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PART A

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PART A

1. **Stationary Check**

   H0: MSCI USA RETURN has a unit root

   H1: MSCI USA RETURN does not have a unit root

   a. **ADF Test**

      i) **Period 1 (Pre-Crisis) 1st June 2007 – 14th September 2008**

Augmented Dickey-Fuller Unit Root Test on MSCI_USA_RETURN

Null Hypothesis: MSCI_USA_RETURN has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=16)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-21.81519	0.0000
Test critical values:	1% level	-3.985690	
	5% level	-3.423296	
	10% level	-3.134591	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(MSCI_USA_RETURN)
Method: Least Squares
Date: 20/11/24 Time: 19:51
Sample (adjusted): 4/06/2007 12/09/2008
Included observations: 335 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MSCI_USA_RETURN(-1)	-1.178226	0.054009	-21.81519	0.0000
C	-0.000344	0.001354	-0.253855	0.7998
@TREND("1/06/2007")	-1.59E-06	6.99E-06	-0.228099	0.8197

R-squared	0.589060	Mean dependent var	3.82E-06
Adjusted R-squared	0.586585	S.D. dependent var	0.019229
S.E. of regression	0.012364	Akaike info criterion	-5.939182
Sum squared resid	0.050750	Schwarz criterion	-5.905026
Log likelihood	997.8130	Hannan-Quinn criter.	-5.925565
F-statistic	237.9524	Durbin-Watson stat	2.016856
Prob(F-statistic)	0.000000		

The ADF test has probability of 0.0000 (less than 0.01), we reject the null hypothesis. Therefore, MSCI USA RETURN does not have a unit root and is stationary.

ii) **Period 2 (During Crisis) 15th September 2008 – 30th April 2009**

Augmented Dickey-Fuller Unit Root Test on MSCI_USA_RETURN

Null Hypothesis: MSCI_USA_RETURN has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-11.75125	0.0000
Test critical values:	1% level	-4.014986	
	5% level	-3.437458	
	10% level	-3.142936	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(MSCI_USA_RETURN)
Method: Least Squares
Date: 21/11/24 Time: 10:21
Sample: 15/09/2008 30/04/2009
Included observations: 164

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MSCI_USA_RETURN(-1)	-1.383542	0.117736	-11.75125	0.0000
D(MSCI_USA_RETURN(-1))	0.196357	0.077455	2.535107	0.0122
C	-0.010223	0.005155	-1.983176	0.0491
@TREND("15/09/2008")	9.80E-05	5.45E-05	1.795808	0.0744

R-squared	0.594774	Mean dependent var	-2.47E-05
Adjusted R-squared	0.587176	S.D. dependent var	0.050929
S.E. of regression	0.032723	Akaike info criterion	-3.977416
Sum squared resid	0.171323	Schwarz criterion	-3.901810
Log likelihood	330.1481	Hannan-Quinn criter.	-3.946723
F-statistic	78.28054	Durbin-Watson stat	1.962395
Prob(F-statistic)	0.000000		

The ADF test has probability of 0.0000 (less than 0.01), we reject the null hypothesis. Therefore, MSCI USA RETURN does not have a unit root and is stationary.

iii) **Period 3 (Post-Crisis) 1st May 2009 – 31st December 2009**

Augmented Dickey-Fuller Unit Root Test on MSCI_USA_RETURN

Null Hypothesis: MSCI_USA_RETURN has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-14.30306	0.0000
Test critical values:	1% level	-4.011352	
	5% level	-3.435708	
	10% level	-3.141907	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(MSCI_USA_RETURN)
Method: Least Squares
Date: 21/11/24 Time: 10:22
Sample: 1/05/2009 31/12/2009
Included observations: 175

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MSCI_USA_RETURN(-1)	-1.088842	0.076126	-14.30306	0.0000
C	0.002370	0.001778	1.332990	0.1843
@TREND("1/05/2009")	-8.82E-06	1.76E-05	-0.500689	0.6172

R-squared	0.543283	Mean dependent var	-5.33E-05
Adjusted R-squared	0.537973	S.D. dependent var	0.017312
S.E. of regression	0.011767	Akaike info criterion	-6.030007
Sum squared resid	0.023816	Schwarz criterion	-5.975754
Log likelihood	530.6256	Hannan-Quinn criter.	-6.008000
F-statistic	102.3005	Durbin-Watson stat	1.974148
Prob(F-statistic)	0.000000		

The ADF test has probability of 0.0000 (less than 0.01), we reject the null hypothesis. Therefore, MSCI USA RETURN does not have a unit root and is stationary.

b. **PP Test**

i) **Period 1 (Pre-Crisis) 1st June 2007 – 14th September 2008**

Phillips-Perron Unit Root Test on MSCI_USA_RETURN

Null Hypothesis: MSCI_USA_RETURN has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-22.23855	0.0000
Test critical values:	1% level	-3.985690	
	5% level	-3.423296	
	10% level	-3.134591	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.000151
HAC corrected variance (Bartlett kernel)	0.000127

Phillips-Perron Test Equation
Dependent Variable: D(MSCI_USA_RETURN)
Method: Least Squares
Date: 20/11/24 Time: 19:53
Sample (adjusted): 4/06/2007 12/09/2008
Included observations: 335 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MSCI_USA_RETURN(-1)	-1.178226	0.054009	-21.81519	0.0000
C	-0.000344	0.001354	-0.253855	0.7998
@TREND("1/06/2007")	-1.59E-06	6.99E-06	-0.228099	0.8197

R-squared	0.589060	Mean dependent var	3.82E-06
Adjusted R-squared	0.586585	S.D. dependent var	0.019229
S.E. of regression	0.012364	Akaike info criterion	-5.939182
Sum squared resid	0.050750	Schwarz criterion	-5.905026
Log likelihood	997.8130	Hannan-Quinn criter.	-5.925565
F-statistic	237.9524	Durbin-Watson stat	2.016856
Prob(F-statistic)	0.000000		

The PP test has a probability of 0.0000 (less than 0.01), we reject the null hypothesis. Therefore, MSCI USA RETURN does not have a unit root and is stationary.

ii) **Period 2 (During Crisis) 15th September 2008 – 30th April 2009**

Phillips-Perron Unit Root Test on MSCI_USA_RETURN

Null Hypothesis: MSCI_USA_RETURN has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-15.31072	0.0000
Test critical values:	1% level	-4.014986	
	5% level	-3.437458	
	10% level	-3.142936	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.001087
HAC corrected variance (Bartlett kernel)	0.000826

Phillips-Perron Test Equation
Dependent Variable: D(MSCI_USA_RETURN)
Method: Least Squares
Date: 21/11/24 Time: 10:24
Sample: 15/09/2008 30/04/2009
Included observations: 164

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MSCI_USA_RETURN(-1)	-1.156743	0.077817	-14.86493	0.0000
C	-0.008675	0.005204	-1.667007	0.0975
@TREND("15/09/2008")	8.35E-05	5.52E-05	1.514389	0.1319

R-squared	0.578497	Mean dependent var	-2.47E-05
Adjusted R-squared	0.573261	S.D. dependent var	0.050929
S.E. of regression	0.033269	Akaike info criterion	-3.950230
Sum squared resid	0.178204	Schwarz criterion	-3.893525
Log likelihood	326.9189	Hannan-Quinn criter.	-3.927210
F-statistic	110.4834	Durbin-Watson stat	2.047657
Prob(F-statistic)	0.000000		

The PP test has a probability of 0.0000 (less than 0.01), we reject the null hypothesis. Therefore, MSCI USA RETURN does not have a unit root and is stationary.

iii) Period 3 (Post-Crisis) 1st May 2009 – 31st December 2009

Phillips-Perron Unit Root Test on MSCI_USA_RETURN

Null Hypothesis: MSCI_USA_RETURN has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-14.30306	0.0000
Test critical values:	1% level	-4.011352	
	5% level	-3.435708	
	10% level	-3.141907	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.000136
HAC corrected variance (Bartlett kernel)	0.000136

Phillips-Perron Test Equation
Dependent Variable: D(MSCI_USA_RETURN)
Method: Least Squares
Date: 21/11/24 Time: 10:23
Sample: 1/05/2009 31/12/2009
Included observations: 175

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MSCI_USA_RETURN(-1)	-1.088842	0.076126	-14.30306	0.0000
C	0.002370	0.001778	1.332990	0.1843
@TREND("1/05/2009")	-8.82E-06	1.76E-05	-0.500689	0.6172

R-squared	0.543283	Mean dependent var	-5.33E-05
Adjusted R-squared	0.537973	S.D. dependent var	0.017312
S.E. of regression	0.011767	Akaike info criterion	-6.030007
Sum squared resid	0.023816	Schwarz criterion	-5.975754
Log likelihood	530.6256	Hannan-Quinn criter.	-6.008000
F-statistic	102.3005	Durbin-Watson stat	1.974148
Prob(F-statistic)	0.000000		

The PP test has a probability of 0.0000 (less than 0.01), we reject the null hypothesis. Therefore, MSCI USA RETURN does not have a unit root and is stationary.

Overall, data is stationary across all periods. Stationarity is essential for mode estimation because it ensures the model parameters are stable and predictable. Furthermore, multiple hypothesis (diagnostic) tests rely on the assumption of data stationarity. If data is nonstationary, parameters and hypothesis tests may not be reliable. Besides, non-stationary data can lead to spurious correlations.

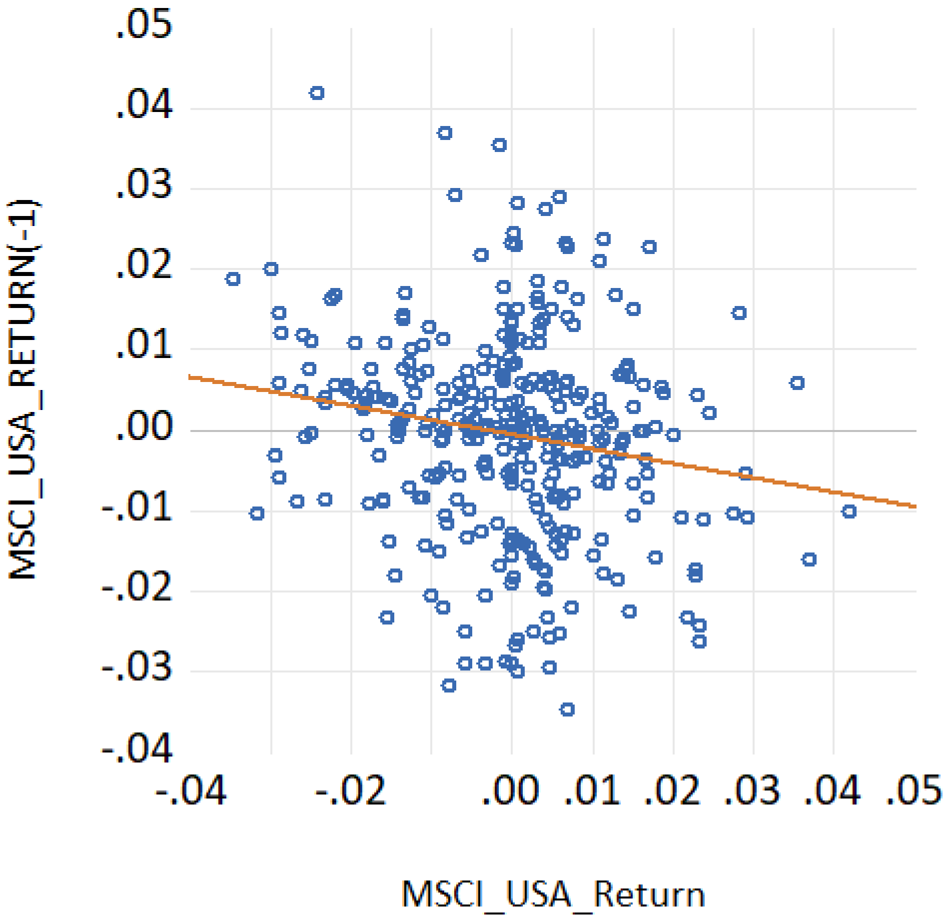
2. Model Selection

a. Linearity Test

In this section, we try to test if the data is linear or not. If the data is linear, we can proceed with ARMA models, however, if the data is non-linear ARCH or GARCH model will be more suitable for the data. This is because non-linear data often suffers from heteroscedasticity problem and AR model is not adequate to capture this complexity fully.

i) Period 1 (Pre-Crisis) 1st June 2007 – 14th September 2008

Scatter Plot



The points show a straight line pointing downward, it is highly likely to be linear. To be sure, we run the BDS test to see if it is significantly linear/non-linear.

BDS Test

H0: The data is linear

H1: The data is non-linear

BDS Test for MSCI_USA_RETURN
Date: 21/11/24 Time: 06:35
Sample: 1/06/2007 12/09/2008
Included observations: 336

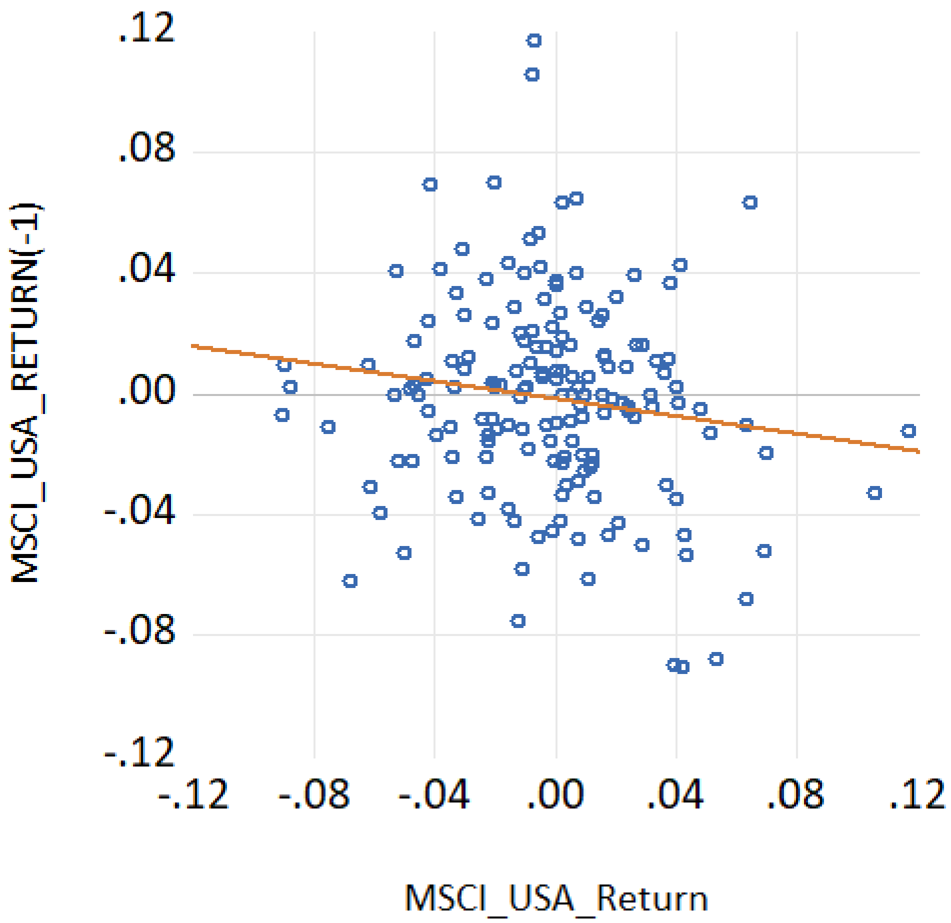
Dimension	BDS Statistic	Std. Error	z-Statistic	Prob.
2	-0.003465	0.004180	-0.829100	0.4070
3	-0.002266	0.005117	-0.442901	0.6578
4	-6.72E-05	0.004698	-0.014313	0.9886
5	0.002291	0.003777	0.606706	0.5440
6	0.002932	0.002810	1.043582	0.2967

Raw epsilon	0.012491		
Pairs within epsilon	60928.00	V-Statistic	0.539683
Triples within epsilon	12499196	V-Statistic	0.329507

Dimension	C(m,n)	c(m,n)	C(1,n-(m-1))	c(1,n-(m-1))	c(1,n-(m-1))^k
2	15961.00	0.285298	30063.00	0.537367	0.288763
3	8534.000	0.153459	29919.00	0.538005	0.155725
4	4604.000	0.083288	29702.00	0.537320	0.083355
5	2654.000	0.048302	29683.00	0.540221	0.046011
6	1546.000	0.028307	29606.00	0.542086	0.025375

Since the probability of all the dimensions in BDS Test is greater than 0.05, we fail to reject the null hypothesis. Therefore, it is concluded that the data is linear. Thus, AR/MA/ARMA models should be tested first for this data before deciding to use ARCH/GARCH models.

ii) **Period 2 (During Crisis) 15th September 2008 – 30th April 2009**
Scatter Plot



The points show a straight line pointing downward, it is highly likely to be linear. To be sure, we run the BDS test to see if it is significantly linear/non-linear.

