

Regime change (SP500)

○ Definition:

There are two methods to detect regime change which are ARCH and GARCH Model.

ARCH is referring to autoregressive conditional heteroskedasticity. The purpose of this model is to observe the volatility of the financial data. The equation for ARCH (1) model with constant asset return is:

$$r_t = \sigma_t e_t$$

With the constant asset return, the error term is independent and identically distributed with 0 mean and constant variance of 1, and $\alpha_0 > 0$ and $0 \leq \alpha_1 < 1$. The equation will be shows as below:

$$\sigma_t^2 = \alpha_0 + \alpha_1 r_{t-1}^2$$

For the GARCH (1,1) model, it is the extension of the ARCH model and its full term is generalized autoregressive conditional heteroskedasticity. The formula of GARCH is adding with additional variables call beta with assumption of white noise and $\alpha_0 > 0$, $0 \leq \alpha_1 < 1$ and $0 \leq \beta_1 < 1$.

$$\sigma_t^2 = \alpha_0 + \alpha_1 r_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

Markov-switching models will be used in this assignment to detect regime change in time series data. The feature of this model adopted the principle of probability to certain state is rely on present state. The equation of Markov model can be observed as below.

$$Pr(X_{n+1} = x \mid X_1 = x_1, X_2 = x_2, \dots, X_n = x_n) = Pr(X_{n+1} = x \mid X_n = x_n)$$

○ Description:

To detect regime, change in the financial market, SP500 has been adopted as a scenario to run the analysis (Yahoo Finance, 2024). The data was collected within the timeframe of 2nd January 2018 to 31st December 2023. Within the 5 years, SP500 had the major issue of pandemic covid-19, continuous US-China tariff, Russia-Ukraine war and so on.

○ Demonstration:

For the sampling algorithm, metropolis-hastings algorithm will be adopted in Markov Chain Monte Carlo with the Bayesian estimation of GARCH model.

Date	Adj Close	Change of SP500, %
2018-01-02	2695.810059	NaN
2018-01-03	2713.060059	0.006378
2018-01-04	2723.989990	0.004021
2018-01-05	2743.149902	0.007009
2018-01-08	2747.709961	0.001661
2018-01-09	2751.290039	0.001302

The data was retrieved from yahoo finance and asset return was calculated that showed inside the column of change of SP500, %.

○ Diagram & Diagnosis

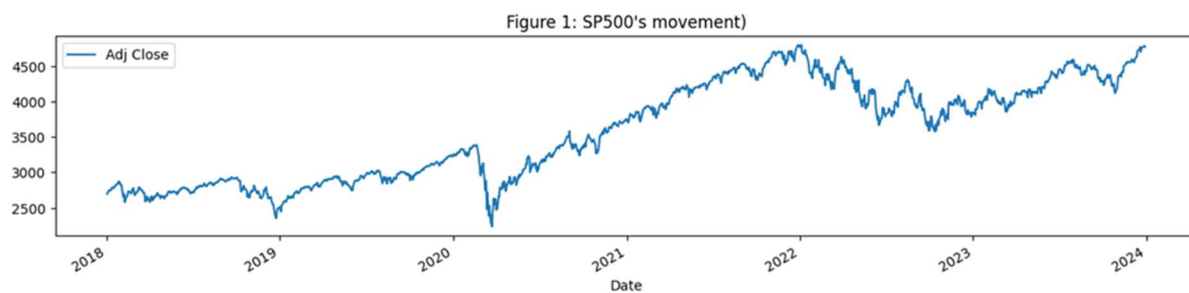


Figure 1: Movement of SP500

From figure 1, it shows an uptrend movement in the long term. Regime change can be observed where bearish trends happen during the first quarter in 2020. After the value of SP500 has gone beyond 2500 and it is slowly bouncing back with a stationary upward trend until the end of 2021. Second regime change showed after 2020, downward trend has shown until the third quarter of 2022. Third regime change has shown which is not significant but it shows an upward trend after the third quarter 2022.

