CHAPTER 13. FORECASTING VOLATILITY I

SOLUTIONS

by

Wei Lin and Yingying Sun

(University of California, Riverside)

Exercise 1

The New York Times, in its Sunday edition (April 14, 21, and 28, 2013) ran a series of three columns 'The Housing Haze' written by Professor Robert Shiller on long term forecasting of home prices. The thrust of these articles is that the return on housing as a long-term investment is very uncertain because a long term forecasting of home prices involves the design of a complex model, which needs to consider as main factors construction costs, population dynamics, population preferences, inflation, and dynamics of interest rates and home prices. Professor Shiller concludes that such a forecasting 'is indeed risky'.

As an economist, this article provides the basis to construct a model for house prices. It contains a good explanation of the two sides of the market, the supply and the demand factors. However, as a forecaster, the article does not put much faith on what it can be accomplished because, on one hand, there is not much dependence between the changes in prices that we see today and those ten year down the road (he is referring to autocorrelation coefficients of order 10), and on the other, all factors are subject to so much uncertainty (we should understand that the time series of interest rate changes, house price changes, inflation, etc. must have very large variances) so that confidence intervals for the long term forecast would be extremely wide and thus, of no much use to todays investors.

The business magazine *Fortune* ran a short article 'Just How Risky Is J.P Morgan Chase?' (April 29, 2013) claiming that, though the banks profits are solid, investors consider the institution risky because of its exposure to the so-called shadow banking system, which is a short-term (intra-day) lending system among financial institutions to fund short-term transactions.

As an economist, we learn that a shadow banking system is a large source of risk and that institutions with a large exposure to it will be in a very fragile situation if a financial crisis develops. J.P. Morgan Chase is considered a systemic important financial institution, which means that a massive failure in their investments decisions (e.g. reckless bets on derivatives) will not be contained within the institution and will propagate through the overall economic system. This is the notion of 'systemic risk'. The financial crisis of 2008 is a prime example. As a forecaster, we learn that the Federal Reserve has estimated that J.P. Morgan Chase will run into a risk loss of $79 billion should a financial crisis develops; however we do not have information on how this forecast has been calculated, though most likely the Fed has constructed an 'stress scenario' or a set of very adverse conditions in the economy (large drops in the stock market, large drop in house prices, very high unemployment, liquidity drain episodes, etc.) and has simulated the effect of these conditions on the balance sheet of the institution.

Exercise 2

We update the time series of the quarterly U.S. Real GDP growth from the webiste

http://research.stlouisfed.org/fred2/series/GDPC1

and the monthly S&P500 index from the Yahoo Finance website. The update of Figures 13.3 and 13.4 in the textbook is more difficult because involves ellaborated methodologies described in the corresponding academic articles cited in the textbook.

We plot GDP growth in Figure 1. We observe the large drop in growth in the aftermath of the financial crisis of 2008; in the the fourth quarter of 2008, growth was -9.3% (in annual rates), but with this exception the volatility of the last years seems to be lower than that in the 1970s, 1980s and 1990s. In Figure 2, we plot the updated time series of the monthly returns to S&P500 index from January 1960 to May 2013. The returns from 2008 M08 to 2013 M05 oscillated between -11.65% and 10.23% approximately; in general the volatility of the most recent years is similar to that in the 1980s but larger than that in the 1990s and early 2000s.