BDS Test

BDS Test for MSCI_USA_RETURN
Date: 21/11/24   Time: 10:54
Sample: 15/09/2008 30/04/2009
Included observations: 164

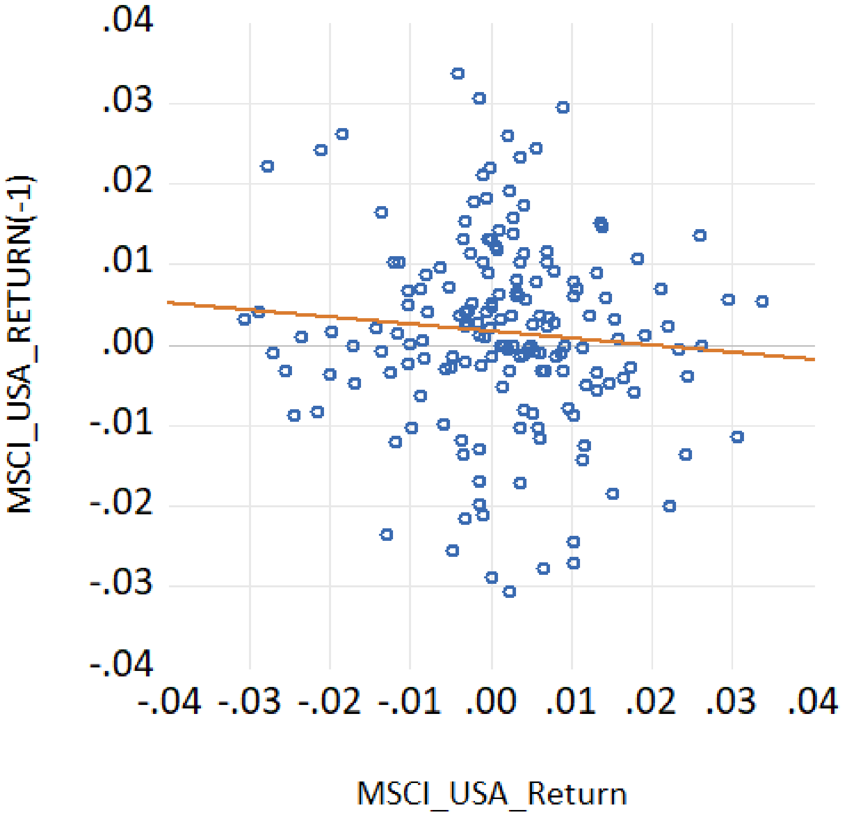
Dimension	BDS Statistic	Std. Error	z-Statistic	Prob.
2	0.009347	0.006150	1.519847	0.1285
3	0.017048	0.007665	2.224322	0.0261
4	0.017603	0.007163	2.457387	0.0140
5	0.014270	0.005862	2.434488	0.0149
6	0.014105	0.004439	3.177112	0.0015

Raw epsilon	0.033552		
Pairs within epsilon	14754.00	V-Statistic	0.548557
Triples within epsilon	1500480.	V-Statistic	0.340172

Dimension	C(m,n)	c(m,n)	C(1,n-(m-1))	c(1,n-(m-1))	c(1,n-(m-1))^k
2	4028.000	0.305082	7180.000	0.543816	0.295736
3	2310.000	0.177134	7081.000	0.542980	0.160085
4	1330.000	0.103261	6968.000	0.540994	0.085658
5	761.0000	0.059827	6858.000	0.539151	0.045557
6	481.0000	0.038293	6755.000	0.537776	0.024188

Since the probability of dimension 2 in BDS Test is greater than 0.05, we fail to reject the null hypothesis in this dimension. However, for other dimensions, the probability is less than 0.05, we reject the null hypothesis. Therefore, it is concluded that the data is nonlinear in higher dimensions. Thus, ARCH/GARCH models should be used instead of AR/MA/ARMA models.

iii) **Period 3 (Post-Crisis) 1st May 2009 – 31st December 2009**
Scatter Plot



The points show a straight line pointing downward, it is highly likely to be linear. To be sure, we run the BDS test to see if it is significantly linear/non-linear.

BDS Test

BDS Test for MSCI_USA_RETURN
Date: 21/11/24 Time: 11:00
Sample: 1/05/2009 31/12/2009
Included observations: 175

Dimension	BDS Statistic	Std. Error	z-Statistic	Prob.
2	-0.007561	0.006707	-1.127339	0.2596
3	-0.003384	0.008432	-0.401366	0.6882
4	0.002743	0.007952	0.344909	0.7302
5	0.006679	0.006567	1.017029	0.3091
6	0.005460	0.005019	1.087667	0.2767

Raw epsilon	0.011720		
Pairs within epsilon	16927.00	V-Statistic	0.552718
Triples within epsilon	1874341.	V-Statistic	0.349731

Dimension	C(m,n)	c(m,n)	C(1,n-(m-1))	c(1,n-(m-1))	c(1,n-(m-1))^k
2	4460.000	0.296326	8297.000	0.551259	0.303887
3	2416.000	0.162387	8173.000	0.549335	0.165772
4	1364.000	0.092751	8055.000	0.547736	0.090009
5	801.0000	0.055108	7933.000	0.545786	0.048430
6	450.0000	0.031326	7812.000	0.543822	0.025867

Since the probability of all the dimensions in BDS Test is greater than 0.05, we fail to reject the null hypothesis. Therefore, it is concluded that the data is linear. Thus, AR/MA/ARMA models should be tested first for this data before deciding to use ARCH/GARCH models.

2.1 Period 1 (Pre-Crisis) 1st June 2007 – 14th September 2008

a. ARMA Model Selection

Correlogram of MSCI_USA_RETURN

Date: 21/11/24 Time: 06:46
Sample: 1/06/2007 12/09/2008
Included observations: 336

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.178	-0.178	10.744	0.001
		2	-0.016	-0.049	10.827	0.004
		3	-0.007	-0.019	10.842	0.013
		4	-0.031	-0.038	11.176	0.025
		5	0.019	0.006	11.301	0.046
		6	-0.098	-0.099	14.574	0.024
		7	0.008	-0.030	14.594	0.042
		8	-0.016	-0.029	14.682	0.066
		9	-0.008	-0.021	14.704	0.099
		10	0.057	0.045	15.849	0.104
		11	0.033	0.053	16.237	0.133
		12	0.013	0.023	16.294	0.178
		13	0.068	0.081	17.909	0.161
		14	-0.051	-0.021	18.819	0.172
		15	-0.022	-0.031	18.995	0.214
		16	-0.023	-0.024	19.179	0.259
		17	0.082	0.089	21.559	0.202
		18	-0.057	-0.025	22.726	0.201
		19	-0.053	-0.051	23.742	0.206
		20	0.012	-0.018	23.794	0.251
		21	-0.024	-0.036	24.003	0.293
		22	0.004	-0.024	24.010	0.347
		23	0.003	-0.002	24.015	0.403
		24	-0.005	-0.018	24.025	0.460
		25	-0.046	-0.061	24.800	0.474
		26	0.032	0.011	25.187	0.508
		27	-0.028	-0.035	25.478	0.548
		28	-0.003	-0.019	25.481	0.602
		29	-0.006	-0.009	25.496	0.652
		30	0.020	0.011	25.647	0.693

Based on the correlogram, there is a cut off on lag 1 in the AC and PAC column. Additionally, there is another cut off on lag 3. We will run ARMA (1,1), ARMA (1,2), ARMA (2,1), ARMA (2,2), ARMA (3,1), ARMA (3,2), ARMA (1,3), ARMA (2,3) and ARMA (3,3). After running the models, we will compare every model and ensure all variables are significant. Then, we select based on the lowest AIC and SIC values. If there is not much difference in the values, we will select based on model which is the most parsimonious (the lower the AR and MA order, the better).

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 06:58
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 29 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000518	0.000534	-0.970637	0.3324
AR(1)	0.204134	0.262330	0.778157	0.4370
MA(1)	-0.389980	0.246980	-1.578994	0.1153
SIGMASQ	0.000151	1.16E-05	13.02739	0.0000

R-squared	0.034942	Mean dependent var	-0.000511
Adjusted R-squared	0.026221	S.D. dependent var	0.012510
S.E. of regression	0.012345	Akaike info criterion	-5.939209
Sum squared resid	0.050595	Schwarz criterion	-5.893767
Log likelihood	1001.787	Hannan-Quinn criter.	-5.921095
F-statistic	4.006875	Durbin-Watson stat	2.006073
Prob(F-statistic)	0.008004		

Inverted AR Roots	.20
Inverted MA Roots	.39

ARMA (1,1)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 06:59
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 27 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000513	0.000485	-1.057134	0.2912
AR(1)	0.575051	0.318163	1.807408	0.0716
AR(2)	0.085747	0.097561	0.878902	0.3801
MA(1)	-0.766007	0.307256	-2.493062	0.0132
SIGMASQ	0.000150	1.14E-05	13.13118	0.0000

R-squared	0.037489	Mean dependent var	-0.000511
Adjusted R-squared	0.025857	S.D. dependent var	0.012510
S.E. of regression	0.012347	Akaike info criterion	-5.935868
Sum squared resid	0.050461	Schwarz criterion	-5.879066
Log likelihood	1002.226	Hannan-Quinn criter.	-5.913225
F-statistic	3.223028	Durbin-Watson stat	2.000275
Prob(F-statistic)	0.012920		

Inverted AR Roots	.70	-.12
Inverted MA Roots	.77	

ARMA (2,1)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 07:00
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 29 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000513	0.000484	-1.060386	0.2897
AR(1)	0.728643	0.440854	1.652801	0.0993
MA(1)	-0.917639	0.445741	-2.058682	0.0403
MA(2)	0.104884	0.124490	0.842509	0.4001
SIGMASQ	0.000150	1.15E-05	13.10971	0.0000

R-squared	0.037284	Mean dependent var	-0.000511
Adjusted R-squared	0.025650	S.D. dependent var	0.012510
S.E. of regression	0.012348	Akaike info criterion	-5.935658
Sum squared resid	0.050472	Schwarz criterion	-5.878856
Log likelihood	1002.191	Hannan-Quinn criter.	-5.913015
F-statistic	3.204728	Durbin-Watson stat	2.003670
Prob(F-statistic)	0.013320		

Inverted AR Roots	.73	
Inverted MA Roots	.78	.13

ARMA (1,2)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 07:01
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 27 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000513	0.000488	-1.052123	0.2935
AR(1)	0.567338	1.043462	0.543708	0.5870
AR(2)	0.089518	0.448699	0.199506	0.8420
MA(1)	-0.758259	1.042073	-0.727645	0.4673
MA(2)	-0.005019	0.603485	-0.008317	0.9934
SIGMASQ	0.000150	1.15E-05	13.10116	0.0000

R-squared	0.037489	Mean dependent var	-0.000511
Adjusted R-squared	0.022906	S.D. dependent var	0.012510
S.E. of regression	0.012366	Akaike info criterion	-5.929916
Sum squared resid	0.050461	Schwarz criterion	-5.861753
Log likelihood	1002.226	Hannan-Quinn criter.	-5.902744
F-statistic	2.570670	Durbin-Watson stat	2.000376
Prob(F-statistic)	0.026714		

Inverted AR Roots	.70	-.13
Inverted MA Roots	.76	-.01

ARMA (2,2)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 07:03
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 31 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000513	0.000488	-1.052096	0.2935
AR(1)	0.572967	0.378723	1.512894	0.1313
AR(2)	0.085750	0.098636	0.869365	0.3853
AR(3)	-0.001009	0.067692	-0.014902	0.9881
MA(1)	-0.763858	0.370670	-2.060752	0.0401
SIGMASQ	0.000150	1.15E-05	13.09929	0.0000

R-squared	0.037490	Mean dependent var	-0.000511
Adjusted R-squared	0.022906	S.D. dependent var	0.012510
S.E. of regression	0.012366	Akaike info criterion	-5.929916
Sum squared resid	0.050461	Schwarz criterion	-5.861754
Log likelihood	1002.226	Hannan-Quinn criter.	-5.902745
F-statistic	2.570700	Durbin-Watson stat	2.000460
Prob(F-statistic)	0.026712		

Inverted AR Roots	.69	.01	-.13
Inverted MA Roots	.76		

ARMA (3,1)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 07:04
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 24 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000499	0.000119	-4.196166	0.0000
AR(1)	-0.106347	0.180698	-0.588533	0.5566
AR(2)	0.838925	0.158049	5.307997	0.0000
AR(3)	0.160513	0.057940	2.770324	0.0059
MA(1)	-0.101380	9.964987	-0.010174	0.9919
MA(2)	-0.898620	111.2192	-0.008080	0.9936
SIGMASQ	0.000147	0.000572	0.256296	0.7979

R-squared	0.059775	Mean dependent var	-0.000511
Adjusted R-squared	0.042628	S.D. dependent var	0.012510
S.E. of regression	0.012240	Akaike info criterion	-5.940736
Sum squared resid	0.049293	Schwarz criterion	-5.861213
Log likelihood	1005.044	Hannan-Quinn criter.	-5.909036
F-statistic	3.486033	Durbin-Watson stat	2.000324
Prob(F-statistic)	0.002349		

Inverted AR Roots	.95	-.20	-.86
Inverted MA Roots	1.00	-.90	

ARMA (3,2)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 07:05
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 20 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000513	0.000487	-1.052222	0.2935
AR(1)	0.666723	0.547087	1.218679	0.2238
MA(1)	-0.858259	0.545493	-1.573364	0.1166
MA(2)	0.108129	0.124082	0.871431	0.3842
MA(3)	-0.020121	0.070086	-0.287091	0.7742
SIGMASQ	0.000150	1.15E-05	13.07100	0.0000

R-squared	0.037607	Mean dependent var	-0.000511
Adjusted R-squared	0.023025	S.D. dependent var	0.012510
S.E. of regression	0.012365	Akaike info criterion	-5.930036
Sum squared resid	0.050455	Schwarz criterion	-5.861873
Log likelihood	1002.246	Hannan-Quinn criter.	-5.902864
F-statistic	2.579061	Durbin-Watson stat	1.999514
Prob(F-statistic)	0.026285		

Inverted AR Roots	.67		
Inverted MA Roots	.75	.05-.15i	.05+.15i

ARMA (1,3)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 07:07
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 43 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000500	0.000122	-4.111259	0.0000
AR(1)	0.061027	0.215221	0.283553	0.7769
AR(2)	0.853369	0.194533	4.386764	0.0000
MA(1)	-0.266172	6.699719	-0.039729	0.9683
MA(2)	-0.901557	15.40305	-0.058531	0.9534
MA(3)	0.167732	4.133433	0.040579	0.9677
SIGMASQ	0.000147	0.000721	0.203636	0.8388

R-squared	0.059046	Mean dependent var	-0.000511
Adjusted R-squared	0.041886	S.D. dependent var	0.012510
S.E. of regression	0.012245	Akaike info criterion	-5.940127
Sum squared resid	0.049331	Schwarz criterion	-5.860604
Log likelihood	1004.941	Hannan-Quinn criter.	-5.908427
F-statistic	3.440885	Durbin-Watson stat	2.006772
Prob(F-statistic)	0.002610		

Inverted AR Roots	.95	-.89	
Inverted MA Roots	1.00	.18	-.92

ARMA (2,3)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 07:05
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 38 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000513	0.000491	-1.043396	0.2975
AR(1)	-0.649602	0.767221	-0.846695	0.3978
AR(2)	0.458207	0.612659	0.747898	0.4551
AR(3)	0.268740	0.287655	0.934244	0.3509
MA(1)	0.462239	0.775894	0.595750	0.5518
MA(2)	-0.606049	0.470371	-1.288448	0.1985
MA(3)	-0.218571	0.396105	-0.551801	0.5815
SIGMASQ	0.000150	1.14E-05	13.12299	0.0000

R-squared	0.041141	Mean dependent var	-0.000511
Adjusted R-squared	0.020677	S.D. dependent var	0.012510
S.E. of regression	0.012380	Akaike info criterion	-5.921733
Sum squared resid	0.050270	Schwarz criterion	-5.830849
Log likelihood	1002.851	Hannan-Quinn criter.	-5.885504
F-statistic	2.010441	Durbin-Watson stat	2.000482
Prob(F-statistic)	0.053284		

Inverted AR Roots	.66	-.51	-.80
Inverted MA Roots	.75	-.34	-.87

ARMA (3,3)

After estimating all the ARMA models, we can see that even though data is linear, the ARMA models fail to provide significant coefficient. It is probable that the underlying process is linear, but the data may exhibit volatility clustering. Furthermore, running white tests on all models show similar results of heteroscedasticity as followed.