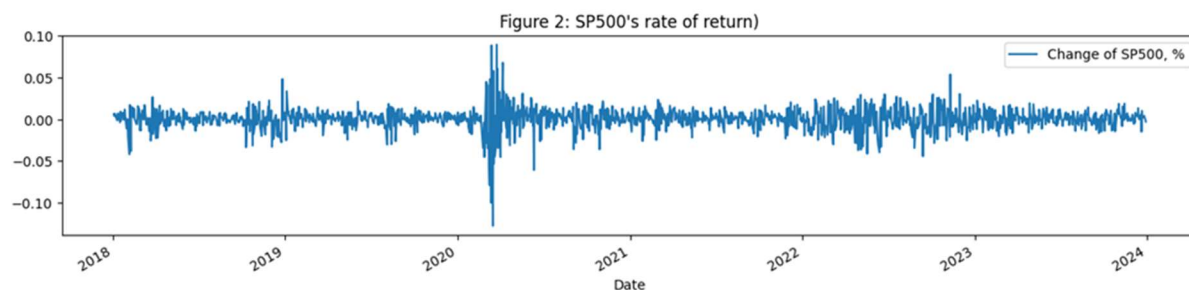


Figure 2: SP500 rate of return

At the initial stage, it remains stationary until the first month of 2020. Moving forward, high volatility (variance) can be observed during the first quarter of 2020 due to the outbreak of covid-19. Overall, it is still oscillated between the values of 0.

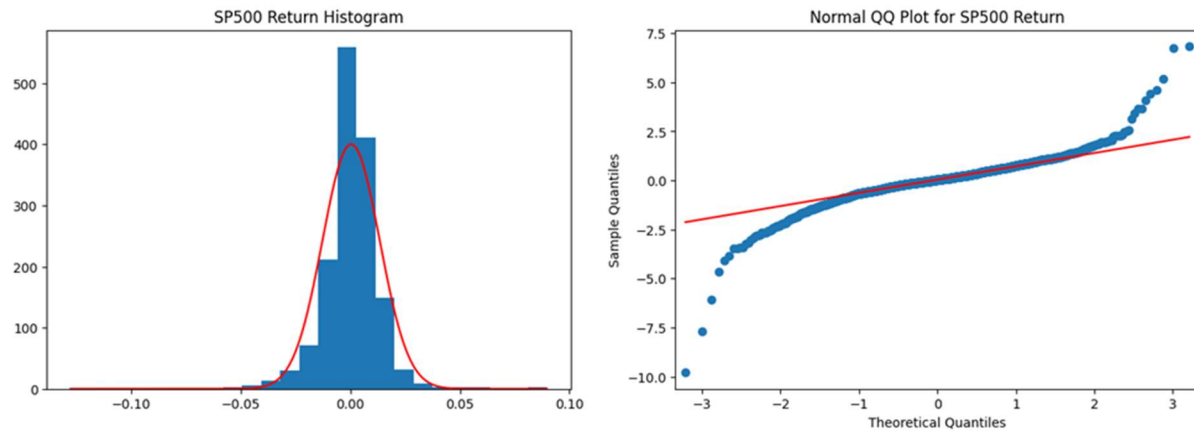


Figure 3: Histogram and normal qq plot of SP 500

At the left visualization has shown a distribution table and histogram's chart. Since the chart has shown an overlap between the chart and distribution curve, it can conclude with a high peak and fatter tails. This indicates higher risk and the possibility to gain a high return.

Focus at the right side, QQ plot, the data observations are not normally distributed toward the linear line. Hence, heteroskedasticity can result.