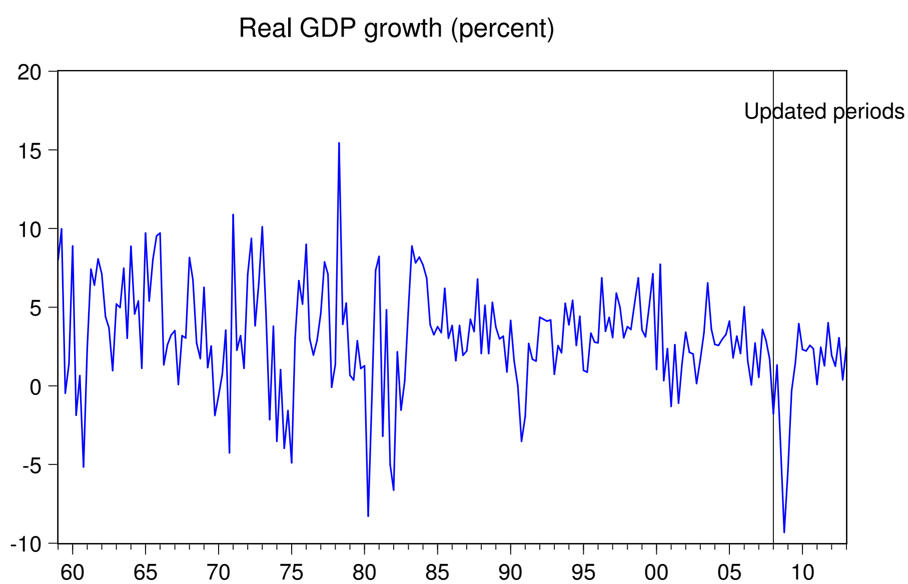


Figure 1: Real GDP Growth

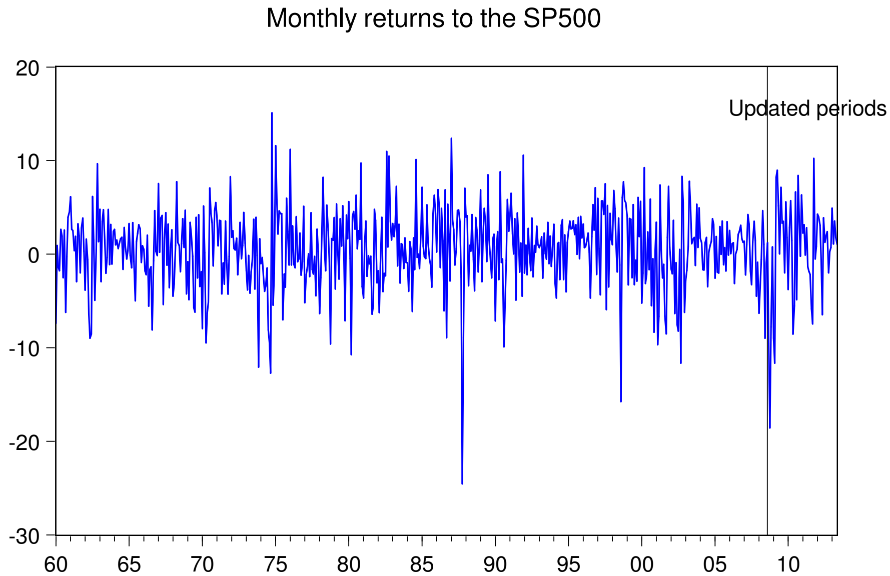


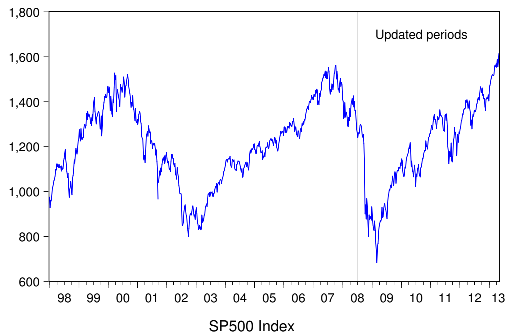
Figure 2: Monthly Returns of the S&P500 Index

Exercise 3

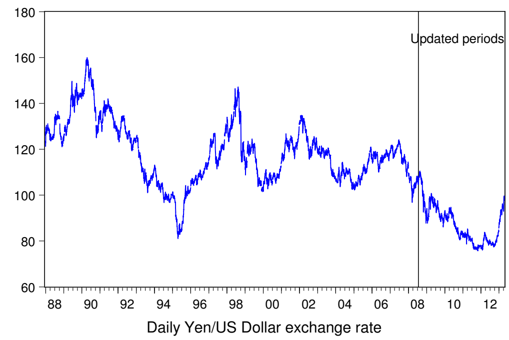
We update the time series of the weekly S&P500 index from the Yahoo Finance website, and the daily Yen/US Dollar exchange rate and the daily 10-year Treasury Constant Maturity Rate from following websites respectively:

http://research.stlouisfed.org/fred2/series/DEXJPUS
http://research.stlouisfed.org/fred2/series/DGS10

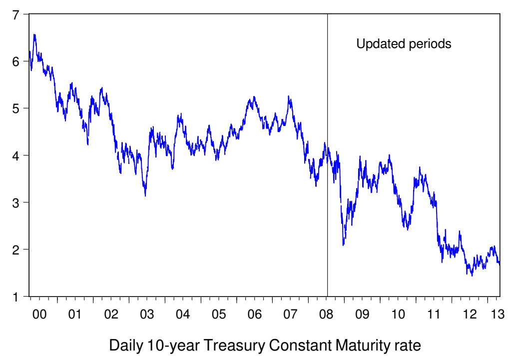
In Figure 3 we plot the three time series. We take log differences of the three series to obtain their corresponding returns, i.e., $r_t = 100 \times [\log p_t - \log p_{t-1}]$. For each return series, we implement MA and EWMA to compute their 1-step-ahead volatility forecasts. For EWMA, we choose the value of λ to be 0.95 for all three series; and for MA, the size of the rolling widow is 4 weeks for weekly data, and 20 trading days for daily data. In Figures 4, 5 and 6 we plot the one-step-ahead volatility forecasts obtained with MA and EWMA specifications.In all three figures, the units are variance units, for instance in Figure 4 (a), the maximum value is a variance of about 140 so that the standard deviation is about 11.83 %. Observe that the forecast of the weekly series is smoother than the daily series and that the EWMA forecasts tend to be smoother (the λ parameter is large) than the MA forecasts. However the volatility profiles from MA and EWMA are very similar. In the three series, the largest volatility shocks corresponds to those triggered by the financial crisis of 2008, in particular for the SP500 and the 10-year Treasure Note; the Yen/$ exchange rate had also experienced a large volatility increase in the late 1990s.



(a) Weekly S&P500 Index

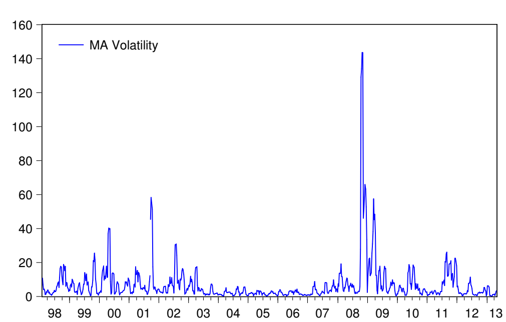


(b) Daily Yen/US Dollar Exchange Rate

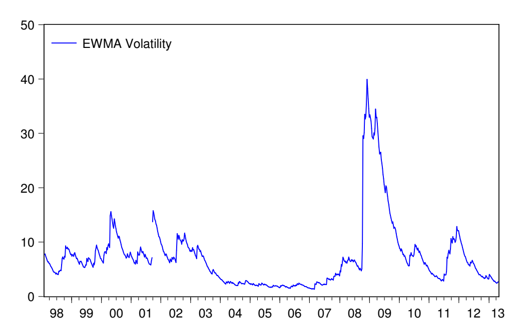


(c) Daily 10-year Treasury Constant Maturity Rate

Figure 3: Time Series of S&P500 Index, Yen/$ Exchange Rate and 10-Year Treasury Note Yield