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	4.26E+23	Prob. F(44,291)	0.0000
Obs*R-squared	336.0000	Prob. Chi-Square(44)	0.0000
Scaled explained SS	360.0287	Prob. Chi-Square(44)	0.0000

Since all the ARMA models suffer from heteroscedasticity, it is more appropriate to use ARCH or GARCH models instead.

b. ARCH Model Selection

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 11:06
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 6 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000492	0.000690	-0.712581	0.4761
		Variance Equation		
C	0.000159	1.30E-05	12.23458	0.0000
RESID(-1)^2	-0.017134	0.036999	-0.463093	0.6433

R-squared	-0.000002	Mean dependent var	-0.000511
Adjusted R-squared	-0.000002	S.D. dependent var	0.012510
S.E. of regression	0.012510	Akaike info criterion	-5.910206
Sum squared resid	0.052427	Schwarz criterion	-5.876125
Log likelihood	995.9147	Hannan-Quinn criter.	-5.896621
Durbin-Watson stat	2.355632		

ARCH (1)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 11:10
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 10 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000465	0.000697	-0.667785	0.5043
Variance Equation				
C	0.000156	1.52E-05	10.28303	0.0000
RESID(-1)^2	-0.017734	0.036194	-0.489962	0.6242
RESID(-2)^2	0.017909	0.053199	0.336634	0.7364

R-squared	-0.000013	Mean dependent var	-0.000511
Adjusted R-squared	-0.000013	S.D. dependent var	0.012510
S.E. of regression	0.012510	Akaike info criterion	-5.904694
Sum squared resid	0.052427	Schwarz criterion	-5.859252
Log likelihood	995.9886	Hannan-Quinn criter.	-5.886580
Durbin-Watson stat	2.355607		

ARCH (2)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 11:11
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 16 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000356	0.000691	-0.515770	0.6060
Variance Equation				
C	0.000143	1.59E-05	8.995597	0.0000
RESID(-1)^2	-0.041777	0.031125	-1.342226	0.1795
RESID(-2)^2	0.028881	0.053330	0.541550	0.5881
RESID(-3)^2	0.102422	0.066017	1.551447	0.1208

R-squared	-0.000153	Mean dependent var	-0.000511
Adjusted R-squared	-0.000153	S.D. dependent var	0.012510
S.E. of regression	0.012511	Akaike info criterion	-5.905447
Sum squared resid	0.052435	Schwarz criterion	-5.848645
Log likelihood	997.1151	Hannan-Quinn criter.	-5.882804
Durbin-Watson stat	2.355277		

ARCH (3)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 11:11
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 18 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2 + C(6)*RESID(-4)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-3.62E-05	0.000675	-0.053613	0.9572
Variance Equation				
C	0.000121	1.78E-05	6.767337	0.0000
RESID(-1)^2	-0.046154	0.027864	-1.656384	0.0976
RESID(-2)^2	0.039948	0.055491	0.719904	0.4716
RESID(-3)^2	0.139267	0.069294	2.009789	0.0445
RESID(-4)^2	0.115492	0.080271	1.438785	0.1502

R-squared	-0.001443	Mean dependent var	-0.000511
Adjusted R-squared	-0.001443	S.D. dependent var	0.012510
S.E. of regression	0.012519	Akaike info criterion	-5.907702
Sum squared resid	0.052502	Schwarz criterion	-5.839540
Log likelihood	998.4940	Hannan-Quinn criter.	-5.880531
Durbin-Watson stat	2.352242		

ARCH (4)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 11:11
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 15 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2 + C(6)*RESID(-4)^2 + C(7)*RESID(-5)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000218	0.000679	-0.321169	0.7481
		Variance Equation		
C	0.000114	1.81E-05	6.305212	0.0000
RESID(-1)^2	-0.042008	0.028603	-1.468638	0.1419
RESID(-2)^2	0.020765	0.058357	0.355827	0.7220
RESID(-3)^2	0.144267	0.070332	2.051242	0.0402
RESID(-4)^2	0.123577	0.082274	1.502010	0.1331
RESID(-5)^2	0.044868	0.036321	1.235331	0.2167

R-squared	-0.000549	Mean dependent var	-0.000511
Adjusted R-squared	-0.000549	S.D. dependent var	0.012510
S.E. of regression	0.012513	Akaike info criterion	-5.904770
Sum squared resid	0.052455	Schwarz criterion	-5.825246
Log likelihood	999.0013	Hannan-Quinn criter.	-5.873069
Durbin-Watson stat	2.354345		

ARCH (5)

Even after estimating ARCH (5), the ARCH models' parameters are still not significant. The lack of significance suggests the ARCH model may not be capturing the underlying volatility structure effectively. As a result, we switch to GARCH model. GARCH model not only account for past squared residuals but also include past conditional variances.

c. GARCH Model Selction

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 11:08
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 23 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000508	0.000696	-0.729639	0.4656
		Variance Equation		
C	9.65E-06	9.12E-06	1.057807	0.2901
RESID(-1)^2	0.032482	0.027346	1.187816	0.2349
GARCH(-1)	0.908302	0.074259	12.23155	0.0000

R-squared	-0.000000	Mean dependent var	-0.000511
Adjusted R-squared	-0.000000	S.D. dependent var	0.012510
S.E. of regression	0.012510	Akaike info criterion	-5.921782
Sum squared resid	0.052427	Schwarz criterion	-5.876340
Log likelihood	998.8594	Hannan-Quinn criter.	-5.903668
Durbin-Watson stat	2.355638		

GARCH (1,1)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 11:09
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 47 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000178	0.000709	-0.250383	0.8023
Variance Equation				
C	1.52E-05	1.12E-05	1.358374	0.1743
RESID(-1)^2	-0.053069	0.033421	-1.587888	0.1123
RESID(-2)^2	0.120481	0.050328	2.393942	0.0167
GARCH(-1)	0.839340	0.095659	8.774270	0.0000

R-squared	-0.000711	Mean dependent var	-0.000511
Adjusted R-squared	-0.000711	S.D. dependent var	0.012510
S.E. of regression	0.012514	Akaike info criterion	-5.925215
Sum squared resid	0.052464	Schwarz criterion	-5.868413
Log likelihood	1000.436	Hannan-Quinn criter.	-5.902572
Durbin-Watson stat	2.353963		

GARCH (2,1)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 11:09
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 26 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1) + C(5)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000477	0.000674	-0.707611	0.4792
Variance Equation				
C	6.10E-06	1.68E-06	3.628191	0.0003
RESID(-1)^2	0.017764	0.010363	1.714167	0.0865
GARCH(-1)	1.813186	0.082318	22.02658	0.0000
GARCH(-2)	-0.869547	0.076294	-11.39734	0.0000

R-squared	-0.000007	Mean dependent var	-0.000511
Adjusted R-squared	-0.000007	S.D. dependent var	0.012510
S.E. of regression	0.012510	Akaike info criterion	-5.928949
Sum squared resid	0.052427	Schwarz criterion	-5.872147
Log likelihood	1001.063	Hannan-Quinn criter.	-5.906306
Durbin-Watson stat	2.355621		

GARCH (1,2)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 11:14
Sample: 1/06/2007 12/09/2008
Included observations: 336
Convergence achieved after 12 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*GARCH(-1)
+ C(6)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000177	0.000611	-0.289972	0.7718
Variance Equation				
C	9.37E-06	2.18E-06	4.291956	0.0000
RESID(-1)^2	-0.106123	0.015615	-6.796288	0.0000
RESID(-2)^2	0.137326	0.018928	7.255079	0.0000
GARCH(-1)	1.761305	0.053185	33.11670	0.0000
GARCH(-2)	-0.852847	0.051956	-16.41482	0.0000

R-squared	-0.000713	Mean dependent var	-0.000511
Adjusted R-squared	-0.000713	S.D. dependent var	0.012510
S.E. of regression	0.012514	Akaike info criterion	-5.956075
Sum squared resid	0.052464	Schwarz criterion	-5.887912
Log likelihood	1006.621	Hannan-Quinn criter.	-5.928903
Durbin-Watson stat	2.353958		

GARCH (2,2)

Based on the GARCH model estimates, only GARCH (1,2) [10% level] and GARCH (2,2) [1% level] has all variables which are significant. Therefore, we decide on the model based on model with lowest AIC and SIC values.

Models	AIC	SIC
GARCH (1,2)	**-5.9289**	**-5.8721**
GARCH (2,2)	**-5.9561**	**-5.8879**

Thus, model GARCH (2,2) is selected.

d. Diagnostic Tests

To ensure our model is robust, we run diagnostic tests on the model. This includes Ljung-Box Q Test and ARCH-LM Test

Ljung-Box Q Test

H0: No autocorrelation in squared residuals
H1: There is autocorrelation in squared residuals

Correlogram of Standardized Residuals

Date: 21/11/24 Time: 12:10
Sample: 1/06/2007 12/09/2008
Included observations: 336

Lag	AC	PAC	Q-Stat	Prob*
1	-0.191	-0.191	12.321	0.000
2	0.004	-0.034	12.326	0.002
3	-0.009	-0.015	12.355	0.006
4	-0.016	-0.022	12.447	0.014
5	-0.000	-0.008	12.447	0.029
6	-0.082	-0.087	14.746	0.022
7	0.002	-0.032	14.748	0.039
8	-0.016	-0.027	14.837	0.062
9	-0.007	-0.020	14.855	0.095
10	0.039	0.030	15.376	0.119
11	0.035	0.047	15.801	0.149
12	0.036	0.047	16.246	0.180
13	0.054	0.073	17.259	0.188
14	-0.066	-0.042	18.795	0.173
15	-0.019	-0.039	18.921	0.217
16	-0.018	-0.023	19.034	0.267
17	0.068	0.073	20.697	0.240
18	-0.024	0.014	20.901	0.284
19	-0.069	-0.062	22.597	0.256
20	0.024	-0.011	22.798	0.299
21	-0.021	-0.028	22.958	0.346
22	0.015	-0.005	23.037	0.400
23	-0.008	-0.009	23.058	0.457

At lag 10, the probability is 0.119 which is more than 0.05, therefore, we fail to reject null hypothesis. Thus, the is no significant autocorrelation in squared residuals.

ARCH-LM Test

H0: No ARCH effect left

H1: Have residual ARCH effect

Heteroskedasticity Test: ARCH

F-statistic	0.407114	Prob. F(1,333)	0.5239
Obs*R-squared	0.409059	Prob. Chi-Square(1)	0.5224

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:15
Sample (adjusted): 4/06/2007 12/09/2008
Included observations: 335 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.012075	0.105502	9.592956	0.0000
WGT_RESID^2(-1)	0.034945	0.054768	0.638055	0.5239

R-squared	0.001221	Mean dependent var	1.048726
Adjusted R-squared	-0.001778	S.D. dependent var	1.618261
S.E. of regression	1.619699	Akaike info criterion	3.808310
Sum squared resid	873.6007	Schwarz criterion	3.831081
Log likelihood	-635.8920	Hannan-Quinn criter.	3.817388
F-statistic	0.407114	Durbin-Watson stat	1.998670
Prob(F-statistic)	0.523876		

Heteroskedasticity Test: ARCH

F-statistic	0.243745	Prob. F(2,331)	0.7838
Obs*R-squared	0.491185	Prob. Chi-Square(2)	0.7822

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:15
Sample (adjusted): 5/06/2007 12/09/2008
Included observations: 334 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.034178	0.119651	8.643275	0.0000
WGT_RESID^2(-1)	0.034522	0.054959	0.628146	0.5303
WGT_RESID^2(-2)	-0.017944	0.054930	-0.326664	0.7441

R-squared	0.001471	Mean dependent var	1.051670
Adjusted R-squared	-0.004563	S.D. dependent var	1.619791
S.E. of regression	1.623482	Akaike info criterion	3.815965
Sum squared resid	872.4145	Schwarz criterion	3.850197
Log likelihood	-634.2661	Hannan-Quinn criter.	3.829613
F-statistic	0.243745	Durbin-Watson stat	1.999218
Prob(F-statistic)	0.783828		

Heteroskedasticity Test: ARCH

F-statistic	0.190173	Prob. F(3,329)	0.9031
Obs*R-squared	0.576456	Prob. Chi-Square(3)	0.9018

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:15
Sample (adjusted): 6/06/2007 12/09/2008
Included observations: 333 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.020612	0.133010	7.673196	0.0000
WGT_RESID^2(-1)	0.034023	0.055139	0.617048	0.5376
WGT_RESID^2(-2)	-0.019340	0.055134	-0.350774	0.7260
WGT_RESID^2(-3)	0.016938	0.055084	0.307497	0.7587

R-squared	0.001731	Mean dependent var	1.053938
Adjusted R-squared	-0.007372	S.D. dependent var	1.621697
S.E. of regression	1.627663	Akaike info criterion	3.824107
Sum squared resid	871.6156	Schwarz criterion	3.869851
Log likelihood	-632.7138	Hannan-Quinn criter.	3.842348
F-statistic	0.190173	Durbin-Watson stat	1.999670
Prob(F-statistic)	0.903063		

Heteroskedasticity Test: ARCH

F-statistic	0.185658	Prob. F(4,327)	0.9458
Obs*R-squared	0.752278	Prob. Chi-Square(4)	0.9447

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:16
Sample (adjusted): 7/06/2007 12/09/2008
Included observations: 332 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.998526	0.144968	6.887925	0.0000
WGT_RESID^2(-1)	0.033184	0.055326	0.599790	0.5491
WGT_RESID^2(-2)	-0.019139	0.055324	-0.345940	0.7296
WGT_RESID^2(-3)	0.015708	0.055308	0.284009	0.7766
WGT_RESID^2(-4)	0.024175	0.056993	0.424181	0.6717

R-squared	0.002266	Mean dependent var	1.054800
Adjusted R-squared	-0.009939	S.D. dependent var	1.624068
S.E. of regression	1.632119	Akaike info criterion	3.832581
Sum squared resid	871.0666	Schwarz criterion	3.889887
Log likelihood	-631.2085	Hannan-Quinn criter.	3.855435
F-statistic	0.185658	Durbin-Watson stat	1.991868
Prob(F-statistic)	0.945787		

Heteroskedasticity Test: ARCH

F-statistic	0.240333	Prob. F(5,325)	0.9444
Obs*R-squared	1.219341	Prob. Chi-Square(5)	0.9430

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:16
Sample (adjusted): 8/06/2007 12/09/2008
Included observations: 331 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.021904	0.155484	6.572421	0.0000
WGT_RESID^2(-1)	0.034627	0.055374	0.625317	0.5322
WGT_RESID^2(-2)	-0.016708	0.055387	-0.301666	0.7631
WGT_RESID^2(-3)	0.016982	0.055374	0.306686	0.7593
WGT_RESID^2(-4)	0.027204	0.057072	0.476649	0.6339
WGT_RESID^2(-5)	-0.036601	0.057103	-0.640967	0.5220

R-squared	0.003684	Mean dependent var	1.049395
Adjusted R-squared	-0.011644	S.D. dependent var	1.623533
S.E. of regression	1.632958	Akaike info criterion	3.836624
Sum squared resid	866.6295	Schwarz criterion	3.905545
Log likelihood	-628.9613	Hannan-Quinn criter.	3.864112
F-statistic	0.240333	Durbin-Watson stat	2.002774
Prob(F-statistic)	0.944399		

Heteroskedasticity Test: ARCH

F-statistic	0.298482	Prob. F(6,323)	0.9374
Obs*R-squared	1.819614	Prob. Chi-Square(6)	0.9355

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:16
Sample (adjusted): 11/06/2007 12/09/2008
Included observations: 330 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.064812	0.166024	6.413615	0.0000
WGT_RESID^2(-1)	0.032289	0.055634	0.580379	0.5621
WGT_RESID^2(-2)	-0.015416	0.055525	-0.277641	0.7815
WGT_RESID^2(-3)	0.018299	0.055520	0.329589	0.7419
WGT_RESID^2(-4)	0.027102	0.057227	0.473580	0.6361
WGT_RESID^2(-5)	-0.034881	0.057279	-0.608965	0.5430
WGT_RESID^2(-6)	-0.044793	0.057277	-0.782048	0.4348

R-squared	0.005514	Mean dependent var	1.048143
Adjusted R-squared	-0.012959	S.D. dependent var	1.625839
S.E. of regression	1.636340	Akaike info criterion	3.843785
Sum squared resid	864.8673	Schwarz criterion	3.924372
Log likelihood	-627.2245	Hannan-Quinn criter.	3.875930
F-statistic	0.298482	Durbin-Watson stat	1.994889
Prob(F-statistic)	0.937392		