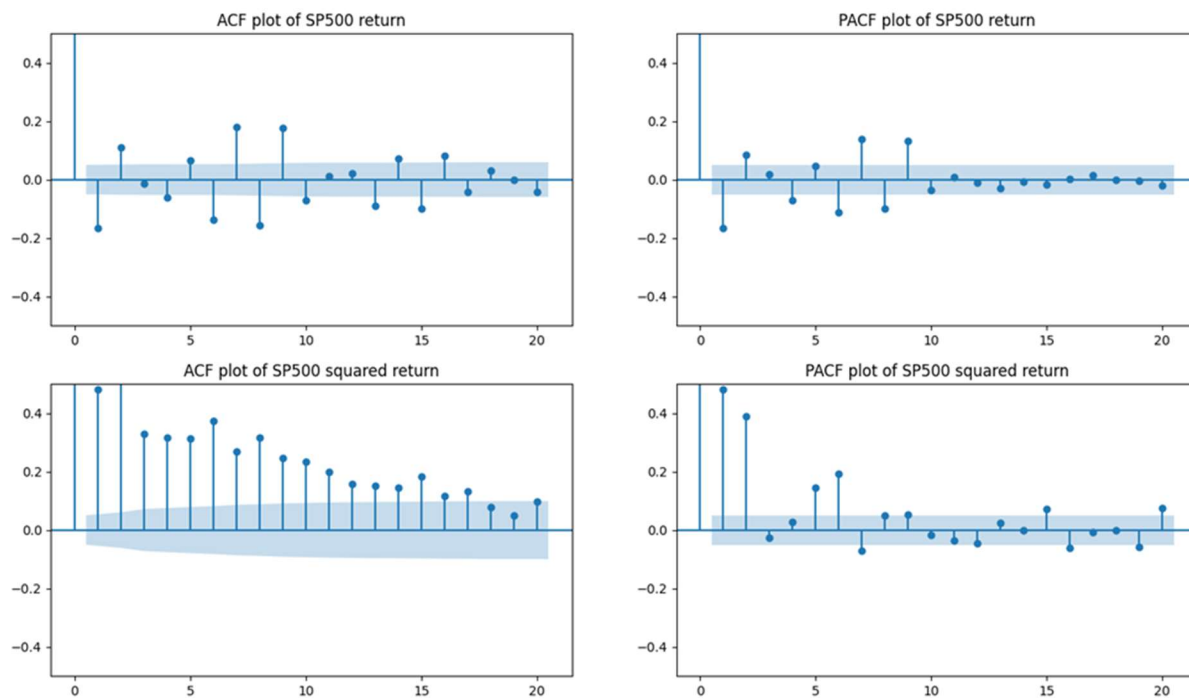


Figure 4: ACF and PACF plots for SP 500 with squared return and normal return

ACF and PACF plots for SP 500 with squared return and normal return have shown a pattern of ARMA model. Hence, it proceeds to conduct GARCH (1,1) model

AR - GARCH Model Results					
Dep. Variable:	Change of SP500, %		R-squared:	0.000	
Mean Model:	AR		Adj. R-squared:	0.000	
Vol Model:	GARCH		Log-Likelihood:	-2149.95	
Distribution:	Normal		AIC:	4307.90	
Method:	Maximum Likelihood		BIC:	4329.18	
			No. Observations:	1508	
Date:	Mon, Apr 08 2024		Df Residuals:	1507	
Time:	13:47:05		Df Model:	1	
Mean Model					
	coef	std err	t	P> t	95.0% Conf. Int.
Const	0.0920	2.207e-02	4.168	3.069e-05	[4.873e-02, 0.135]
Volatility Model					
	coef	std err	t	P> t	95.0% Conf. Int.
omega	0.0488	1.527e-02	3.193	1.410e-03	[1.883e-02, 7.869e-02]
alpha[1]	0.1990	3.559e-02	5.591	2.260e-08	[0.129, 0.269]
beta[1]	0.7769	3.149e-02	24.672	2.119e-134	[0.715, 0.839]

Figure 5: GARCH (1,1) with normal white noise

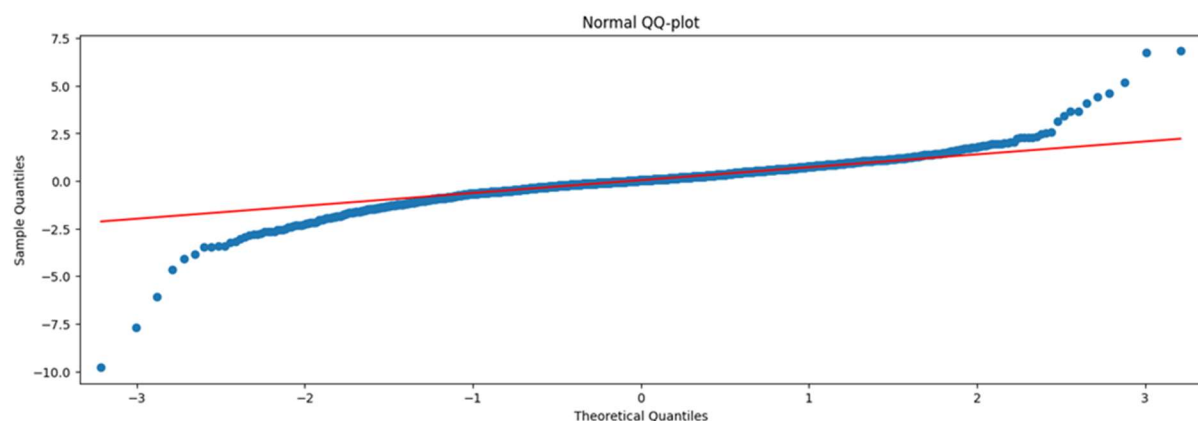


Figure 6: Normal QQ-plot of GARCH (1,1) model with normal white noise

Figure 5 has shown GARCH (1,1) with normal white noise. Overall, it shows a good fit model as the p-values are less than 0.05. Hence, it is significant and a good fit model has results.