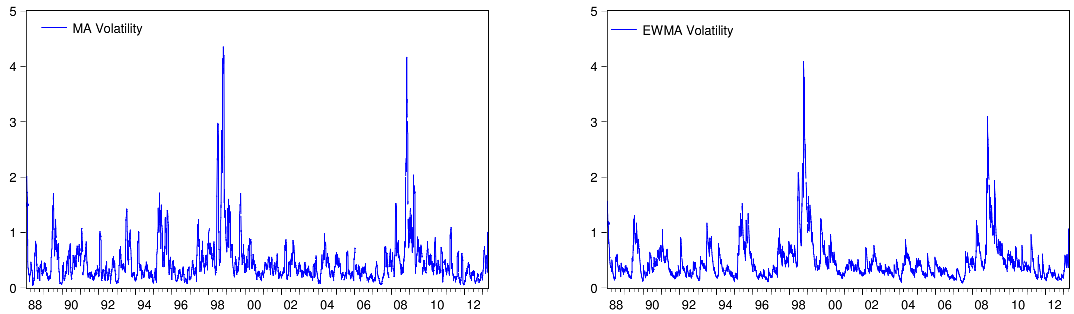


(a) MA / Rolling Window: 4 weeks



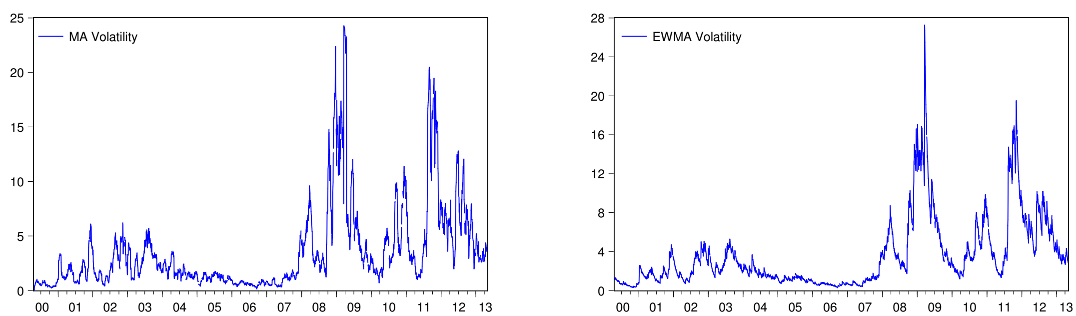
(b) EWMA / $\lambda = 0.95$

Figure 4: 1-step-ahead Volatility Forecast, Weekly Returns to S&P500 Index



(a) MA / Rolling Window: 20 days (b) EWMA / $\lambda = 0.95$

Figure 5: 1-step-ahead Volatility Forecast, Daily Return to Yen/U.S. dollar Exchange Rate Returns

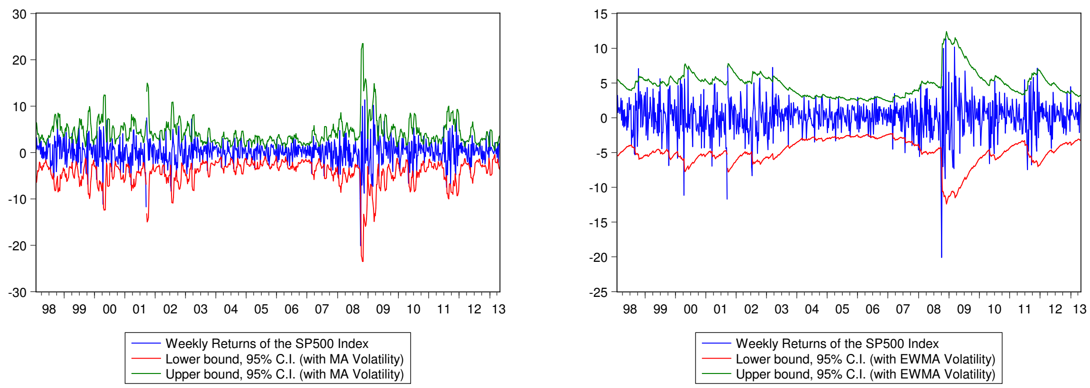


(a) MA / Rolling Window: 20 days (b) EWMA / $\lambda = 0.95$

Figure 6: 1-step-ahead Volatility Forecast, Daily Return to 10-year Treasury Note Returns

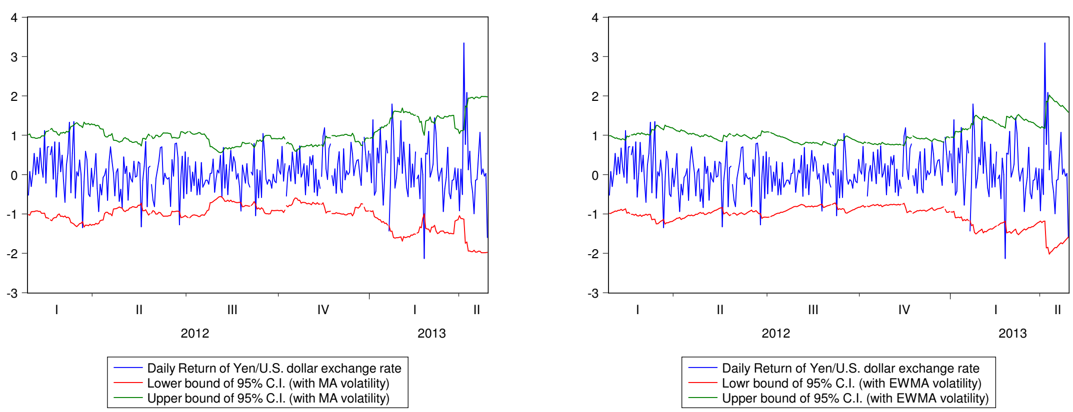
Exercise 4

In Figures 7, 8 and 9, we plot the 95% interval forecast for the returns of each of the three series in Exercise 3. Under the assumption of conditional normality of returns, the forecast interval is $\mu \pm 1.96\sigma_{t+1|t}$. Since $\mu = 0$, the interval reduces to $\pm 1.96\sigma_{t+1|t}$, where the conditional standard deviation is obtained from the MA and EWMA forecasts. With only a few exceptions, observe that the realized returns are contained within the 95% confidence interval.