Heteroskedasticity Test: ARCH

F-statistic	0.277270	Prob. F(7,321)	0.9626
Obs*R-squared	1.977305	Prob. Chi-Square(7)	0.9611

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:16
Sample (adjusted): 12/06/2007 12/09/2008
Included observations: 329 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.047362	0.177468	5.901697	0.0000
WGT_RESID^2(-1)	0.033483	0.055803	0.600021	0.5489
WGT_RESID^2(-2)	-0.012424	0.055793	-0.222675	0.8239
WGT_RESID^2(-3)	0.017331	0.055671	0.311315	0.7558
WGT_RESID^2(-4)	0.026437	0.057376	0.460772	0.6453
WGT_RESID^2(-5)	-0.035809	0.057449	-0.623306	0.5335
WGT_RESID^2(-6)	-0.046697	0.057466	-0.812613	0.4170
WGT_RESID^2(-7)	0.020669	0.058080	0.355867	0.7222

R-squared	0.006010	Mean dependent var	1.051293
Adjusted R-squared	-0.015666	S.D. dependent var	1.627307
S.E. of regression	1.640004	Akaike info criterion	3.851290
Sum squared resid	863.3655	Schwarz criterion	3.943595
Log likelihood	-625.5371	Hannan-Quinn criter.	3.888113
F-statistic	0.277270	Durbin-Watson stat	1.999962
Prob(F-statistic)	0.962552		

Heteroskedasticity Test: ARCH

F-statistic	0.246678	Prob. F(8,319)	0.9814
Obs*R-squared	2.016626	Prob. Chi-Square(8)	0.9805

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:17
Sample (adjusted): 13/06/2007 12/09/2008
Included observations: 328 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.037696	0.187938	5.521496	0.0000
WGT_RESID^2(-1)	0.032906	0.056017	0.587419	0.5573
WGT_RESID^2(-2)	-0.011882	0.056006	-0.212157	0.8321
WGT_RESID^2(-3)	0.018376	0.055984	0.328237	0.7429
WGT_RESID^2(-4)	0.025889	0.057597	0.449477	0.6534
WGT_RESID^2(-5)	-0.035951	0.057641	-0.623704	0.5333
WGT_RESID^2(-6)	-0.046877	0.057685	-0.812642	0.4170
WGT_RESID^2(-7)	0.019851	0.058336	0.340282	0.7339
WGT_RESID^2(-8)	0.011099	0.058332	0.190277	0.8492

R-squared	0.006148	Mean dependent var	1.052119
Adjusted R-squared	-0.018776	S.D. dependent var	1.629724
S.E. of regression	1.644953	Akaike info criterion	3.860356
Sum squared resid	863.1722	Schwarz criterion	3.964432
Log likelihood	-624.0983	Hannan-Quinn criter.	3.901879
F-statistic	0.246678	Durbin-Watson stat	1.998694
Prob(F-statistic)	0.981444		

Heteroskedasticity Test: ARCH

F-statistic	0.223997	Prob. F(9,317)	0.9910
Obs*R-squared	2.066425	Prob. Chi-Square(9)	0.9904

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:17
Sample (adjusted): 14/06/2007 12/09/2008
Included observations: 327 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.018759	0.197708	5.152859	0.0000
WGT_RESID^2(-1)	0.032910	0.056187	0.585726	0.5585
WGT_RESID^2(-2)	-0.011638	0.056215	-0.207020	0.8361
WGT_RESID^2(-3)	0.018787	0.056193	0.334333	0.7383
WGT_RESID^2(-4)	0.025454	0.057911	0.439528	0.6606
WGT_RESID^2(-5)	-0.036452	0.057859	-0.630027	0.5291
WGT_RESID^2(-6)	-0.046348	0.057873	-0.800860	0.4238
WGT_RESID^2(-7)	0.020605	0.058545	0.351944	0.7251
WGT_RESID^2(-8)	0.011023	0.058581	0.188165	0.8509
WGT_RESID^2(-9)	0.016366	0.058515	0.279692	0.7799

R-squared	0.006319	Mean dependent var	1.050586
Adjusted R-squared	-0.021892	S.D. dependent var	1.631985
S.E. of regression	1.649752	Akaike info criterion	3.869231
Sum squared resid	862.7732	Schwarz criterion	3.985132
Log likelihood	-622.6192	Hannan-Quinn criter.	3.915477
F-statistic	0.223997	Durbin-Watson stat	1.996719
Prob(F-statistic)	0.990956		

Heteroskedasticity Test: ARCH

F-statistic	0.210947	Prob. F(10,315)	0.9953
Obs*R-squared	2.168614	Prob. Chi-Square(10)	0.9949

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:17
Sample (adjusted): 15/06/2007 12/09/2008
Included observations: 326 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.045389	0.206672	5.058193	0.0000
WGT_RESID^2(-1)	0.033625	0.056343	0.596785	0.5511
WGT_RESID^2(-2)	-0.011730	0.056366	-0.208105	0.8353
WGT_RESID^2(-3)	0.018207	0.056382	0.322920	0.7470
WGT_RESID^2(-4)	0.025128	0.058095	0.432531	0.6657
WGT_RESID^2(-5)	-0.035411	0.058152	-0.608945	0.5430
WGT_RESID^2(-6)	-0.045706	0.058070	-0.787089	0.4318
WGT_RESID^2(-7)	0.019852	0.058710	0.338135	0.7355
WGT_RESID^2(-8)	0.009699	0.058773	0.165026	0.8690
WGT_RESID^2(-9)	0.016216	0.058744	0.276041	0.7827
WGT_RESID^2(-10)	-0.022906	0.058686	-0.390305	0.6966

R-squared	0.006652	Mean dependent var	1.053250
Adjusted R-squared	-0.024883	S.D. dependent var	1.633782
S.E. of regression	1.653983	Akaike info criterion	3.877410
Sum squared resid	861.7331	Schwarz criterion	4.005189
Log likelihood	-621.0178	Hannan-Quinn criter.	3.928401
F-statistic	0.210947	Durbin-Watson stat	2.001174
Prob(F-statistic)	0.995252		

Since the probability value for ARCH-LM Test for lag 1 through lag 10 is greater than 0.05, we fail to reject null hypothesis. Thus, there are no ARCH effect.

Therefore, the model GARCH (2,2) is robust for the Pre-Crisis period and is selected for forecasting.

2.2 Period 2 (During Crisis) 15th September 2008 – 30th April 2009

a. ARCH Model Selection

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 12:22
Sample: 15/09/2008 30/04/2009
Included observations: 164
Convergence achieved after 13 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.001594	0.002681	-0.594475	0.5522
		Variance Equation		
C	0.001119	0.000114	9.843824	0.0000
RESID(-1)^2	0.006133	0.076129	0.080558	0.9358

R-squared	-0.000001	Mean dependent var	-0.001618
Adjusted R-squared	-0.000001	S.D. dependent var	0.033655
S.E. of regression	0.033655	Akaike info criterion	-3.914892
Sum squared resid	0.184621	Schwarz criterion	-3.858187
Log likelihood	324.0211	Hannan-Quinn criter.	-3.891872
Durbin-Watson stat	2.276361		

ARCH (1)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 12:23
Sample: 15/09/2008 30/04/2009
Included observations: 164
Convergence achieved after 16 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000881	0.002427	-0.362813	0.7167
		Variance Equation		
C	0.000852	0.000125	6.809363	0.0000
RESID(-1)^2	0.033801	0.081209	0.416216	0.6773
RESID(-2)^2	0.199567	0.099574	2.004216	0.0450

R-squared	-0.000483	Mean dependent var	-0.001618
Adjusted R-squared	-0.000483	S.D. dependent var	0.033655
S.E. of regression	0.033663	Akaike info criterion	-3.950789
Sum squared resid	0.184710	Schwarz criterion	-3.875182
Log likelihood	327.9647	Hannan-Quinn criter.	-3.920096
Durbin-Watson stat	2.275263		

ARCH (2)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 12:23
Sample: 15/09/2008 30/04/2009
Included observations: 164
Convergence achieved after 22 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000831	0.002433	-0.341418	0.7328
Variance Equation				
C	0.000866	0.000140	6.177829	0.0000
RESID(-1)^2	0.041949	0.083909	0.499936	0.6171
RESID(-2)^2	0.201160	0.101492	1.982017	0.0475
RESID(-3)^2	-0.020908	0.082351	-0.253889	0.7996

R-squared	-0.000551	Mean dependent var	-0.001618
Adjusted R-squared	-0.000551	S.D. dependent var	0.033655
S.E. of regression	0.033664	Akaike info criterion	-3.939332
Sum squared resid	0.184722	Schwarz criterion	-3.844824
Log likelihood	328.0252	Hannan-Quinn criter.	-3.900966
Durbin-Watson stat	2.275109		

ARCH (3)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 12:23
Sample: 15/09/2008 30/04/2009
Included observations: 164
Convergence achieved after 28 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2 + C(6)*RESID(-4)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000876	0.002551	-0.343395	0.7313
Variance Equation				
C	0.000822	0.000155	5.320289	0.0000
RESID(-1)^2	0.037212	0.081742	0.455240	0.6489
RESID(-2)^2	0.179697	0.106792	1.682672	0.0924
RESID(-3)^2	-0.012511	0.086729	-0.144257	0.8853
RESID(-4)^2	0.052768	0.086655	0.608947	0.5426

R-squared	-0.000489	Mean dependent var	-0.001618
Adjusted R-squared	-0.000489	S.D. dependent var	0.033655
S.E. of regression	0.033663	Akaike info criterion	-3.928408
Sum squared resid	0.184711	Schwarz criterion	-3.814998
Log likelihood	328.1295	Hannan-Quinn criter.	-3.882368
Durbin-Watson stat	2.275249		

ARCH (4)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 12:24
Sample: 15/09/2008 30/04/2009
Included observations: 164
Convergence achieved after 25 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2 + C(6)*RESID(-4)^2 + C(7)*RESID(-5)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000921	0.002122	0.433802	0.6644
		Variance Equation		
C	0.000485	0.000133	3.646850	0.0003
RESID(-1)^2	0.023706	0.062668	0.378287	0.7052
RESID(-2)^2	0.111876	0.084870	1.318214	0.1874
RESID(-3)^2	-0.019587	0.067249	-0.291265	0.7708
RESID(-4)^2	0.067970	0.092755	0.732797	0.4637
RESID(-5)^2	0.380699	0.147564	2.579893	0.0099

R-squared	-0.005726	Mean dependent var	-0.001618
Adjusted R-squared	-0.005726	S.D. dependent var	0.033655
S.E. of regression	0.033751	Akaike info criterion	-4.006408
Sum squared resid	0.185678	Schwarz criterion	-3.874096
Log likelihood	335.5254	Hannan-Quinn criter.	-3.952694
Durbin-Watson stat	2.263403		

ARCH (5)

Even after estimating ARCH (5), the ARCH models' parameters are still not significant. The lack of significance suggests the ARCH model may not be capturing the underlying volatility structure effectively. As a result, we switch to GARCH model. GARCH model not only account for past squared residuals but also include past conditional variances.

b. GARCH Model Selection

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 12:26
Sample: 15/09/2008 30/04/2009
Included observations: 164
Convergence achieved after 17 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-8.55E-05	0.002337	-0.036597	0.9708
Variance Equation				
C	1.81E-05	2.34E-05	0.771648	0.4403
RESID(-1)^2	0.067861	0.041926	1.618578	0.1055
GARCH(-1)	0.907239	0.054830	16.54635	0.0000

R-squared	-0.002086	Mean dependent var	-0.001618
Adjusted R-squared	-0.002086	S.D. dependent var	0.033655
S.E. of regression	0.033690	Akaike info criterion	-4.041577
Sum squared resid	0.185006	Schwarz criterion	-3.965970
Log likelihood	335.4093	Hannan-Quinn criter.	-4.010883
Durbin-Watson stat	2.271623		

GARCH (1,1)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 12:27
Sample: 15/09/2008 30/04/2009
Included observations: 164
Convergence achieved after 25 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000156	0.002423	-0.064437	0.9486
		Variance Equation		
C	2.01E-05	2.53E-05	0.793100	0.4277
RESID(-1)^2	-0.036552	0.058769	-0.621962	0.5340
RESID(-2)^2	0.109168	0.053194	2.052254	0.0401
GARCH(-1)	0.898750	0.058851	15.27162	0.0000

R-squared	-0.001899	Mean dependent var	-0.001618
Adjusted R-squared	-0.001899	S.D. dependent var	0.033655
S.E. of regression	0.033687	Akaike info criterion	-4.046467
Sum squared resid	0.184971	Schwarz criterion	-3.951958
Log likelihood	336.8103	Hannan-Quinn criter.	-4.008100
Durbin-Watson stat	2.272048		

GARCH (2,1)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 12:27
Sample: 15/09/2008 30/04/2009
Included observations: 164
Convergence achieved after 132 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1) + C(5)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000101	0.001954	-0.051646	0.9588
Variance Equation				
C	1.60E-05	5.28E-06	3.032963	0.0024
RESID(-1)^2	0.043969	0.013172	3.338061	0.0008
GARCH(-1)	1.815922	0.027538	65.94166	0.0000
GARCH(-2)	-0.870176	0.023012	-37.81451	0.0000

R-squared	-0.002045	Mean dependent var	-0.001618
Adjusted R-squared	-0.002045	S.D. dependent var	0.033655
S.E. of regression	0.033689	Akaike info criterion	-4.085840
Sum squared resid	0.184998	Schwarz criterion	-3.991332
Log likelihood	340.0389	Hannan-Quinn criter.	-4.047474
Durbin-Watson stat	2.271717		

GARCH (1,2)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 12:27
Sample: 15/09/2008 30/04/2009
Included observations: 164
Convergence achieved after 25 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*GARCH(-1)
+ C(6)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000201	0.002415	-0.083142	0.9337
Variance Equation				
C	2.36E-05	3.33E-05	0.709875	0.4778
RESID(-1)^2	-0.040644	0.058909	-0.689942	0.4902
RESID(-2)^2	0.119866	0.053895	2.224083	0.0261
GARCH(-1)	0.635187	0.729314	0.870939	0.3838
GARCH(-2)	0.250858	0.672268	0.373152	0.7090

R-squared	-0.001784	Mean dependent var	-0.001618
Adjusted R-squared	-0.001784	S.D. dependent var	0.033655
S.E. of regression	0.033685	Akaike info criterion	-4.033825
Sum squared resid	0.184950	Schwarz criterion	-3.920415
Log likelihood	336.7737	Hannan-Quinn criter.	-3.987785
Durbin-Watson stat	2.272308		

GARCH (2,2)

We choose GARCH (1,2) because all the parameters are significant (probability <0.05).

c. **Diagnostic Tests**

Ljung-Box Q Test

H0: No autocorrelation in squared residuals

H1: There is autocorrelation in squared residuals

Correlogram of Standardized Residuals

Date: 21/11/24 Time: 12:32
Sample: 15/09/2008 30/04/2009
Included observations: 164

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.145	-0.145	3.5071	0.061
		2	-0.090	-0.113	4.8671	0.088
		3	0.109	0.080	6.8599	0.077
		4	0.005	0.025	6.8635	0.143
		5	-0.030	-0.008	7.0155	0.219
		6	-0.012	-0.026	7.0417	0.317
		7	-0.012	-0.025	7.0648	0.422
		8	-0.011	-0.017	7.0860	0.527
		9	-0.012	-0.015	7.1097	0.626
		10	0.017	0.015	7.1599	0.710
		11	-0.051	-0.048	7.6165	0.747
		12	-0.030	-0.042	7.7729	0.803
		13	0.045	0.022	8.1335	0.835
		14	-0.061	-0.052	8.8145	0.843
		15	-0.020	-0.025	8.8881	0.883
		16	0.069	0.048	9.7703	0.878
		17	0.026	0.049	9.8975	0.908
		18	-0.106	-0.086	11.990	0.848
		19	0.008	-0.030	12.002	0.886
		20	0.031	-0.001	12.180	0.910
		21	-0.025	-0.005	12.300	0.931
		22	-0.029	-0.027	12.460	0.947
		23	0.073	0.057	13.478	0.941

At lag 10, the probability is 0.710 which is more than 0.05, therefore, we fail to reject null hypothesis. Thus, the is no significant autocorrelation in squared residuals.