Additionally, the normal QQ-plot is not yet normally distributed as shown in figure 6. The model should be improved for better prediction.

```
self._init_dates(dates, freq)
Markov Switching Model Results
=====
Dep. Variable:    Change of SP500, %    No. Observations:    1508
Model:           MarkovRegression      Log Likelihood       4716.145
Date:            Mon, 08 Apr 2024      AIC                  -9424.291
Time:            15:28:09              BIC                  -9403.017
Sample:          0                    HQIC                 -9416.367
                  - 1508
Covariance Type: approx
                  Regime 0 parameters
=====
              coef    std err          z      P>|z|      [0.025    0.975]
-----
sigma2      5.344e-05  3.79e-06   14.088    0.000    4.6e-05    6.09e-05
                  Regime 1 parameters
=====
              coef    std err          z      P>|z|      [0.025    0.975]
-----
sigma2      0.0004    4.44e-05   10.063    0.000    0.000    0.001
                  Regime transition parameters
=====
              coef    std err          z      P>|z|      [0.025    0.975]
-----
p[0->0]     0.9827     0.005   189.987    0.000    0.973    0.993
p[1->0]     0.0418     0.014    2.990    0.003    0.014    0.069
=====
```

Figure 7: Regime Detection for SP 500

H0: There is no regime change has been detected

H1: Regime change has been detected.

Based on the Markov switching model result shown in figure6, the p-values are less than 0.05. Hence, null hypothesis is rejected. It can determine that regime change has been detected. The first regime (regime 0 parameters) is referring to low regime with an extreme lower value of 5.344e-05. The second regime is referring to high regime with a value of 0.0005. The given lower value can be explained that the data collect was based on daily basis.

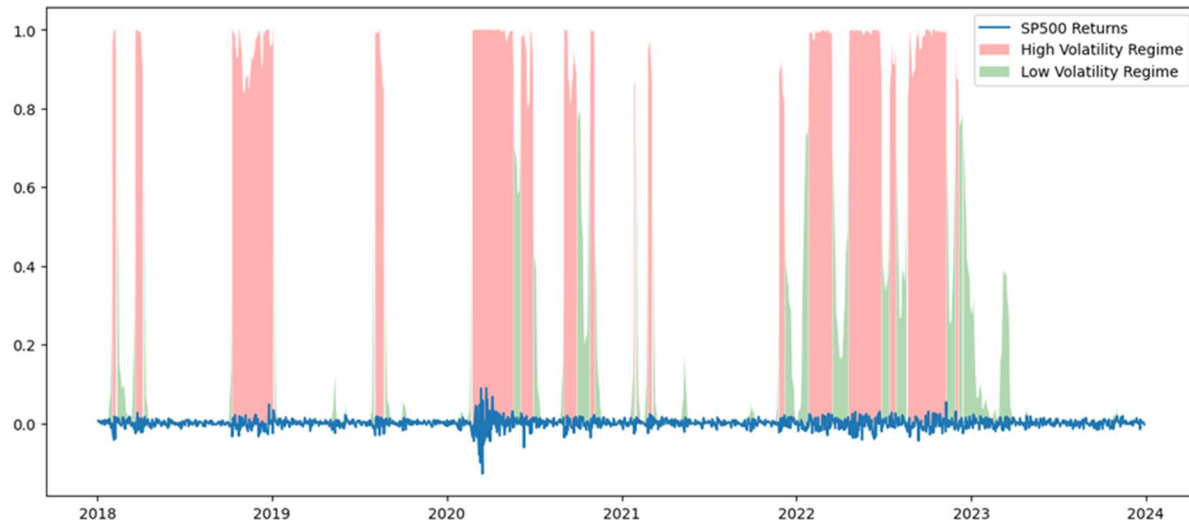


Figure 8: High and low regime change of SP500 returns.

The red color has a high volatility regime and green refers to low volatility.

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[57.74777382 23.93811101]
```

Low regime is expected to retain for 58 days and high regime is retain for 24 days.

○ Damage:

Without detecting regime change, the prediction of financial modeling can be useless. It is because I am unable to know what will happen next. Secondly, wrong trading positions can result in investors only being able to depend on luck. Risk management will be weakened as investors do not know how much volume they need to hedge and could have a high possibility of widening the loss.

○ Directions

Additionally, if the data observations are unable to meet normally distributed which show in normal QQ plot for GARCH (1,1) with normal white noise. The prediction result could result in underfitting or overfitting. Thus, it should select an appropriate method for the consistency of prediction by determining the maximum likelihood.

○ Deployment

From the figure 8, it has captured the period of high and low volatility regime. Low regime is referring to low volatility and the financial market is undergoing recovery stage. Hence, call position or long investment strategy is recommended.

With the high regime change mean high volatility and reflect downturn of the financial market. Put option or short investment strategy is recommended.

Reference

“S&P 500 INDEX”. *Yahoo Finance*, uploaded by Yahoo Finance, 2024, <https://finance.yahoo.com/quote/%5ESPX/> . Accessed 6th April 2024.