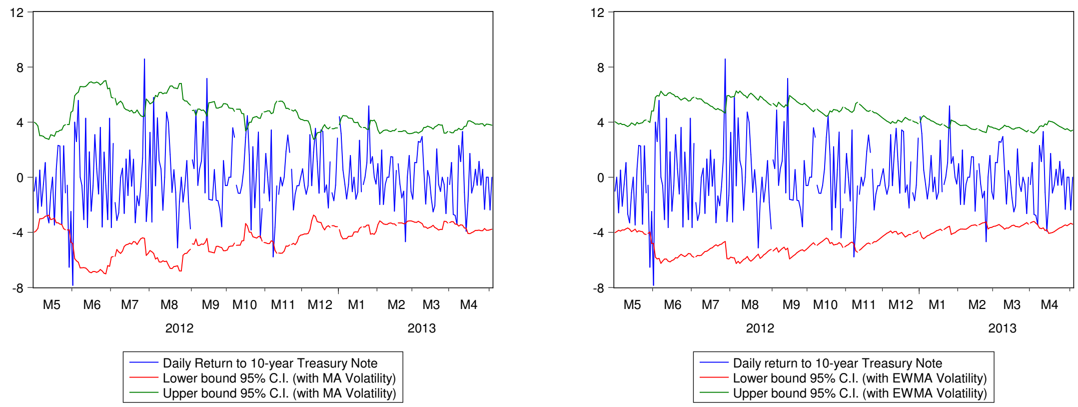
(a) MA / Rolling Window: 4 weeks (b) EWMA / $\lambda = 0.95$

Figure 7: 95% Confidence Interval Forecast, Weekly Returns to S&P500 Index



(a) MA / Rolling Window: 20 days (b) EWMA / $\lambda = 0.95$

Figure 8: 95% Confidence Interval Forecast, Daily Return to Yen/$ Exchange Rate Returns



(a) MA / Rolling Window: 20 days (b) EWMA / $\lambda = 0.95$

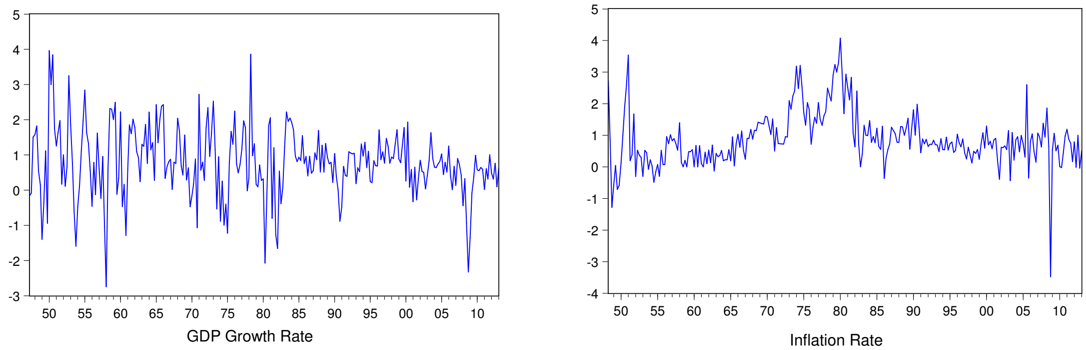
Figure 9: 95% Confidence Interval Forecast, Daily Return to 10-year Treasury Note Returns

Exercise 5

We download the quarterly U.S. inflation rate and real GDP growth rate (growth rate from quarter to quarter) from the following websites:

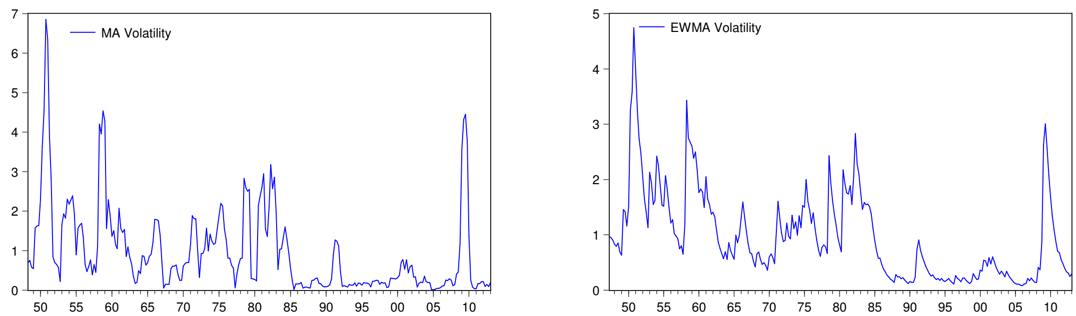
http://research.stlouisfed.org/fred2/series/CPIAUCSL
http://research.stlouisfed.org/fred2/series/GDPC1

The unconditional mean for GDP growth rate is 0.78% and for the inflation rate is 0.88%. In Figure 10 we plot these two time series. We have chosen 4 quarters as the rolling window for the MA specification and $\lambda = 0.8$ for the EWMA. The 1-step-ahead volatility forecasts for GDP growth are plotted in Figures 11a and 11b and those for the inflation rate in Figures 12a and 12b. For both series, observe the 'great moderation' period from mid-1980s to mid- 2000s when the volatility of GDP growth was well under 1% and the volatility of the inflation rate was even lower approaching close to zero. The volatility profiles provided by the MA and EWMA estimators are very similar for both series but the EWMA forecasts tend to be smoother than the MA forecasts. In Figures 13 and 14, we plot the 95% confidence intervals for the naive 1-step-ahead forecast of GDP growth and inflation rate respectively, i.e., $\mu \pm 1.96\sigma_{t+1|t}$, where μ is the unconditional mean of the series and $\sigma_{t+1|t}$ is the squared root of the MA and EWMA volatility forecasts. Overall, the realized values of GDP growth and inflation fall within the bounds of the interval, though for the inflation rate the intervals are extremely wide for practical purposes.