ARCH-LM Test

H0: No ARCH effect left

H1: Have residual ARCH effect

Heteroskedasticity Test: ARCH

F-statistic	0.623818	Prob. F(1,161)	0.4308
Obs*R-squared	0.629129	Prob. Chi-Square(1)	0.4277

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:37
Sample (adjusted): 16/09/2008 30/04/2009
Included observations: 163 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.040299	0.135411	7.682528	0.0000
WGT_RESID^2(-1)	-0.062201	0.078753	-0.789821	0.4308

R-squared	0.003860	Mean dependent var	0.978872
Adjusted R-squared	-0.002328	S.D. dependent var	1.413577
S.E. of regression	1.415222	Akaike info criterion	3.544643
Sum squared resid	322.4592	Schwarz criterion	3.582603
Log likelihood	-286.8884	Hannan-Quinn criter.	3.560055
F-statistic	0.623818	Durbin-Watson stat	1.998265
Prob(F-statistic)	0.430794		

Heteroskedasticity Test: ARCH

F-statistic	0.434190	Prob. F(2,159)	0.6486
Obs*R-squared	0.879958	Prob. Chi-Square(2)	0.6440

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:58
Sample (adjusted): 17/09/2008 30/04/2009
Included observations: 162 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.087273	0.159635	6.810999	0.0000
WGT_RESID^2(-1)	-0.063778	0.079288	-0.804383	0.4224
WGT_RESID^2(-2)	-0.041222	0.079269	-0.520028	0.6038

R-squared	0.005432	Mean dependent var	0.983704
Adjusted R-squared	-0.007078	S.D. dependent var	1.416610
S.E. of regression	1.421615	Akaike info criterion	3.559809
Sum squared resid	321.3372	Schwarz criterion	3.616987
Log likelihood	-285.3445	Hannan-Quinn criter.	3.583024
F-statistic	0.434190	Durbin-Watson stat	2.005748
Prob(F-statistic)	0.648555		

Heteroskedasticity Test: ARCH

F-statistic	1.319421	Prob. F(3,157)	0.2701
Obs*R-squared	3.959290	Prob. Chi-Square(3)	0.2659

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:59
Sample (adjusted): 18/09/2008 30/04/2009
Included observations: 161 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.238129	0.181777	6.811245	0.0000
WGT_RESID^2(-1)	-0.069017	0.079147	-0.872008	0.3845
WGT_RESID^2(-2)	-0.050894	0.079168	-0.642859	0.5213
WGT_RESID^2(-3)	-0.139333	0.079177	-1.759773	0.0804

R-squared	0.024592	Mean dependent var	0.981039
Adjusted R-squared	0.005953	S.D. dependent var	1.420623
S.E. of regression	1.416387	Akaike info criterion	3.558627
Sum squared resid	314.9661	Schwarz criterion	3.635184
Log likelihood	-282.4695	Hannan-Quinn criter.	3.589712
F-statistic	1.319421	Durbin-Watson stat	2.018683
Prob(F-statistic)	0.270058		

Heteroskedasticity Test: ARCH

F-statistic	1.242898	Prob. F(4,155)	0.2951
Obs*R-squared	4.972474	Prob. Chi-Square(4)	0.2901

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:59
Sample (adjusted): 19/09/2008 30/04/2009
Included observations: 160 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.339728	0.209055	6.408489	0.0000
WGT_RESID^2(-1)	-0.080914	0.080222	-1.008625	0.3147
WGT_RESID^2(-2)	-0.054687	0.079593	-0.687085	0.4931
WGT_RESID^2(-3)	-0.145777	0.079663	-1.829910	0.0692
WGT_RESID^2(-4)	-0.081356	0.080338	-1.012677	0.3128

R-squared	0.031078	Mean dependent var	0.979690
Adjusted R-squared	0.006074	S.D. dependent var	1.424980
S.E. of regression	1.420646	Akaike info criterion	3.570851
Sum squared resid	312.8263	Schwarz criterion	3.666951
Log likelihood	-280.6681	Hannan-Quinn criter.	3.609874
F-statistic	1.242898	Durbin-Watson stat	1.981747
Prob(F-statistic)	0.295089		

Heteroskedasticity Test: ARCH

F-statistic	1.208346	Prob. F(5,153)	0.3079
Obs*R-squared	6.040147	Prob. Chi-Square(5)	0.3023

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:59
Sample (adjusted): 22/09/2008 30/04/2009
Included observations: 159 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.221928	0.237704	5.140540	0.0000
WGT_RESID^2(-1)	-0.073887	0.080745	-0.915056	0.3616
WGT_RESID^2(-2)	-0.042158	0.080745	-0.522114	0.6023
WGT_RESID^2(-3)	-0.140434	0.080111	-1.752987	0.0816
WGT_RESID^2(-4)	-0.073903	0.080913	-0.913366	0.3625
WGT_RESID^2(-5)	0.084971	0.080905	1.050252	0.2953

R-squared	0.037988	Mean dependent var	0.978920
Adjusted R-squared	0.006550	S.D. dependent var	1.429449
S.E. of regression	1.424759	Akaike info criterion	3.582888
Sum squared resid	310.5807	Schwarz criterion	3.698696
Log likelihood	-278.8396	Hannan-Quinn criter.	3.629917
F-statistic	1.208346	Durbin-Watson stat	1.999501
Prob(F-statistic)	0.307859		

Heteroskedasticity Test: ARCH

F-statistic	1.005494	Prob. F(6,151)	0.4239
Obs*R-squared	6.070116	Prob. Chi-Square(6)	0.4154

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 12:59
Sample (adjusted): 23/09/2008 30/04/2009
Included observations: 158 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.195049	0.261577	4.568632	0.0000
WGT_RESID^2(-1)	-0.075565	0.081526	-0.926881	0.3555
WGT_RESID^2(-2)	-0.040454	0.081519	-0.496247	0.6204
WGT_RESID^2(-3)	-0.137232	0.081543	-1.682937	0.0945
WGT_RESID^2(-4)	-0.072958	0.081605	-0.894039	0.3727
WGT_RESID^2(-5)	0.086842	0.081735	1.062473	0.2897
WGT_RESID^2(-6)	0.021097	0.081849	0.257755	0.7969

R-squared	0.038418	Mean dependent var	0.979228
Adjusted R-squared	0.000210	S.D. dependent var	1.433988
S.E. of regression	1.433838	Akaike info criterion	3.601879
Sum squared resid	310.4396	Schwarz criterion	3.737563
Log likelihood	-277.5484	Hannan-Quinn criter.	3.656982
F-statistic	1.005494	Durbin-Watson stat	1.995353
Prob(F-statistic)	0.423939		

Heteroskedasticity Test: ARCH

F-statistic	0.842194	Prob. F(7,149)	0.5541
Obs*R-squared	5.975462	Prob. Chi-Square(7)	0.5426

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:00
Sample (adjusted): 24/09/2008 30/04/2009
Included observations: 157 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.183777	0.284044	4.167583	0.0001
WGT_RESID^2(-1)	-0.075925	0.082011	-0.925797	0.3560
WGT_RESID^2(-2)	-0.041233	0.082257	-0.501271	0.6169
WGT_RESID^2(-3)	-0.135706	0.082303	-1.648859	0.1013
WGT_RESID^2(-4)	-0.070351	0.083014	-0.847452	0.3981
WGT_RESID^2(-5)	0.085828	0.082395	1.041672	0.2993
WGT_RESID^2(-6)	0.023090	0.082680	0.279268	0.7804
WGT_RESID^2(-7)	0.011642	0.082526	0.141074	0.8880

R-squared	0.038060	Mean dependent var	0.984507
Adjusted R-squared	-0.007132	S.D. dependent var	1.437036
S.E. of regression	1.442151	Akaike info criterion	3.619760
Sum squared resid	309.8901	Schwarz criterion	3.775492
Log likelihood	-276.1512	Hannan-Quinn criter.	3.683008
F-statistic	0.842194	Durbin-Watson stat	1.996885
Prob(F-statistic)	0.554073		

Heteroskedasticity Test: ARCH

F-statistic	0.749587	Prob. F(8,147)	0.6476
Obs*R-squared	6.114414	Prob. Chi-Square(8)	0.6344

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:00
Sample (adjusted): 25/09/2008 30/04/2009
Included observations: 156 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.225752	0.304893	4.020268	0.0001
WGT_RESID^2(-1)	-0.078083	0.082468	-0.946828	0.3453
WGT_RESID^2(-2)	-0.041228	0.082655	-0.498790	0.6187
WGT_RESID^2(-3)	-0.133567	0.082949	-1.610227	0.1095
WGT_RESID^2(-4)	-0.071983	0.083677	-0.860249	0.3911
WGT_RESID^2(-5)	0.083057	0.083708	0.992218	0.3227
WGT_RESID^2(-6)	0.019432	0.083250	0.233422	0.8158
WGT_RESID^2(-7)	0.010692	0.083277	0.128390	0.8980
WGT_RESID^2(-8)	-0.025860	0.082922	-0.311863	0.7556

R-squared	0.039195	Mean dependent var	0.990805
Adjusted R-squared	-0.013094	S.D. dependent var	1.439489
S.E. of regression	1.448883	Akaike info criterion	3.635424
Sum squared resid	308.5914	Schwarz criterion	3.811377
Log likelihood	-274.5630	Hannan-Quinn criter.	3.706888
F-statistic	0.749587	Durbin-Watson stat	1.999615
Prob(F-statistic)	0.647624		

Heteroskedasticity Test: ARCH

F-statistic	0.670786	Prob. F(9,145)	0.7343
Obs*R-squared	6.195476	Prob. Chi-Square(9)	0.7202

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:00
Sample (adjusted): 26/09/2008 30/04/2009
Included observations: 155 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.223556	0.323951	3.776974	0.0002
WGT_RESID^2(-1)	-0.080874	0.083088	-0.973352	0.3320
WGT_RESID^2(-2)	-0.043608	0.083214	-0.524043	0.6010
WGT_RESID^2(-3)	-0.134426	0.083462	-1.610636	0.1094
WGT_RESID^2(-4)	-0.073333	0.084503	-0.867811	0.3869
WGT_RESID^2(-5)	0.084003	0.084409	0.995185	0.3213
WGT_RESID^2(-6)	0.021981	0.084513	0.260096	0.7952
WGT_RESID^2(-7)	0.009340	0.083875	0.111354	0.9115
WGT_RESID^2(-8)	-0.023722	0.083751	-0.283246	0.7774
WGT_RESID^2(-9)	0.010817	0.085059	0.127173	0.8990

R-squared	0.039971	Mean dependent var	0.995537
Adjusted R-squared	-0.019617	S.D. dependent var	1.442937
S.E. of regression	1.457022	Akaike info criterion	3.653007
Sum squared resid	307.8224	Schwarz criterion	3.849357
Log likelihood	-273.1080	Hannan-Quinn criter.	3.732760
F-statistic	0.670786	Durbin-Watson stat	1.999296
Prob(F-statistic)	0.734282		

Heteroskedasticity Test: ARCH

F-statistic	0.644000	Prob. F(10,143)	0.7740
Obs*R-squared	6.636507	Prob. Chi-Square(10)	0.7593

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:01
Sample (adjusted): 29/09/2008 30/04/2009
Included observations: 154 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.202434	0.342064	3.515234	0.0006
WGT_RESID^2(-1)	-0.084733	0.083508	-1.014663	0.3120
WGT_RESID^2(-2)	-0.047779	0.083709	-0.570768	0.5691
WGT_RESID^2(-3)	-0.138337	0.083882	-1.649188	0.1013
WGT_RESID^2(-4)	-0.075677	0.084872	-0.891664	0.3741
WGT_RESID^2(-5)	0.080044	0.085083	0.940779	0.3484
WGT_RESID^2(-6)	0.025071	0.085079	0.294681	0.7687
WGT_RESID^2(-7)	0.015692	0.085021	0.184563	0.8538
WGT_RESID^2(-8)	-0.024905	0.084196	-0.295798	0.7678
WGT_RESID^2(-9)	0.015485	0.085681	0.180725	0.8568
WGT_RESID^2(-10)	0.034615	0.085463	0.405033	0.6861

R-squared	0.043094	Mean dependent var	1.001973
Adjusted R-squared	-0.023822	S.D. dependent var	1.445411
S.E. of regression	1.462526	Akaike info criterion	3.666957
Sum squared resid	305.8746	Schwarz criterion	3.883882
Log likelihood	-271.3557	Hannan-Quinn criter.	3.755071
F-statistic	0.644000	Durbin-Watson stat	1.851911
Prob(F-statistic)	0.774033		

Since the probability value for ARCH-LM Test for lag 1 through lag 10 is greater than 0.05, we fail to reject null hypothesis. Thus, there are no ARCH effect.

Therefore, the model GARCH (1,2) is robust for the During Crisis period and is selected for forecasting.

2.3 Period 3 (Post-Crisis) 1st May 2009 – 31st December 2009

a. ARMA Model Selection

Correlogram of MSCI_USA_RETURN

Date: 21/11/24 Time: 13:06
Sample: 1/05/2009 31/12/2009
Included observations: 175

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.087	-0.087	1.3502	0.245
		2	0.122	0.115	4.0196	0.134
		3	-0.180	-0.164	9.8657	0.020
		4	0.085	0.050	11.172	0.025
		5	-0.009	0.038	11.189	0.048
		6	0.025	-0.018	11.300	0.080
		7	-0.175	-0.163	16.922	0.018
		8	0.054	0.040	17.461	0.026
		9	-0.215	-0.191	26.102	0.002
		10	0.053	-0.034	26.629	0.003
		11	-0.099	-0.031	28.494	0.003
		12	-0.021	-0.103	28.575	0.005
		13	-0.002	0.021	28.576	0.008
		14	0.040	0.021	28.890	0.011
		15	-0.115	-0.147	31.462	0.008
		16	0.019	-0.049	31.535	0.011
		17	-0.011	0.037	31.560	0.017
		18	0.117	0.006	34.272	0.012
		19	0.031	0.034	34.468	0.016
		20	-0.025	-0.037	34.590	0.022
		21	-0.002	-0.025	34.591	0.031
		22	0.022	0.003	34.688	0.042
		23	-0.031	-0.053	34.881	0.053
		24	0.050	-0.003	35.388	0.063
		25	-0.060	-0.023	36.131	0.070
		26	-0.022	-0.056	36.228	0.088
		27	-0.018	-0.012	36.295	0.109
		28	0.001	0.012	36.295	0.135
		29	0.031	0.018	36.497	0.160

Based on the correlogram, there is a cut off on lag 1 in the AC and PAC column. Additionally, there is another cut off on lag 2. We will run ARMA (1,1), ARMA (1,2), ARMA (2,1) and ARMA (2,2) After running the models, we will compare every model and ensure all variables are significant. Then, we select based on the lowest AIC and SIC values. If there is not much difference in the values, we will select based on model which is the most parsimonious (the lower the AR and MA order, the better).

