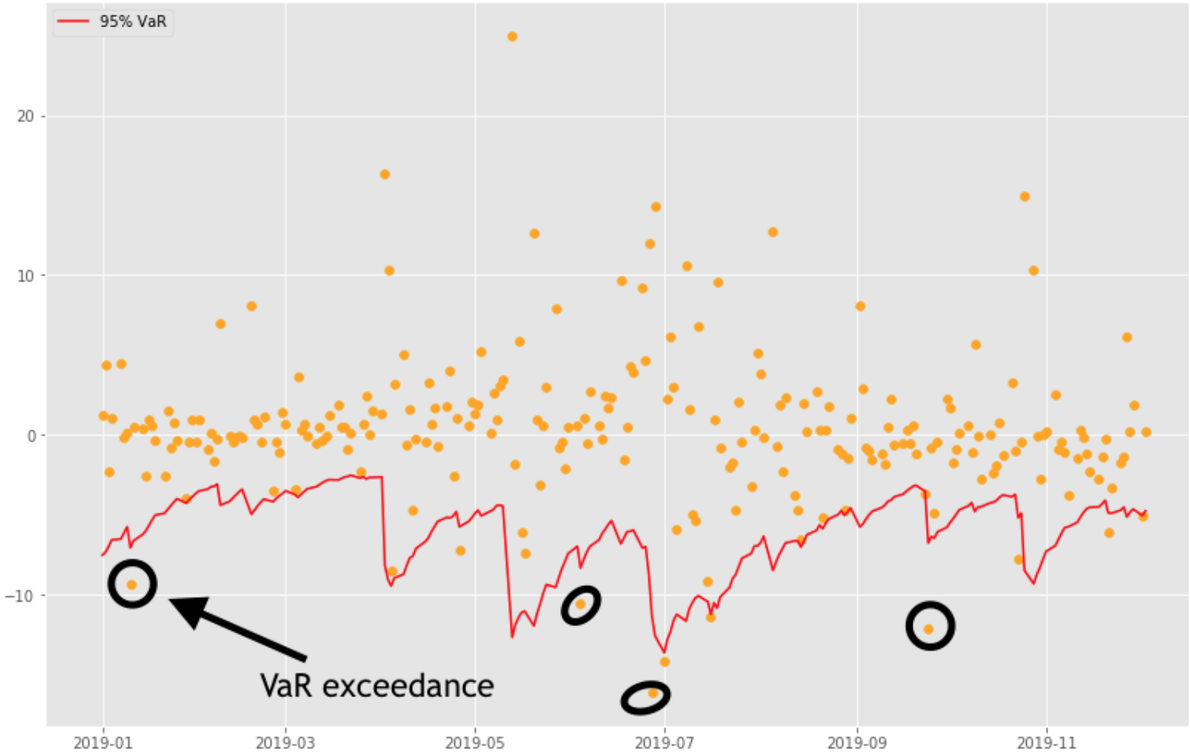
5% probability the portfolio will fall in value by 1 million dollars or more over a 1-day period

10-day 1% VaR of $9 million

1% probability the portfolio will fall in value by 9 million dollars or more over a 10-day period

VaR in risk management

- Set risk limits
- VaR exceedance: portfolio loss exceeds the VaR



Dynamic VaR with GARCH

- More realistic VaR estimation with GARCH
- *VaR = mean + (GARCH vol) * quantile*

```
VaR = mean_forecast.values + np.sqrt(variance_forecast).values * quantile
```

Dynamic VaR calculation

- Step 1: Use GARCH model to make variance forecast

```
# Specify and fit a GARCH model
basic_gm = arch_model(bitcoin_data['Return'], p = 1, q = 1,
                      mean = 'constant', vol = 'GARCH', dist = 't')
gm_result = basic_gm.fit()
```

```
# Make variance forecast
gm_forecast = gm_result.forecast(start = '2019-01-01')
```

Dynamic VaR calculation (cont.)

- Step 2: Use GARCH model to obtain forward-looking mean and volatility

```
mean_forecast = gm_forecast.mean['2019-01-01':]
variance_forecast = gm_forecast.variance['2019-01-01':]
```

- Step 3: Obtain the quantile according to a confidence level
  1. Parametric VaR
  2. Empirical VaR

Parametric VaR

Estimate quantiles based on GARCH assumed distribution of the standardized residuals

```
# Assume a Student's t-distribution
# ppf(): Percent point function

q_parametric = garch_model.distribution.ppf(0.05, nu)
```

Empirical VaR

Estimate quantiles based on the observed distribution of the GARCH standardized residuals

```
q_empirical = std_resid.quantile(0.05)
```

Let's practice!