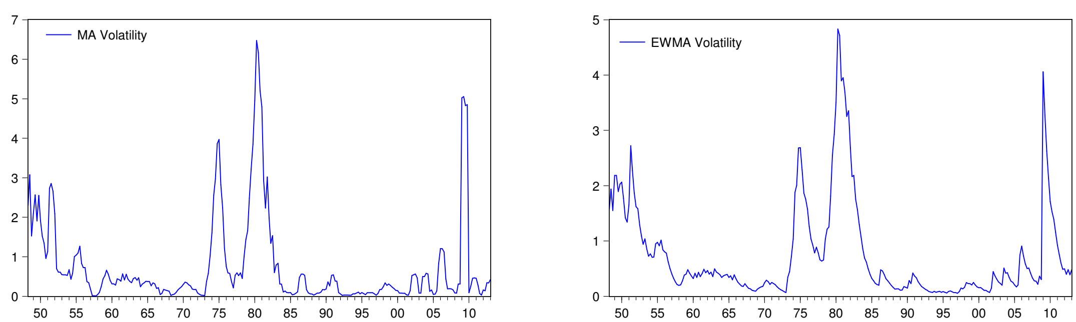
(a) GDP Growth (b) Inflation Rate

Figure 10: Time Series Plots for GDP Growth and Inflation Rate



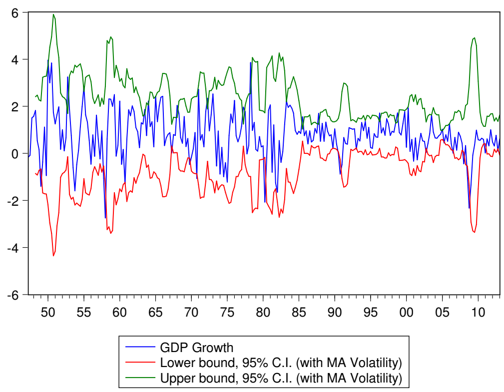
(a) MA / Rolling Window: 4 quarters (b) EWMA / $\lambda = 0.8$