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 13:40
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 51 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001497	0.000847	1.768013	0.0788
AR(1)	-0.985253	0.013803	-71.38072	0.0000
MA(1)	0.922496	0.039874	23.13530	0.0000
SIGMASQ	0.000129	1.32E-05	9.758208	0.0000

R-squared	0.064415	Mean dependent var	0.001468
Adjusted R-squared	0.048001	S.D. dependent var	0.011753
S.E. of regression	0.011468	Akaike info criterion	-6.072311
Sum squared resid	0.022488	Schwarz criterion	-5.999973
Log likelihood	535.3272	Hannan-Quinn criter.	-6.042969
F-statistic	3.924423	Durbin-Watson stat	1.919472
Prob(F-statistic)	0.009664		

Inverted AR Roots	-.99
Inverted MA Roots	-.92

ARMA (1,1)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 13:40
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 56 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001500	0.000891	1.683844	0.0940
AR(1)	-0.929772	0.105592	-8.805350	0.0000
AR(2)	0.052357	0.094973	0.551285	0.5822
MA(1)	0.909715	0.048531	18.74502	0.0000
SIGMASQ	0.000128	1.31E-05	9.788491	0.0000

R-squared	0.066541	Mean dependent var	0.001468
Adjusted R-squared	0.044577	S.D. dependent var	0.011753
S.E. of regression	0.011488	Akaike info criterion	-6.063113
Sum squared resid	0.022436	Schwarz criterion	-5.972691
Log likelihood	535.5224	Hannan-Quinn criter.	-6.026435
F-statistic	3.029586	Durbin-Watson stat	2.003528
Prob(F-statistic)	0.019112		

Inverted AR Roots	.05	-.98
Inverted MA Roots	-.91	

ARMA (2,1)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 13:41
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 53 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001500	0.000888	1.688786	0.0931
AR(1)	-0.982928	0.016878	-58.23735	0.0000
MA(1)	0.961986	0.083547	11.51428	0.0000
MA(2)	0.048026	0.088060	0.545384	0.5862
SIGMASQ	0.000128	1.31E-05	9.770492	0.0000

R-squared	0.066505	Mean dependent var	0.001468
Adjusted R-squared	0.044540	S.D. dependent var	0.011753
S.E. of regression	0.011488	Akaike info criterion	-6.063078
Sum squared resid	0.022437	Schwarz criterion	-5.972656
Log likelihood	535.5194	Hannan-Quinn criter.	-6.026400
F-statistic	3.027809	Durbin-Watson stat	2.002236
Prob(F-statistic)	0.019167		

Inverted AR Roots	-.98	
Inverted MA Roots	-.05	-.91

ARMA (1,2)

Dependent Variable: MSCI_USA_RETURN
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 21/11/24 Time: 13:41
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 96 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001533	0.000293	5.238684	0.0000
AR(1)	-0.074053	0.054804	-1.351243	0.1784
AR(2)	0.898800	0.048014	18.71969	0.0000
MA(1)	-0.073081	18.94217	-0.003858	0.9969
MA(2)	-0.926919	297.2954	-0.003118	0.9975
SIGMASQ	0.000123	0.000924	0.132915	0.8944

R-squared	0.106234	Mean dependent var	0.001468
Adjusted R-squared	0.079792	S.D. dependent var	0.011753
S.E. of regression	0.011275	Akaike info criterion	-6.082653
Sum squared resid	0.021482	Schwarz criterion	-5.974146
Log likelihood	538.2321	Hannan-Quinn criter.	-6.038639
F-statistic	4.017523	Durbin-Watson stat	1.850379
Prob(F-statistic)	0.001805		

Inverted AR Roots	.91	-.99
Inverted MA Roots	1.00	-.93

ARMA (2,2)

Since only ARMA (1,1) with all variables significant at 10% level, we choose this model. However, to ensure this model is robust, we run it through some diagnostic tests.

b. Diagnostic Test (for ARMA)

Ljung-Box Q test

H0: No autocorrelation in squared residuals

H1: There is autocorrelation in squared residuals

Correlogram of Residuals

Date: 21/11/24 Time: 13:46
Sample: 1/05/2009 31/12/2009
Q-statistic probabilities adjusted for 2 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.037	0.037	0.2496	
		2	0.006	0.005	0.2569	
		3	-0.078	-0.078	1.3449	0.246
		4	-0.025	-0.020	1.4598	0.482
		5	0.105	0.109	3.4753	0.324
		6	-0.083	-0.098	4.7306	0.316
		7	-0.093	-0.094	6.3183	0.276
		8	-0.039	-0.012	6.6018	0.359
		9	-0.149	-0.158	10.732	0.151
		10	-0.030	-0.053	10.898	0.208
		11	-0.030	-0.014	11.067	0.271
		12	-0.103	-0.127	13.098	0.218
		13	0.072	0.056	14.092	0.228
		14	-0.024	-0.015	14.203	0.288
		15	-0.064	-0.124	14.992	0.308

At lag 10, the probability is 0.208 which is greater than 0.05, we fail to reject null hypothesis. Therefore, there is no significant autocorrelations. Thus, residuals resemble white noise.

Durbin-Watson

Durbin-Watson stat	1.919472

Durbin-Watson Stat is 1.919472 which is close to 2, which suggests no significant autocorrelation in the residuals.

White Test

H0: Homoscedasticity of residuals

H1: Heteroscedasticity of residuals

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	2.71E+23	Prob. F(14,160)	0.0000
Obs*R-squared	175.0000	Prob. Chi-Square(14)	0.0000
Scaled explained SS	189.3395	Prob. Chi-Square(14)	0.0000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:47
Sample: 1/05/2009 31/12/2009
Included observations: 175

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000129	2.72E-15	4.72E+10	0.0000
GRADF_01^2	1.08E-18	3.34E-19	3.224806	0.0015
GRADF_01*GRADF_02	1.34E-19	1.69E-19	0.794135	0.4283
GRADF_01*GRADF_03	6.46E-19	5.27E-19	1.225899	0.2220
GRADF_01*GRADF_04	-1.44E-22	2.21E-22	-0.652794	0.5148
GRADF_01	-3.87E-18	1.69E-18	-2.292571	0.0232
GRADF_02^2	8.04E-18	2.16E-18	3.723849	0.0003
GRADF_02*GRADF_03	-2.68E-17	8.95E-18	-2.994173	0.0032
GRADF_02*GRADF_04	-3.40E-22	3.22E-21	-0.105799	0.9159
GRADF_02	8.08E-18	3.25E-17	0.248501	0.8041
GRADF_03^2	1.42E-17	1.36E-17	1.046006	0.2971
GRADF_03*GRADF_04	5.68E-22	8.54E-21	0.066440	0.9471
GRADF_03	-2.84E-16	9.21E-17	-3.080372	0.0024
GRADF_04^2	-5.03E-24	4.02E-24	-1.249529	0.2133
GRADF_04	3.30E-08	7.02E-19	4.70E+10	0.0000

R-squared	1.000000	Mean dependent var	0.000129
Adjusted R-squared	1.000000	S.D. dependent var	0.000194
S.E. of regression	1.31E-15	Sum squared resid	2.76E-28
F-statistic	2.71E+23	Durbin-Watson stat	2.055356
Prob(F-statistic)	0.000000		

The probability (F-stat) is 0.0000 which is less than 0.05, thus, we reject null hypothesis. Therefore, heteroscedasticity of residuals is exhibited in the model indicating variance of residuals changes across observations. Thus, we will estimate the data using ARCH/GARCH models instead to account for this problem.

c. ARCH Model Selection

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 13:50
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 25 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.001528	0.000914	1.671112	0.0947
		Variance Equation		
C	0.000157	1.71E-05	9.173342	0.0000
RESID(-1)^2	-0.128268	0.038568	-3.325783	0.0009

R-squared	-0.000026	Mean dependent var	0.001468
Adjusted R-squared	-0.000026	S.D. dependent var	0.011753
S.E. of regression	0.011753	Akaike info criterion	-6.041005
Sum squared resid	0.024036	Schwarz criterion	-5.986751
Log likelihood	531.5879	Hannan-Quinn criter.	-6.018998
Durbin-Watson stat	2.167975		

ARCH (1)

Since ARCH (1) has all variables as statistically significant (probability < 0.01), we will choose this model first. However, diagnostic tests are needed to ensure there is no ARCH effect left that is not captured by the model and no autocorrelation of squared residuals. If there is ARCH effect left, we will increase the lag for ARCH.

d. Diagnostic Test (for ARCH)

ARCH LM Test

H0: No ARCH effect left

H1: Have residual ARCH effect

Heteroskedasticity Test: ARCH

F-statistic	0.847405	Prob. F(1,172)	0.3586
Obs*R-squared	0.853056	Prob. Chi-Square(1)	0.3557

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:55
Sample (adjusted): 4/05/2009 31/12/2009
Included observations: 174 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.934993	0.143266	6.526291	0.0000
WGT_RESID^2(-1)	0.069960	0.075998	0.920546	0.3586

R-squared	0.004903	Mean dependent var	1.005010
Adjusted R-squared	-0.000883	S.D. dependent var	1.600766
S.E. of regression	1.601472	Akaike info criterion	3.791151
Sum squared resid	441.1306	Schwarz criterion	3.827462
Log likelihood	-327.8302	Hannan-Quinn criter.	3.805881
F-statistic	0.847405	Durbin-Watson stat	1.910129
Prob(F-statistic)	0.358577		

Heteroskedasticity Test: ARCH

F-statistic	0.943910	Prob. F(2,170)	0.3911
Obs*R-squared	1.900035	Prob. Chi-Square(2)	0.3867

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:55
Sample (adjusted): 5/05/2009 31/12/2009
Included observations: 173 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.834240	0.154949	5.383970	0.0000
WGT_RESID^2(-1)	0.077224	0.073585	1.049450	0.2955
WGT_RESID^2(-2)	0.059726	0.073603	0.811462	0.4182

R-squared	0.010983	Mean dependent var	0.972035
Adjusted R-squared	-0.000653	S.D. dependent var	1.545008
S.E. of regression	1.545512	Akaike info criterion	3.725776
Sum squared resid	406.0632	Schwarz criterion	3.780458
Log likelihood	-319.2797	Hannan-Quinn criter.	3.747960
F-statistic	0.943910	Durbin-Watson stat	2.021856
Prob(F-statistic)	0.391133		

Heteroskedasticity Test: ARCH

F-statistic	2.468799	Prob. F(3,168)	0.0638
Obs*R-squared	7.262564	Prob. Chi-Square(3)	0.0640

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:55
Sample (adjusted): 6/05/2009 31/12/2009
Included observations: 172 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.681824	0.166613	4.092259	0.0001
WGT_RESID^2(-1)	0.066289	0.075910	0.873261	0.3838
WGT_RESID^2(-2)	0.048942	0.073138	0.669176	0.5043
WGT_RESID^2(-3)	0.171953	0.073054	2.353764	0.0197

R-squared	0.042224	Mean dependent var	0.969845
Adjusted R-squared	0.025121	S.D. dependent var	1.549249
S.E. of regression	1.529666	Akaike info criterion	3.710957
Sum squared resid	393.0996	Schwarz criterion	3.784155
Log likelihood	-315.1423	Hannan-Quinn criter.	3.740655
F-statistic	2.468799	Durbin-Watson stat	2.013009
Prob(F-statistic)	0.063794		

Heteroskedasticity Test: ARCH

F-statistic	1.878981	Prob. F(4,166)	0.1164
Obs*R-squared	7.406944	Prob. Chi-Square(4)	0.1159

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:56
Sample (adjusted): 7/05/2009 31/12/2009
Included observations: 171 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.656709	0.176508	3.720564	0.0003
WGT_RESID^2(-1)	0.059601	0.077552	0.768524	0.4433
WGT_RESID^2(-2)	0.042574	0.076541	0.556224	0.5788
WGT_RESID^2(-3)	0.171184	0.073670	2.323646	0.0214
WGT_RESID^2(-4)	0.036072	0.074703	0.482881	0.6298

R-squared	0.043315	Mean dependent var	0.967060
Adjusted R-squared	0.020263	S.D. dependent var	1.553367
S.E. of regression	1.537549	Akaike info criterion	3.727060
Sum squared resid	392.4335	Schwarz criterion	3.818922
Log likelihood	-313.6636	Hannan-Quinn criter.	3.764334
F-statistic	1.878981	Durbin-Watson stat	2.007037
Prob(F-statistic)	0.116442		

Heteroskedasticity Test: ARCH

F-statistic	1.773872	Prob. F(5,164)	0.1209
Obs*R-squared	8.722142	Prob. Chi-Square(5)	0.1207

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:56
Sample (adjusted): 8/05/2009 31/12/2009
Included observations: 170 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.586373	0.184955	3.170349	0.0018
WGT_RESID^2(-1)	0.055968	0.077698	0.720324	0.4724
WGT_RESID^2(-2)	0.025089	0.077816	0.322419	0.7475
WGT_RESID^2(-3)	0.169054	0.076744	2.202846	0.0290
WGT_RESID^2(-4)	0.031583	0.075000	0.421105	0.6742
WGT_RESID^2(-5)	0.096222	0.074880	1.285015	0.2006

R-squared	0.051307	Mean dependent var	0.962169
Adjusted R-squared	0.022383	S.D. dependent var	1.556635
S.E. of regression	1.539115	Akaike info criterion	3.734949
Sum squared resid	388.4957	Schwarz criterion	3.845624
Log likelihood	-311.4707	Hannan-Quinn criter.	3.779860
F-statistic	1.773872	Durbin-Watson stat	1.983870
Prob(F-statistic)	0.120933		

Heteroskedasticity Test: ARCH

F-statistic	1.487837	Prob. F(6,162)	0.1854
Obs*R-squared	8.826382	Prob. Chi-Square(6)	0.1836

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:56
Sample (adjusted): 11/05/2009 31/12/2009
Included observations: 169 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.579098	0.190621	3.037949	0.0028
WGT_RESID^2(-1)	0.053692	0.077642	0.691534	0.4902
WGT_RESID^2(-2)	0.021380	0.077415	0.276175	0.7828
WGT_RESID^2(-3)	0.163282	0.077428	2.108816	0.0365
WGT_RESID^2(-4)	-0.009687	0.077485	-0.125016	0.9007
WGT_RESID^2(-5)	0.104219	0.074651	1.396088	0.1646
WGT_RESID^2(-6)	0.033662	0.074861	0.449658	0.6536

R-squared	0.052227	Mean dependent var	0.944208
Adjusted R-squared	0.017124	S.D. dependent var	1.543492
S.E. of regression	1.530219	Akaike info criterion	3.729237
Sum squared resid	379.3346	Schwarz criterion	3.858878
Log likelihood	-308.1205	Hannan-Quinn criter.	3.781848
F-statistic	1.487837	Durbin-Watson stat	2.028716
Prob(F-statistic)	0.185374		

Heteroskedasticity Test: ARCH

F-statistic	1.127172	Prob. F(7,160)	0.3486
Obs*R-squared	7.895367	Prob. Chi-Square(7)	0.3419

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:57
Sample (adjusted): 12/05/2009 31/12/2009
Included observations: 168 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.570772	0.193667	2.947185	0.0037
WGT_RESID^2(-1)	0.020127	0.077126	0.260963	0.7945
WGT_RESID^2(-2)	0.017441	0.076358	0.228403	0.8196
WGT_RESID^2(-3)	0.158217	0.076040	2.080698	0.0391
WGT_RESID^2(-4)	-0.016547	0.077084	-0.214667	0.8303
WGT_RESID^2(-5)	0.047630	0.076102	0.625874	0.5323
WGT_RESID^2(-6)	0.047040	0.073751	0.637822	0.5245
WGT_RESID^2(-7)	0.072829	0.073567	0.989968	0.3237

R-squared	0.046996	Mean dependent var	0.916707
Adjusted R-squared	0.005302	S.D. dependent var	1.506006
S.E. of regression	1.502008	Akaike info criterion	3.697931
Sum squared resid	360.9645	Schwarz criterion	3.846691
Log likelihood	-302.6262	Hannan-Quinn criter.	3.758305
F-statistic	1.127172	Durbin-Watson stat	1.967489
Prob(F-statistic)	0.348631		

Heteroskedasticity Test: ARCH

F-statistic	1.064724	Prob. F(8,158)	0.3906
Obs*R-squared	8.542454	Prob. Chi-Square(8)	0.3823

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:57
Sample (adjusted): 13/05/2009 31/12/2009
Included observations: 167 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.534192	0.200933	2.658557	0.0087
WGT_RESID^2(-1)	0.033816	0.079316	0.426352	0.6704
WGT_RESID^2(-2)	0.027107	0.077421	0.350122	0.7267
WGT_RESID^2(-3)	0.154536	0.076640	2.016376	0.0455
WGT_RESID^2(-4)	-0.018351	0.077351	-0.237236	0.8128
WGT_RESID^2(-5)	0.042179	0.077368	0.545171	0.5864
WGT_RESID^2(-6)	0.064973	0.076473	0.849609	0.3968
WGT_RESID^2(-7)	0.066034	0.074115	0.890962	0.3743
WGT_RESID^2(-8)	0.021788	0.074064	0.294179	0.7690

R-squared	0.051152	Mean dependent var	0.921751
Adjusted R-squared	0.003110	S.D. dependent var	1.509111
S.E. of regression	1.506763	Akaike info criterion	3.710190
Sum squared resid	358.7130	Schwarz criterion	3.878226
Log likelihood	-300.8009	Hannan-Quinn criter.	3.778392
F-statistic	1.064724	Durbin-Watson stat	1.936272
Prob(F-statistic)	0.390594		

Heteroskedasticity Test: ARCH

F-statistic	0.724347	Prob. F(9,156)	0.6861
Obs*R-squared	6.658749	Prob. Chi-Square(9)	0.6726

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:57
Sample (adjusted): 14/05/2009 31/12/2009
Included observations: 166 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.607897	0.204053	2.979113	0.0034
WGT_RESID^2(-1)	0.049440	0.078484	0.629934	0.5297
WGT_RESID^2(-2)	-0.010437	0.078322	-0.133256	0.8942
WGT_RESID^2(-3)	0.128483	0.076430	1.681068	0.0948
WGT_RESID^2(-4)	-0.013506	0.076607	-0.176299	0.8603
WGT_RESID^2(-5)	0.046669	0.076341	0.611321	0.5419
WGT_RESID^2(-6)	0.074633	0.076420	0.976611	0.3303
WGT_RESID^2(-7)	0.018484	0.075651	0.244330	0.8073
WGT_RESID^2(-8)	0.037528	0.073325	0.511807	0.6095
WGT_RESID^2(-9)	-0.034978	0.073079	-0.478632	0.6329

R-squared	0.040113	Mean dependent var	0.895539
Adjusted R-squared	-0.015265	S.D. dependent var	1.475055
S.E. of regression	1.486271	Akaike info criterion	3.688767
Sum squared resid	344.6041	Schwarz criterion	3.876237
Log likelihood	-296.1677	Hannan-Quinn criter.	3.764862
F-statistic	0.724347	Durbin-Watson stat	1.981193
Prob(F-statistic)	0.686071		

Heteroskedasticity Test: ARCH

F-statistic	0.752238	Prob. F(10,154)	0.6743
Obs*R-squared	7.684337	Prob. Chi-Square(10)	0.6596

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 13:58
Sample (adjusted): 15/05/2009 31/12/2009
Included observations: 165 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.549110	0.211911	2.591236	0.0105
WGT_RESID^2(-1)	0.058375	0.080277	0.727167	0.4682
WGT_RESID^2(-2)	-0.014879	0.078823	-0.188760	0.8505
WGT_RESID^2(-3)	0.128365	0.078562	1.633928	0.1043
WGT_RESID^2(-4)	-0.013103	0.077361	-0.169368	0.8657
WGT_RESID^2(-5)	0.039592	0.076836	0.515281	0.6071
WGT_RESID^2(-6)	0.072523	0.076661	0.946022	0.3456
WGT_RESID^2(-7)	0.004829	0.076886	0.062802	0.9500
WGT_RESID^2(-8)	0.043187	0.075901	0.568988	0.5702
WGT_RESID^2(-9)	-0.039331	0.073577	-0.534565	0.5937
WGT_RESID^2(-10)	0.075506	0.073340	1.029528	0.3048

R-squared	0.046572	Mean dependent var	0.891926
Adjusted R-squared	-0.015339	S.D. dependent var	1.478808
S.E. of regression	1.490107	Akaike info criterion	3.699913
Sum squared resid	341.9445	Schwarz criterion	3.906976
Log likelihood	-294.2428	Hannan-Quinn criter.	3.783967
F-statistic	0.752238	Durbin-Watson stat	1.996367
Prob(F-statistic)	0.674326		

Since the probability value for ARCH-LM Test for lag 1 through lag 10 is greater than 0.05, we fail to reject null hypothesis. Thus, there are no ARCH effect.