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Dynamic covariance in portfolio optimization

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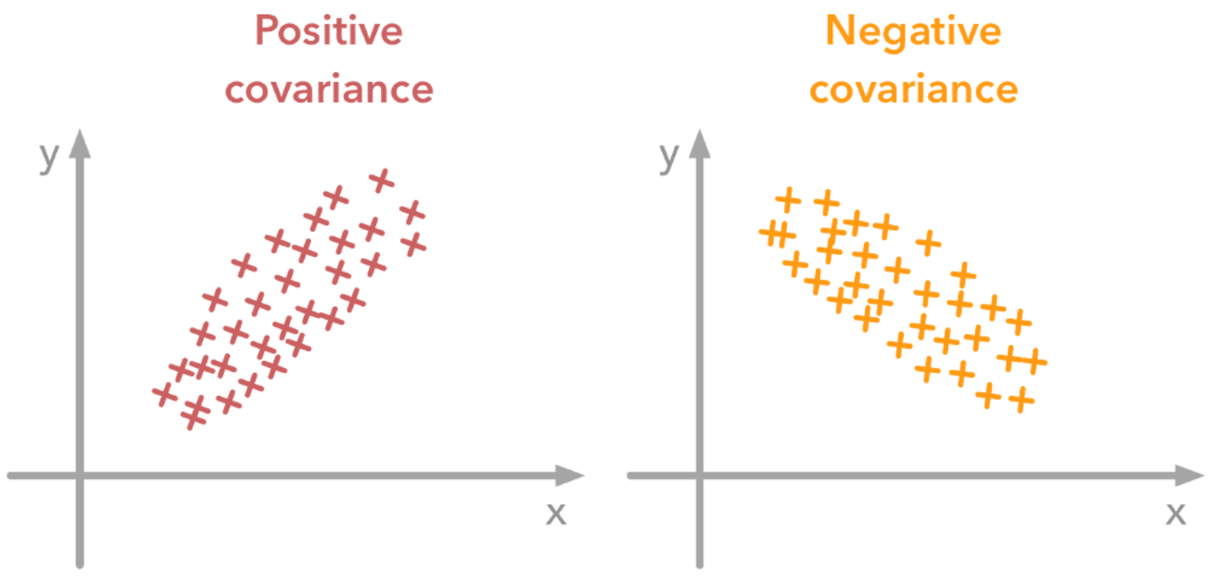
What is covariance

- Describe the relationship between movement of two variables
- Positive covariance: move together
- Negative covariance; move in the opposite directions



Dynamic covariance with GARCH

If two asset returns have correlation ρ and time-varying volatility of σ_1 and σ_2 :

$$Covariance = \rho \cdot \sigma_1 \cdot \sigma_2$$

```
covariance =  correlation * garch_vol1 * garch_vol2
```

Calculate GARCH covariance in Python

Step 1: Fit GARCH models and obtain volatility for each return series

```
# gm_eur, gm_cad are fitted GARCH models
vol_eur = gm_eur.conditional_volatility
vol_cad = gm_cad.conditional_volatility
```

Step 2: Compute standardized residuals from the fitted GARCH models

```
resid_eur = gm_eur.resid/vol_eur
resid_cad = gm_cad.resid/vol_cad
```

Calculate GARCH covariance in Python (cont.)

Step 3: Compute ρ as simple correlation of standardized residuals

```
corr = np.corrcoef(resid_eur, resid_cad)[0,1]
```

Step 4: Compute GARCH covariance by multiplying the correlation and volatility.

```
covariance =  corr * vol_eur * vol_cad
```

Modern portfolio theory (MPT)

- Pioneered by Harry Markowitz in his paper "Portfolio Selection"(1952)
- Take advantage of the diversification effect
- The optimal portfolio can yield the maximum return with the minimum risk

MPT intuition

- Variance of a simple two-asset portfolio:

_W1∗ Variance1 + W2∗ Variance2 + 2∗W1∗W2∗Covariance _

- Diversification effect:

Risk can be reduced in a portfolio by pairing assets that have a negative covariance

Let's practice!

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Dynamic Beta in portfolio management

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What is Beta

- Stock Beta:

a measure of stock volatility in relation to the general market

- Systematic risk:

the portion of the risk that cannot be diversified away

Beta in portfolio management

_Gauge investment risk _

Market Beta = 1: used as benchmark

Beta > 1: the stock bears more risks than the general market

Beta < 1: the stock bears less risks than the general market

Beta in CAPM

- Estimate risk premium of a stock

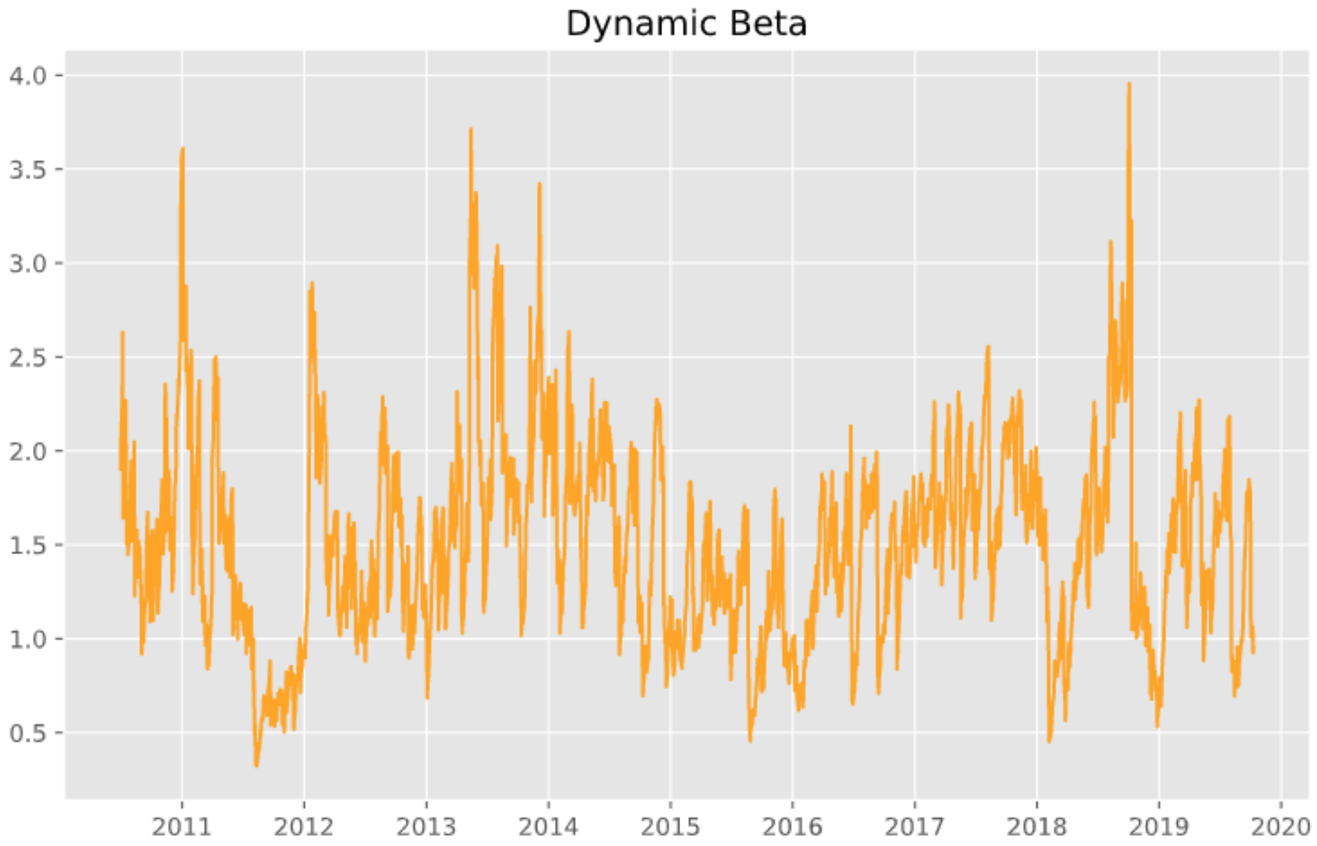
CAPM: Capital Asset Pricing Model

$$E(R_s) = R_f + \beta(E(R_m) - R_f)$$

- $E(R_s)$: stock required rate of return
- R_f: risk-free rate (e.g. Treasuries)
- $E(R_m)$: market expected return (e.g. S&P 500)
- $E(R_m) - R_f$: Market premium

Dynamic Beta with GARCH

$Beta$ = ρ * σ_stock / σ__market



Calculate dynamic Beta in Python

1). Compute correlation between S&P500 and stock

```
resid_stock = stock_gm.resid / stock_gm.conditional_volatility
resid_sp500 = sp500_gm.resid / sp500_gm.conditional_volatility
```

```
correlation = numpy.corrcoef(resid_stock, resid_sp500)[0, 1]
```

2). Compute dynamic Beta for the stock

```
stock_beta = correlation * (stock_gm.conditional_volatility /
                            sp500_gm.conditional_volatility)
```

Let's practice!

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Congratulations!

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You did it

- Fit GARCH models
- Make volatility forecast
- Evaluate model performance
- GARCH in action: VaR, covariance, Beta

Going forward

- Time series analysis
- ARIMA (AutoRegressive Integrated Moving Average) models
- CAPM (Capital Asset Pricing Model)
- Portfolio optimization

Have fun and keep improving!

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