Figure 11: 1-step-ahead Volatility Forecast of GDP Growth

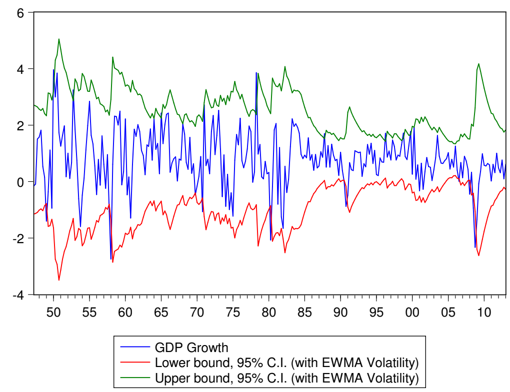


(a) MA / Rolling Window: 4 quarters (b) EWMA / $\lambda = 0.8$

Figure 12: 1-step-ahead Volatility Forecast of Inflation Rate

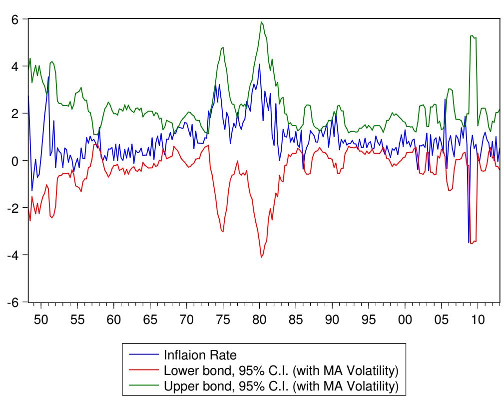


(a) MA / Rolling Window: 4 quarters

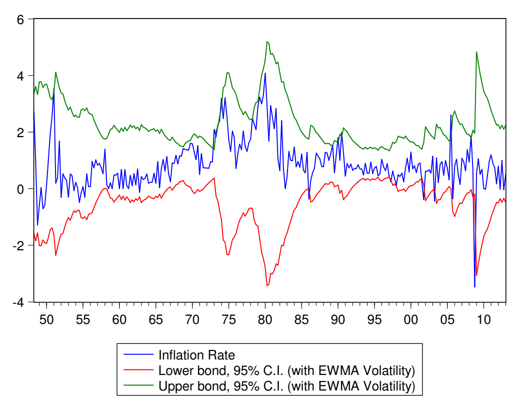


(b) EWMA / $\lambda = 0.8$

Figure 13: 95% Confidence Interval Forecast (1-step-ahead) for GDP Growth



(a) MA / Rolling Window: 4 quarters



(b) EWMA / $\lambda = 0.8$

Figure 14: 95% Confidence Interval Forecast (1-step-ahead) for Inflation Rate

Exercise 6

We have selected an AR(3) process for the conditional mean of both the quarterly U.S. inflation rate and real GDP growth in Exercise 5, following the specification strategies that we have studied in Chapter 8. We report the estimation results in Tables 1 and 2, and we reserve the last 17 observations (from 2009Q1 to 2013Q1) to assess the out-of-sample forecast. From each model, we compute the 1-step-ahead forecasts $\widehat{\mu}_{t+1|t}$ and the corresponding forecast errors over the last 17 observations. We need the residuals from the estimation sample and the forecast errors from the forecast sample to calculate the 1-step-ahead MA and EWMA volatility forecast $\widehat{\sigma}^2_{t+1|t}$. The rolling window for the MA estimates is 4 quarters, and $\lambda = 0.8$ for the EWMA estimates. Under the normality assumption, the 95% confidence interval forecast is $[\widehat{\mu}_{t+1|t} - 1.96\widehat{\sigma}_{t+1|t}, \widehat{\mu}_{t+1|t} + 1.96\widehat{\sigma}_{t+1|t}]$ for each of the last 17 observations. In Figures 15a, 15b, 16a and 16b, we plot the MA and EWMA volatility forecasts; the shaded area denotes the last 17 observations in the forecast sample. Observe that the MA and EWMA volatility forecasts based on the conditional mean models are smaller than those forecasts based on the unconditional means (Exercise 5), in particular for the inflation rate. The conditional mean model for the inflation rate is very helpful because it captures very well the dynamics of the series on the mid-1970s to mid-1980s so that the residuals are small and, consequently, the volatility estimates are also small. In Figures 15c, 15d, 16c and 16d we plot the 95% confidence interval forecasts based on MA and EWMA volatility forecasts for the inflation rate and real GDP growth rate respectively. The intervals get narrow over the forecast sample because the shock of 2008 has already been absorbed by 2013. As expected, once the conditional mean of the series is properly modeled, the intervals are narrower than in the unconditional case because the volatility forecasts are smaller. Thus, the conditional mean models are helpful to narrow the uncertainty of the forecasts.

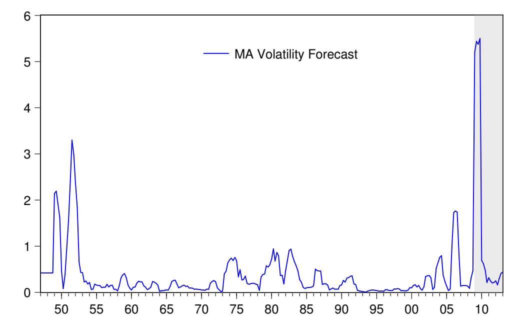
Dependent Variable: INFL
Method: Least Squares
Sample (adjusted): 1948Q1 2008Q4
Included observations: 244 after adjustments
Convergence achieved after 3 iterations
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.788041	0.213799	3.685895	0.0003
AR(1)	0.370147	0.10452	3.541406	0.0005
AR(2)	0.106837	0.092009	1.161164	0.2467
AR(3)	0.326175	0.074952	4.351791	0.0000
R-squared	0.447286	Mean dependent var		0.901877
Adjusted R-squared	0.440377	S.D. dependent var		0.874288
S.E. of regression	0.654037	Akaike info criterion		2.004953
Sum squared resid	102.6635	Schwarz criterion		2.062283
Log likelihood	-240.6042	Hannan-Quinn criter.		2.028042
F-statistic	64.74025	Durbin-Watson stat		1.696113
Prob(F-statistic)	0.000000			
Inverted AR Roots	0.9	-.26+.54i	-.26-.54i	

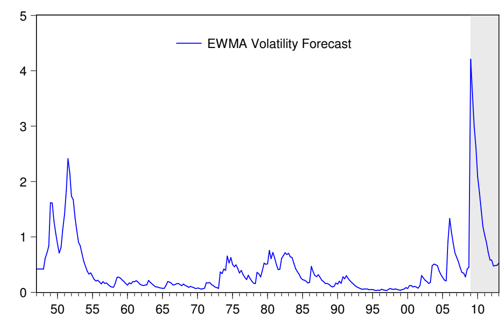
Table 1: Estimation Results for Quarterly Inflation Rate

Dependent Variable: GRGDP				
Method: Least Squares				
Sample (adjusted): 1948Q1 2008Q4				
Included observations: 244 after adjustments				
Convergence achieved after 3 iterations				
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.799274	0.092824	8.610601	0.0000
AR(1)	0.338882	0.066103	5.126541	0.0000
AR(2)	0.125637	0.071547	1.756005	0.0804
AR(3)	-0.11425	0.065457	-1.745403	0.0822
R-squared	0.141872	Mean dependent var		0.808152
Adjusted R-squared	0.131146	S.D. dependent var		1.003848
S.E. of regression	0.935711	Akaike info criterion		2.721237
Sum squared resid	210.1331	Schwarz criterion		2.778568
Log likelihood	-327.9909	Hannan-Quinn criter.		2.744327
F-statistic	13.22621	Durbin-Watson stat		1.991356
Prob(F-statistic)	0.000000			
Inverted AR Roots	.40-.29i	.40+.29i	-0.46	

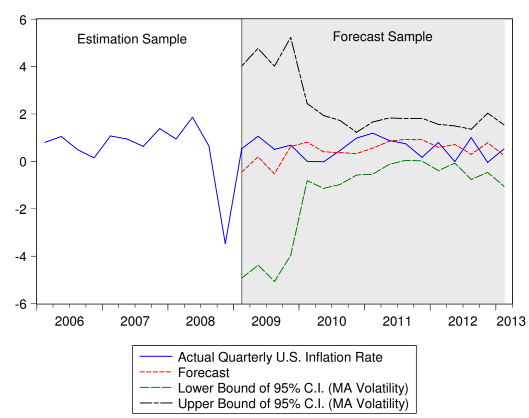
Table 2: Estimation Results for Quarterly Real GDP Growth Rate



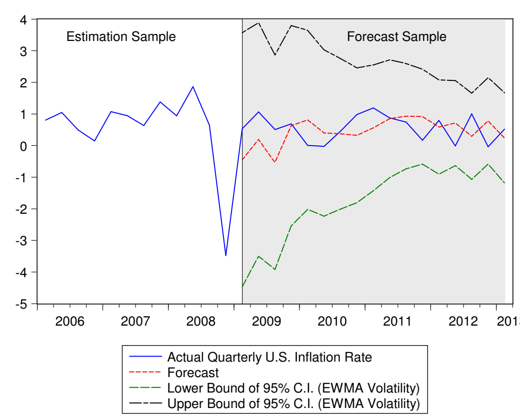
(a) MA Volatility Forecast
Rolling Window: 4 Quarters