Ljung-Box Q Test

H0: No autocorrelation in squared residuals

H1: There is autocorrelation in squared residuals

Correlogram of Standardized Residuals

Date: 21/11/24 Time: 14:01
Sample: 1/05/2009 31/12/2009
Included observations: 175

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.134	-0.134	3.2053	0.073
		2	0.146	0.131	7.0446	0.030
		3	-0.191	-0.162	13.597	0.004
		4	0.107	0.054	15.679	0.003
		5	-0.020	0.042	15.754	0.008
		6	0.024	-0.025	15.859	0.015
		7	-0.175	-0.161	21.512	0.003
		8	0.065	0.038	22.300	0.004
		9	-0.218	-0.191	31.172	0.000
		10	0.063	-0.040	31.919	0.000
		11	-0.105	-0.024	33.987	0.000
		12	0.007	-0.083	33.995	0.001
		13	-0.005	0.023	34.001	0.001
		14	0.042	0.024	34.346	0.002
		15	-0.115	-0.140	36.922	0.001
		16	0.029	-0.048	37.089	0.002
		17	-0.013	0.036	37.123	0.003
		18	0.109	0.001	39.479	0.002
		19	0.018	0.038	39.547	0.004
		20	-0.011	-0.019	39.573	0.006
		21	0.014	0.036	39.615	0.008

At lag 10, the probability is 0.000 which is less than 0.05, we reject null hypothesis. Therefore, there is significant autocorrelations. Thus, residuals do not resemble white noise, and we must re-specify the model.

e. Re-Selection of ARCH Model

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 14:06
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 87 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.001340	0.000925	1.447769	0.1477
Variance Equation				
C	0.000141	1.92E-05	7.309011	0.0000
RESID(-1)^2	-0.114170	0.037252	-3.064831	0.0022
RESID(-2)^2	0.104786	0.083100	1.260962	0.2073

R-squared	-0.000119	Mean dependent var	0.001468
Adjusted R-squared	-0.000119	S.D. dependent var	0.011753
S.E. of regression	0.011754	Akaike info criterion	-6.037398
Sum squared resid	0.024039	Schwarz criterion	-5.965060
Log likelihood	532.2723	Hannan-Quinn criter.	-6.008056
Durbin-Watson stat	2.167774		

ARCH (2)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 14:06
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 10 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.001482	0.000635	2.335387	0.0195
Variance Equation				
C	0.000121	1.63E-05	7.410613	0.0000
RESID(-1)^2	-0.122167	0.023159	-5.275032	0.0000
RESID(-2)^2	0.107216	0.070144	1.528516	0.1264
RESID(-3)^2	0.108818	0.085253	1.276422	0.2018

R-squared	-0.000002	Mean dependent var	0.001468
Adjusted R-squared	-0.000002	S.D. dependent var	0.011753
S.E. of regression	0.011753	Akaike info criterion	-6.065124
Sum squared resid	0.024036	Schwarz criterion	-5.974702
Log likelihood	535.6983	Hannan-Quinn criter.	-6.028446
Durbin-Watson stat	2.168029		

ARCH (3)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 14:07
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 96 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2 + C(6)*RESID(-4)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.001409	0.000744	1.893396	0.0583
Variance Equation				
C	9.93E-05	1.83E-05	5.425876	0.0000
RESID(-1)^2	-0.105182	0.028426	-3.700271	0.0002
RESID(-2)^2	0.104333	0.070204	1.486151	0.1372
RESID(-3)^2	0.185654	0.109651	1.693134	0.0904
RESID(-4)^2	0.078896	0.067503	1.168777	0.2425

R-squared	-0.000025	Mean dependent var	0.001468
Adjusted R-squared	-0.000025	S.D. dependent var	0.011753
S.E. of regression	0.011753	Akaike info criterion	-6.061644
Sum squared resid	0.024036	Schwarz criterion	-5.953137
Log likelihood	536.3938	Hannan-Quinn criter.	-6.017630
Durbin-Watson stat	2.167978		

ARCH (4)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 14:07
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 20 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*RESID(-3)^2 + C(6)*RESID(-4)^2 + C(7)*RESID(-5)^2

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.001506	0.000803	1.875878	0.0607
Variance Equation				
C	9.78E-05	1.76E-05	5.570467	0.0000
RESID(-1)^2	-0.112145	0.023702	-4.731419	0.0000
RESID(-2)^2	0.086079	0.066329	1.297748	0.1944
RESID(-3)^2	0.153495	0.104248	1.472405	0.1409
RESID(-4)^2	0.068923	0.059468	1.158994	0.2465
RESID(-5)^2	0.051345	0.053325	0.962877	0.3356

R-squared	-0.000011	Mean dependent var	0.001468
Adjusted R-squared	-0.000011	S.D. dependent var	0.011753
S.E. of regression	0.011753	Akaike info criterion	-6.052470
Sum squared resid	0.024036	Schwarz criterion	-5.925878
Log likelihood	536.5911	Hannan-Quinn criter.	-6.001121
Durbin-Watson stat	2.168010		

ARCH (5)

Even after estimating ARCH (5), the ARCH models' parameters are still not significant. The lack of significance suggests the ARCH model may not be capturing the underlying volatility structure effectively. As a result, we switch to GARCH model. GARCH model not only account for past squared residuals but also include past conditional variances.

f. GARCH Model Selection

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 14:08
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 21 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.001582	0.000767	2.063842	0.0390
		Variance Equation		
C	1.18E-06	1.06E-06	1.116226	0.2643
RESID(-1)^2	-0.054941	0.023416	-2.346328	0.0190
GARCH(-1)	1.035080	0.022452	46.10191	0.0000

R-squared	-0.000095	Mean dependent var	0.001468
Adjusted R-squared	-0.000095	S.D. dependent var	0.011753
S.E. of regression	0.011754	Akaike info criterion	-6.176629
Sum squared resid	0.024038	Schwarz criterion	-6.104291
Log likelihood	544.4551	Hannan-Quinn criter.	-6.147287
Durbin-Watson stat	2.167826		

GARCH (1,1)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 14:09
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 19 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1) + C(5)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.001701	0.000800	2.127375	0.0334
Variance Equation				
C	1.21E-06	1.79E-06	0.678236	0.4976
RESID(-1)^2	-0.069310	0.067991	-1.019396	0.3080
GARCH(-1)	0.755843	1.133253	0.666968	0.5048
GARCH(-2)	0.289628	1.172049	0.247113	0.8048

R-squared	-0.000396	Mean dependent var	0.001468
Adjusted R-squared	-0.000396	S.D. dependent var	0.011753
S.E. of regression	0.011755	Akaike info criterion	-6.172243
Sum squared resid	0.024045	Schwarz criterion	-6.081821
Log likelihood	545.0713	Hannan-Quinn criter.	-6.135565
Durbin-Watson stat	2.167173		

GARCH (1,2)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 14:09
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 15 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.001127	0.000842	1.339249	0.1805
Variance Equation				
C	1.19E-05	6.64E-06	1.793128	0.0730
RESID(-1)^2	-0.134114	0.025512	-5.256847	0.0000
RESID(-2)^2	0.173931	0.045802	3.797446	0.0001
GARCH(-1)	0.859924	0.062209	13.82317	0.0000

R-squared	-0.000845	Mean dependent var	0.001468
Adjusted R-squared	-0.000845	S.D. dependent var	0.011753
S.E. of regression	0.011758	Akaike info criterion	-6.095726
Sum squared resid	0.024056	Schwarz criterion	-6.005304
Log likelihood	538.3761	Hannan-Quinn criter.	-6.059049
Durbin-Watson stat	2.166203		

GARCH (2,1)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 14:10
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 10 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*GARCH(-1) + C(6)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.001301	0.000850	1.530352	0.1259
Variance Equation				
C	9.79E-06	3.99E-06	2.453210	0.0142
RESID(-1)^2	-0.137246	0.023072	-5.948602	0.0000
RESID(-2)^2	0.173471	0.048362	3.586911	0.0003
GARCH(-1)	0.726039	0.338721	2.143470	0.0321
GARCH(-2)	0.152128	0.351523	0.432770	0.6652

R-squared	-0.000203	Mean dependent var	0.001468
Adjusted R-squared	-0.000203	S.D. dependent var	0.011753
S.E. of regression	0.011754	Akaike info criterion	-6.085858
Sum squared resid	0.024041	Schwarz criterion	-5.977351
Log likelihood	538.5126	Hannan-Quinn criter.	-6.041845
Durbin-Watson stat	2.167593		

GARCH (2,2)

We select GARCH (2,1) for our model as all its variables are significant at 10% level (probability < 0.1). Other models' parameters are not statistically significant at any level.

g. Diagnostic Test

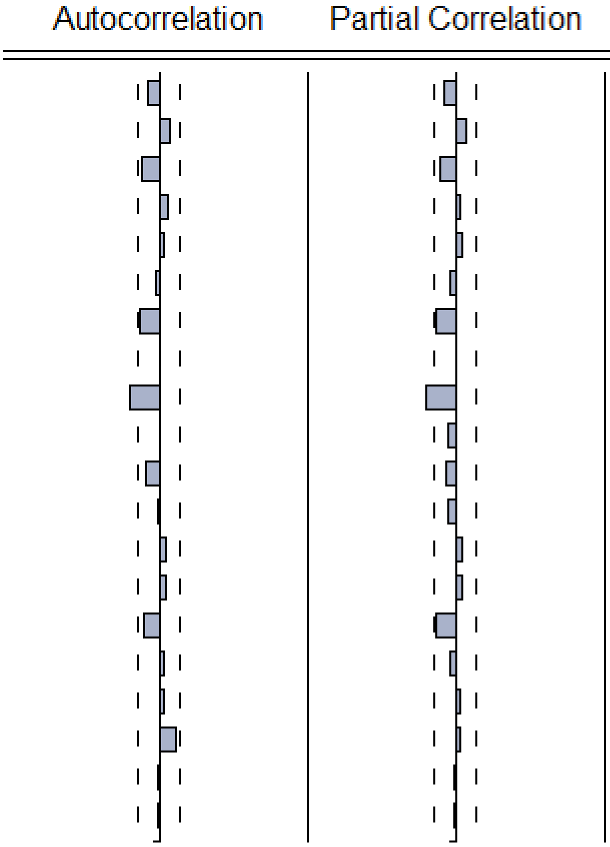
Ljung-Box Q Test

H0: No autocorrelation in squared residuals

H1: There is autocorrelation in squared residuals

Correlogram of Standardized Residuals

Date: 21/11/24 Time: 21:10
Sample: 1/05/2009 31/12/2009
Included observations: 175



Lag	AC	PAC	Q-Stat	Prob*
1	-0.081	-0.081	1.1675	0.280
2	0.080	0.074	2.3136	0.314
3	-0.120	-0.109	4.9116	0.178
4	0.059	0.037	5.5334	0.237
5	0.030	0.054	5.7001	0.336
6	-0.022	-0.037	5.7865	0.448
7	-0.132	-0.135	8.9944	0.253
8	0.008	0.003	9.0065	0.342
9	-0.203	-0.203	16.709	0.053
10	0.007	-0.055	16.717	0.081
11	-0.093	-0.060	18.359	0.074
12	-0.003	-0.054	18.360	0.105
13	0.042	0.051	18.693	0.133
14	0.042	0.044	19.028	0.164
15	-0.099	-0.125	20.911	0.140
16	0.025	-0.029	21.032	0.177
17	0.025	0.032	21.153	0.220
18	0.119	0.026	23.941	0.157
19	-0.005	-0.004	23.945	0.198
20	-0.008	-0.013	23.957	0.244

At lag 10, the probability is 0.081 which is more than 0.05, therefore, we fail to reject null hypothesis. Thus, the is no significant autocorrelation in squared residuals.

ARCH-LM Test

H0: No ARCH effect left

H1: Have residual ARCH effect

Heteroskedasticity Test: ARCH

F-statistic	2.365419	Prob. F(1,172)	0.1259
Obs*R-squared	2.360462	Prob. Chi-Square(1)	0.1244

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 21:12
Sample (adjusted): 4/05/2009 31/12/2009
Included observations: 174 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.895488	0.141117	6.345708	0.0000
WGT_RESID^2(-1)	0.116361	0.075658	1.537992	0.1259

R-squared	0.013566	Mean dependent var	1.012466
Adjusted R-squared	0.007831	S.D. dependent var	1.574125
S.E. of regression	1.567950	Akaike info criterion	3.748843
Sum squared resid	422.8564	Schwarz criterion	3.785154
Log likelihood	-324.1493	Hannan-Quinn criter.	3.763573
F-statistic	2.365419	Durbin-Watson stat	1.968087
Prob(F-statistic)	0.125888		

Heteroskedasticity Test: ARCH

F-statistic	1.444638	Prob. F(2,170)	0.2387
Obs*R-squared	2.891126	Prob. Chi-Square(2)	0.2356

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 21:13
Sample (adjusted): 5/05/2009 31/12/2009
Included observations: 173 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.916114	0.157026	5.834144	0.0000
WGT_RESID^2(-1)	0.126349	0.076190	1.658339	0.0991
WGT_RESID^2(-2)	-0.043054	0.076198	-0.565024	0.5728

R-squared	0.016712	Mean dependent var	1.000296
Adjusted R-squared	0.005144	S.D. dependent var	1.570464
S.E. of regression	1.566420	Akaike info criterion	3.752651
Sum squared resid	417.1240	Schwarz criterion	3.807333
Log likelihood	-321.6043	Hannan-Quinn criter.	3.774835
F-statistic	1.444638	Durbin-Watson stat	1.980346
Prob(F-statistic)	0.238712		

Heteroskedasticity Test: ARCH

F-statistic	1.158508	Prob. F(3,168)	0.3273
Obs*R-squared	3.486155	Prob. Chi-Square(3)	0.3226

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 21:13
Sample (adjusted): 6/05/2009 31/12/2009
Included observations: 172 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.877592	0.173183	5.067430	0.0000
WGT_RESID^2(-1)	0.134405	0.076962	1.746376	0.0826
WGT_RESID^2(-2)	-0.051833	0.077136	-0.671970	0.5025
WGT_RESID^2(-3)	0.045300	0.076579	0.591544	0.5550

R-squared	0.020268	Mean dependent var	1.005155
Adjusted R-squared	0.002773	S.D. dependent var	1.573744
S.E. of regression	1.571561	Akaike info criterion	3.764996
Sum squared resid	414.9268	Schwarz criterion	3.838194
Log likelihood	-319.7897	Hannan-Quinn criter.	3.794694
F-statistic	1.158508	Durbin-Watson stat	1.999246
Prob(F-statistic)	0.327271		

Heteroskedasticity Test: ARCH

F-statistic	0.850655	Prob. F(4,166)	0.4950
Obs*R-squared	3.434703	Prob. Chi-Square(4)	0.4879

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 21:13
Sample (adjusted): 7/05/2009 31/12/2009
Included observations: 171 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.883565	0.187891	4.702539	0.0000
WGT_RESID^2(-1)	0.134565	0.077631	1.733407	0.0849
WGT_RESID^2(-2)	-0.051880	0.078210	-0.663342	0.5080
WGT_RESID^2(-3)	0.045915	0.077745	0.590587	0.5556
WGT_RESID^2(-4)	-0.006295	0.077204	-0.081531	0.9351

R-squared	0.020086	Mean dependent var	1.006982
Adjusted R-squared	-0.003526	S.D. dependent var	1.578183
S.E. of regression	1.580963	Akaike info criterion	3.782749
Sum squared resid	414.9079	Schwarz criterion	3.874611
Log likelihood	-318.4251	Hannan-Quinn criter.	3.820023
F-statistic	0.850655	Durbin-Watson stat	1.999255
Prob(F-statistic)	0.495047		

Heteroskedasticity Test: ARCH

F-statistic	0.681914	Prob. F(5,164)	0.6378
Obs*R-squared	3.462327	Prob. Chi-Square(5)	0.6291

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 21:13
Sample (adjusted): 8/05/2009 31/12/2009
Included observations: 170 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.874361	0.202274	4.322651	0.0000
WGT_RESID^2(-1)	0.134597	0.078089	1.723638	0.0867
WGT_RESID^2(-2)	-0.053309	0.078873	-0.675892	0.5001
WGT_RESID^2(-3)	0.048341	0.078822	0.613295	0.5405
WGT_RESID^2(-4)	-0.008692	0.078354	-0.110933	0.9118
WGT_RESID^2(-5)	0.012128	0.077733	0.156021	0.8762

R-squared	0.020367	Mean dependent var	1.008212
Adjusted R-squared	-0.009500	S.D. dependent var	1.582763
S.E. of regression	1.590264	Akaike info criterion	3.800333
Sum squared resid	414.7460	Schwarz criterion	3.911008
Log likelihood	-317.0283	Hannan-Quinn criter.	3.845244
F-statistic	0.681914	Durbin-Watson stat	1.994652
Prob(F-statistic)	0.637761		

Heteroskedasticity Test: ARCH

F-statistic	0.578697	Prob. F(6,162)	0.7469
Obs*R-squared	3.546210	Prob. Chi-Square(6)	0.7378

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 21:14
Sample (adjusted): 11/05/2009 31/12/2009
Included observations: 169 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.875881	0.215778	4.059186	0.0001
WGT_RESID^2(-1)	0.135575	0.078462	1.727899	0.0859
WGT_RESID^2(-2)	-0.053376	0.079237	-0.673618	0.5015
WGT_RESID^2(-3)	0.051945	0.079388	0.654318	0.5138
WGT_RESID^2(-4)	-0.015580	0.079347	-0.196358	0.8446
WGT_RESID^2(-5)	0.016695	0.078776	0.211929	0.8324
WGT_RESID^2(-6)	-0.010030	0.078151	-0.128338	0.8980

R-squared	0.020983	Mean dependent var	1.002151
Adjusted R-squared	-0.015276	S.D. dependent var	1.585487
S.E. of regression	1.597552	Akaike info criterion	3.815359
Sum squared resid	413.4517	Schwarz criterion	3.945000
Log likelihood	-315.3979	Hannan-Quinn criter.	3.867970
F-statistic	0.578697	Durbin-Watson stat	2.002563
Prob(F-statistic)	0.746939		

Heteroskedasticity Test: ARCH

F-statistic	0.465256	Prob. F(7,160)	0.8585
Obs*R-squared	3.351417	Prob. Chi-Square(7)	0.8507

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 21:14
Sample (adjusted): 12/05/2009 31/12/2009
Included observations: 168 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.866912	0.229083	3.784266	0.0002
WGT_RESID^2(-1)	0.132203	0.078923	1.675084	0.0959
WGT_RESID^2(-2)	-0.051985	0.079605	-0.653042	0.5147
WGT_RESID^2(-3)	0.051842	0.079735	0.650180	0.5165
WGT_RESID^2(-4)	-0.011997	0.079904	-0.150138	0.8808
WGT_RESID^2(-5)	0.009752	0.079763	0.122267	0.9028
WGT_RESID^2(-6)	-0.006552	0.079169	-0.082755	0.9341
WGT_RESID^2(-7)	0.003352	0.078571	0.042660	0.9660

R-squared	0.019949	Mean dependent var	0.993636
Adjusted R-squared	-0.022928	S.D. dependent var	1.586346
S.E. of regression	1.604429	Akaike info criterion	3.829861
Sum squared resid	411.8709	Schwarz criterion	3.978621
Log likelihood	-313.7083	Hannan-Quinn criter.	3.890235
F-statistic	0.465256	Durbin-Watson stat	1.990025
Prob(F-statistic)	0.858536		

Heteroskedasticity Test: ARCH

F-statistic	0.417258	Prob. F(8,158)	0.9094
Obs*R-squared	3.455205	Prob. Chi-Square(8)	0.9026

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 21:14
Sample (adjusted): 13/05/2009 31/12/2009
Included observations: 167 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.879640	0.242202	3.631838	0.0004
WGT_RESID^2(-1)	0.135576	0.079455	1.706336	0.0899
WGT_RESID^2(-2)	-0.049617	0.080077	-0.619621	0.5364
WGT_RESID^2(-3)	0.050882	0.080138	0.634926	0.5264
WGT_RESID^2(-4)	-0.012204	0.080293	-0.151992	0.8794
WGT_RESID^2(-5)	0.007000	0.080353	0.087115	0.9307
WGT_RESID^2(-6)	-0.001049	0.080196	-0.013077	0.9896
WGT_RESID^2(-7)	0.001253	0.079614	0.015740	0.9875
WGT_RESID^2(-8)	-0.010965	0.079022	-0.138765	0.8898

R-squared	0.020690	Mean dependent var	0.999448
Adjusted R-squared	-0.028895	S.D. dependent var	1.589322
S.E. of regression	1.612121	Akaike info criterion	3.845364
Sum squared resid	410.6315	Schwarz criterion	4.013400
Log likelihood	-312.0879	Hannan-Quinn criter.	3.913566
F-statistic	0.417258	Durbin-Watson stat	1.981234
Prob(F-statistic)	0.909368		

Heteroskedasticity Test: ARCH

F-statistic	0.597199	Prob. F(9,156)	0.7980
Obs*R-squared	5.528836	Prob. Chi-Square(9)	0.7860

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 21:15
Sample (adjusted): 14/05/2009 31/12/2009
Included observations: 166 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.971435	0.252944	3.840519	0.0002
WGT_RESID^2(-1)	0.139846	0.079230	1.765057	0.0795
WGT_RESID^2(-2)	-0.055994	0.079919	-0.700636	0.4846
WGT_RESID^2(-3)	0.045193	0.079872	0.565820	0.5723
WGT_RESID^2(-4)	-0.009289	0.079963	-0.116168	0.9077
WGT_RESID^2(-5)	0.005795	0.080013	0.072430	0.9424
WGT_RESID^2(-6)	0.009233	0.080054	0.115332	0.9083
WGT_RESID^2(-7)	-0.016323	0.079914	-0.204258	0.8384
WGT_RESID^2(-8)	0.007146	0.079339	0.090069	0.9283
WGT_RESID^2(-9)	-0.104360	0.078688	-1.326246	0.1867

R-squared	0.033306	Mean dependent var	0.988176
Adjusted R-squared	-0.022465	S.D. dependent var	1.587422
S.E. of regression	1.605153	Akaike info criterion	3.842665
Sum squared resid	401.9366	Schwarz criterion	4.030135
Log likelihood	-308.9412	Hannan-Quinn criter.	3.918760
F-statistic	0.597199	Durbin-Watson stat	1.988583
Prob(F-statistic)	0.797970		

Heteroskedasticity Test: ARCH

F-statistic	0.558433	Prob. F(10,154)	0.8456
Obs*R-squared	5.773842	Prob. Chi-Square(10)	0.8339

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 21/11/24 Time: 21:15
Sample (adjusted): 15/05/2009 31/12/2009
Included observations: 165 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.972809	0.268260	3.626365	0.0004
WGT_RESID^2(-1)	0.144369	0.080509	1.793215	0.0749
WGT_RESID^2(-2)	-0.059108	0.080532	-0.733970	0.4641
WGT_RESID^2(-3)	0.048594	0.080520	0.603509	0.5471
WGT_RESID^2(-4)	-0.007534	0.080456	-0.093638	0.9255
WGT_RESID^2(-5)	0.005053	0.080458	0.062808	0.9500
WGT_RESID^2(-6)	0.009089	0.080493	0.112920	0.9102
WGT_RESID^2(-7)	-0.019010	0.080549	-0.236002	0.8137
WGT_RESID^2(-8)	0.012312	0.080430	0.153071	0.8785
WGT_RESID^2(-9)	-0.107045	0.079770	-1.341918	0.1816
WGT_RESID^2(-10)	-0.001173	0.079607	-0.014734	0.9883

R-squared	0.034993	Mean dependent var	0.990664
Adjusted R-squared	-0.027670	S.D. dependent var	1.591929
S.E. of regression	1.613803	Akaike info criterion	3.859405
Sum squared resid	401.0716	Schwarz criterion	4.066468
Log likelihood	-307.4009	Hannan-Quinn criter.	3.943459
F-statistic	0.558433	Durbin-Watson stat	1.999420
Prob(F-statistic)	0.845597		

Since the probability value for ARCH-LM Test for lag 1 through lag 10 is greater than 0.05, we fail to reject null hypothesis. Thus, there are no ARCH effect.

3. Model Interpretation

Pre-Crisis: GARCH (2,2)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 21:17
Sample: 2/07/2007 12/09/2008
Included observations: 315
Convergence achieved after 11 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*GARCH(-1) + C(6)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000198	0.000646	-0.306699	0.7591
Variance Equation				
C	9.60E-06	2.46E-06	3.904371	0.0001
RESID(-1)^2	-0.111946	0.014013	-7.988639	0.0000
RESID(-2)^2	0.145294	0.018098	8.028196	0.0000
GARCH(-1)	1.753671	0.060010	29.22309	0.0000
GARCH(-2)	-0.844167	0.058374	-14.46138	0.0000

R-squared	-0.000506	Mean dependent var	-0.000484
Adjusted R-squared	-0.000506	S.D. dependent var	0.012742
S.E. of regression	0.012745	Akaike info criterion	-5.910813
Sum squared resid	0.051004	Schwarz criterion	-5.839336
Log likelihood	936.9531	Hannan-Quinn criter.	-5.882255
Durbin-Watson stat	2.352580		

The mean equation shows no strong evidence of significant mean return in MSCI USA Return during this period.

The small positive constant (c) shows a low baseline level of market volatility during the period (pre-crisis).

The value for the previous squared residuals is negative (which should is not supposed to be as theoretically not valid in standard GARCH model, violating assumption of positive conditional variance). This may be caused by model misspecification (ARCH/GARCH models could not capture the pattern in data), data irregularities (outliers) or instability.

The second lag of squared residuals indicate that past shock from two period ago contribute to the current volatility. The coefficient of 0.145 suggest that if there was a shock in two period ago, its squared value is scaled by 0.145 to affect the current variance.

The GARCH coefficient of 1.753 suggest strong persistence in volatility, where high past volatility leads to high future volatility.

The GARCH (-2) is negative and significant which either suggest overfitting or unusual volatility dynamics. It suggests shocks from two period ago affects current volatility negatively.

During Crisis: GARCH (1,2)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 21:18
Sample: 15/09/2008 30/04/2009
Included observations: 164
Convergence achieved after 132 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1) + C(5)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.000101	0.001954	-0.051646	0.9588
Variance Equation				
C	1.60E-05	5.28E-06	3.032963	0.0024
RESID(-1)^2	0.043969	0.013172	3.338061	0.0008
GARCH(-1)	1.815922	0.027538	65.94166	0.0000
GARCH(-2)	-0.870176	0.023012	-37.81451	0.0000

R-squared	-0.002045	Mean dependent var	-0.001618
Adjusted R-squared	-0.002045	S.D. dependent var	0.033655
S.E. of regression	0.033689	Akaike info criterion	-4.085840
Sum squared resid	0.184998	Schwarz criterion	-3.991332
Log likelihood	340.0389	Hannan-Quinn criter.	-4.047474
Durbin-Watson stat	2.271717		

The mean equation shows no strong evidence of significant mean return in MSCI USA Return during this period.

The small positive constant (c) shows a low baseline level of market volatility during the period (pre-crisis).

The value for the previous squared residuals is 0.044 indicates that past shock still affects current volatility but to a smaller degree than pure ARCH model. If there was a shock in past period, its squared value is scaled by 0.044 to affect the current variance.

The GARCH coefficient of 1.816 suggest strong persistence in volatility, where high past volatility leads to high future volatility.

The GARCH (-2) is negative and significant which either suggest overfitting or unusual volatility dynamics. It suggests shocks from two period ago affects current volatility negatively.

Post-Crisis: GARCH (2,1)

Dependent Variable: MSCI_USA_RETURN
Method: ML ARCH - Normal distribution (Marquardt / EViews legacy)
Date: 21/11/24 Time: 21:15
Sample: 1/05/2009 31/12/2009
Included observations: 175
Convergence achieved after 15 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*RESID(-2)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.001127	0.000842	1.339249	0.1805
Variance Equation				
C	1.19E-05	6.64E-06	1.793128	0.0730
RESID(-1)^2	-0.134114	0.025512	-5.256847	0.0000
RESID(-2)^2	0.173931	0.045802	3.797446	0.0001
GARCH(-1)	0.859924	0.062209	13.82317	0.0000

R-squared	-0.000845	Mean dependent var	0.001468
Adjusted R-squared	-0.000845	S.D. dependent var	0.011753
S.E. of regression	0.011758	Akaike info criterion	-6.095726
Sum squared resid	0.024056	Schwarz criterion	-6.005304
Log likelihood	538.3761	Hannan-Quinn criter.	-6.059049
Durbin-Watson stat	2.166203		

The small positive constant (c) shows a low baseline level of market volatility during the period (pre-crisis).

The value for the previous squared residuals is negative (which should is not supposed to be as theoretically not valid in standard GARCH model, violating assumption of positive conditional variance). This may be caused by model misspecification (ARCH/GARCH models could not capture the pattern in data), data irregularities (outliers) or instability.

The second lag of squared residuals indicate that past shock from two period ago contribute to the current volatility. The coefficient of 0.174 suggest that if there was a shock in two period ago, its squared value is scaled by 0.174 to affect the current variance.

The GARCH coefficient of 0.860 suggest strong persistence in volatility, where high past volatility leads to high future volatility.

PART B

1. **Summary of Findings**

Period	1	2	3
Return	Relatively stable returns	Significant fluctuations in returns	Low but more stable returns
Volatility	Low	High	Reduced however still fluctuate
Economy	Generally stable	Instability (Crisis leads to uncertainty)	Improved stability (In economic recovery)

2. **Market Behaviour and Volatility Dynamics**

The volatility was low pre-crisis as there is little to NO shocks that could affects the return and causing it to be unstable. Therefore, the volatility is stable (little to no fluctuation) with stable return. However, the worldwide financial crisis has crashed the market. People are out of jobs and do not have money to buy necessities, therefore, the production of goods and services has lowered during this period. Furthermore, the collapse of major financial institutions has created uncertainty about the stability of the financial system. Investors' confidence in the market is all time low as companies slowly started to go out of business. They were also unsure about the solvency of banks and other financial institutions. This leads to panic and massive sell-offs in the stock market. Panic selling with no buyers resulted in lack of liquidity, which in turn exacerbated market volatility. Furthermore, many financial institutions and investors were highly leveraged (borrow money to mostly invest in assets). When the price began to fall due to the crisis, they were forced to sell their assets as soon as possible to ensure they can meet margin calls and reduce their losses. This also led to the reduced asset price or return and increased volatility. Crisis also can be translated to period of high price levels (inflation), therefore, investors are more likely to be risk averse during this period. This made the investors to focus more on safer assets such as government bond and not the MSCI Index (which covers the market). Post-crisis which means the economy is recovering. Investors' trusts and confidence slowly returns as the market price returns and volatility is greatly reduced. This can mainly be attributed to the policy interventions that helped stabilized the economy. However, the crisis has left a significant and lasting impact on the market. Investors are still cautious, thus, there were great emphasis on diversification and risk management.