(b) EWMA Volatility Forecast
$\lambda = 0.8$

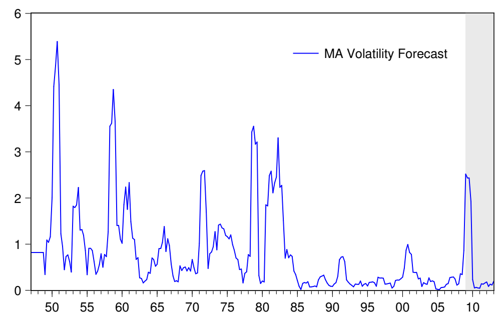


(c) 1-step-ahead 95% Confidence Interval Forecast based on MA Volatility

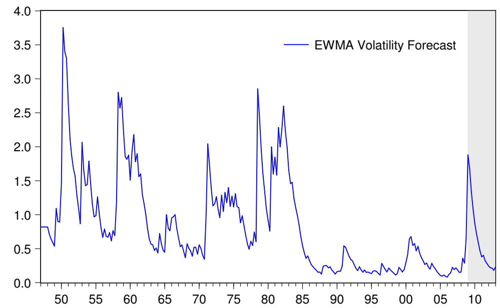


(d) 1-step-ahead 95% Confidence Interval Forecast based on EWMA Volatility

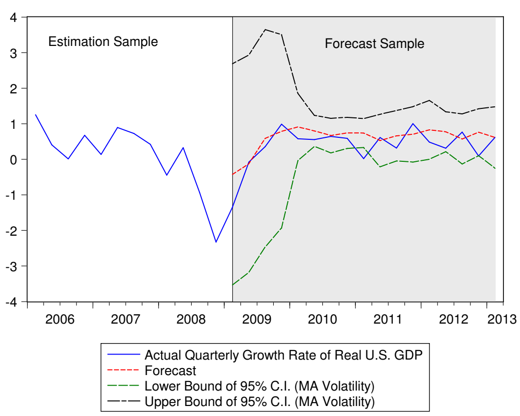
Figure 15: Quarterly U.S. Inflation



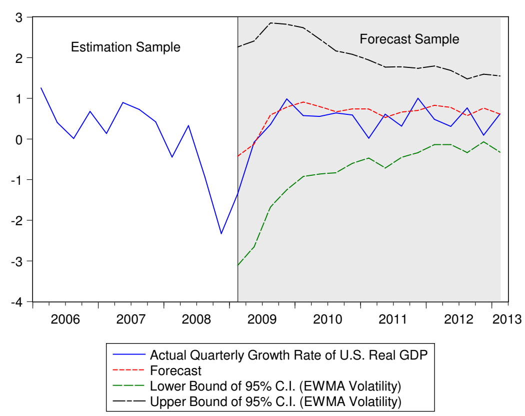
(a) MA Volatility Forecast
Rolling Window: 4 Quarters



(b) EWMA Volatility Forecast
$\lambda = 0.8$



(c) 1-step-ahead 95% Confidence Interval Forecast based on MA Volatility



(d) 1-step-ahead 95% Confidence Interval Forecast based on EWMA Volatility

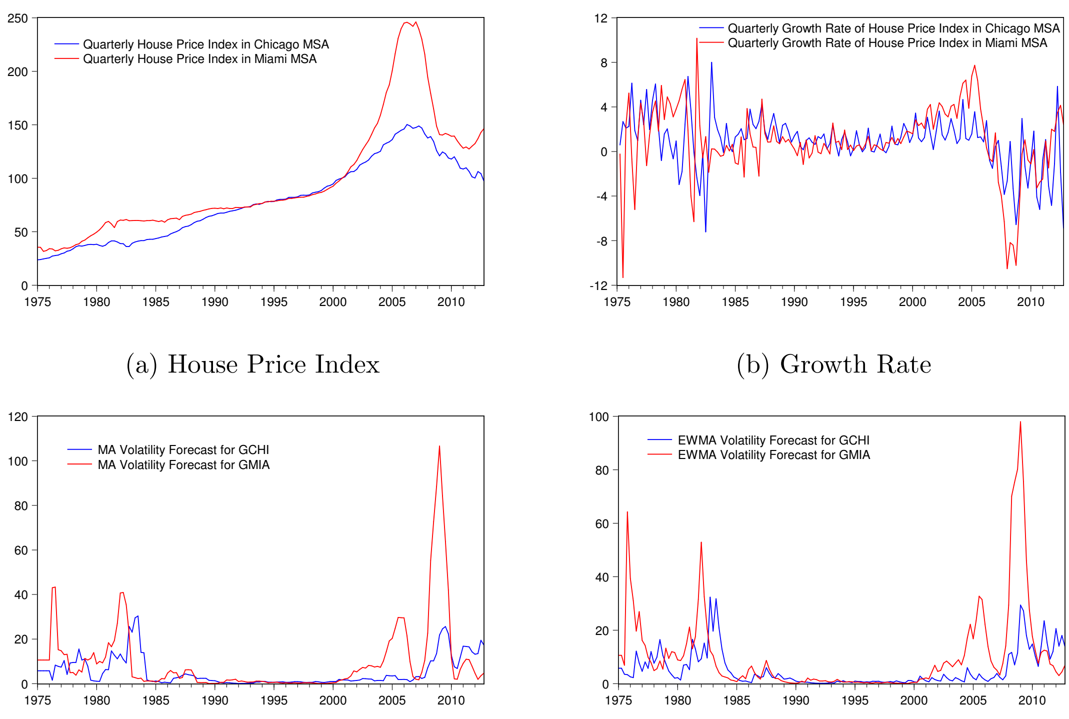
Figure 16: Quarterly U.S. Real GDP Growth Rate

Exercise 7

We download the time series of the quarterly house price index (value of the index at the end of the quarter) for two MSAs: Chicago MSA (Chicago-Joliet-Naperville IL-IN-WI) and Miami MSA (Miami-Fort Lauderdale-Pompano Beach FL), which are denoted as "ICHI" and "IMIA" respectively.

http://www.freddiemac.com/finance/fmhpi/

The house price indices range from 1975Q1 to 2012Q4 and are plotted in Figure 17a. We take the log differences to obtain the growth rates of house price index, denoted as "GCHI" and "GMIA" respectively and plotted in Figure 17b. The housing bubble of 2008 was more pronounced in the Miami market than in Chicago and the subsequent decline in prices much more severe, though it seems that by the end of 2012, Miami is recovering at a stronger pace than Chicago. Observe that both markets exhibit strong seasonality intra-year; on average, prices tend to increase in spring and summer and to decrease in fall and winter. For each market, we calculate the 1-step-ahead volatility forecast by implementing MA with a rolling window of 4 quarters (this window will smooth the quarterly seasonality out of the variance) and EWMA with $\lambda = 0.6$. In Figure 17c and 17d, we plot the MA and EWMA volatility forecast for the growth rates of the two MSA house price index. The episodes of large volatility are common to both markets, mainly mid-1970s to mid-1980s and the 2008 crisis with its aftermath but, in general, the Miami market is much more volatile that the Chicago market.



(a) House Price Index

(b) Growth Rate

(c) MA (Rolling Window: 4 quarters)

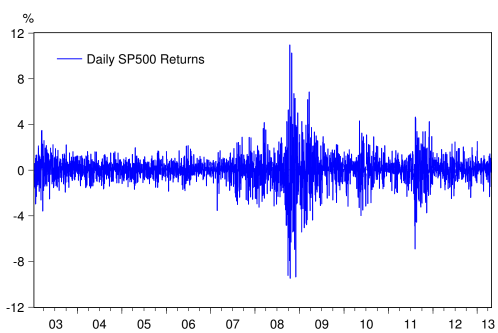
(d) EWMA ($\lambda = 0.6$)

Figure 17: House Price Index, Growth Rates, and Volatility Forecasts of Two MSAs

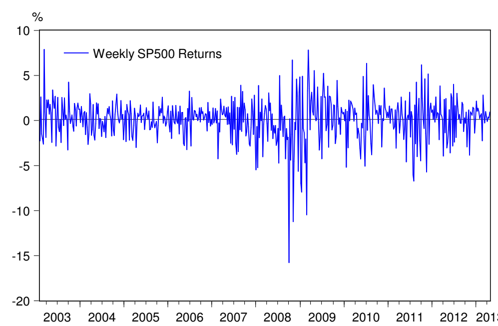
Exercise 8

We download the S&P500 stock price index at the daily, weekly, and monthly frequencies from Yahoo Finance website. The index prices are adjusted close prices for dividends and splits, and range from 2003/1/2 to 2013/4/29. The high frequency (daily) data are converted into low frequency (weekly or monthly) data by taking the last observation corresponding to each low frequency time interval (each week or each month). We take log differences of the three series to obtain the index returns at the three frequencies: $r_t = 100 \times [\log p_t - \log p_{t-1}]$. In Figure 18, we plot the three index returns series. The profiles of the time series are very similar across frequencies but as the frequency becomes lower, the series become less noisy and smoother because the very short term fluctuations are smoothed out of the data.

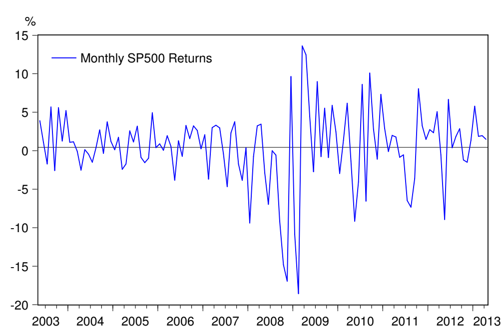
For each return series, we compute their 1-step-ahead MA and EWMA volatility forecasts. For EWMA, we choose the value of λ to be 0.95 for all series; and for MA, the sizes of rolling widow are 20 trading days, 4 weeks and 3 months for daily, weekly, and monthly data respectively. In Figures 19, 20, and 21, we plot the one-step-ahead MA and EWMA volatility forecasts for the three frequencies. There are two large episodes of volatility in the last decade, the global shock of 2008-2009 and the European sovereign crisis of 2010-2011, the former being about three order of magnitude larger than the latter. The MA volatility estimates have similar profiles across frequencies and become smoother as the frequency decreases. The EWMA volatility estimates are also smoother than the MA estimates because the smoothing parameter λ is very large. However, for the monthly frequency, the smoothing parameter is too large, it smooths the data too much and, as a result, we are only able to observe the 2008-2009 volatility episode.



(a) Daily Frequency

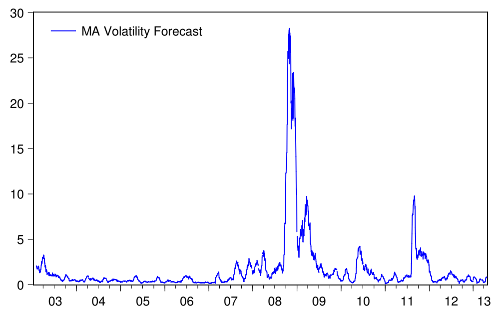


(b) Weekly Frequency

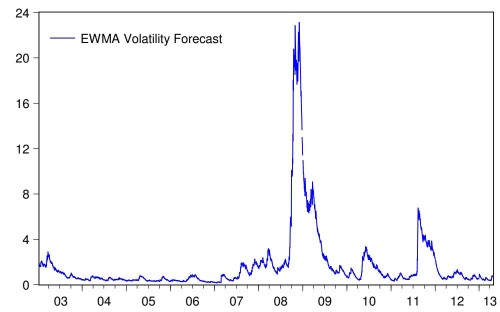


(c) Monthly Frequency

Figure 18: Returns to S&P500 Index at Three Different Frequencies

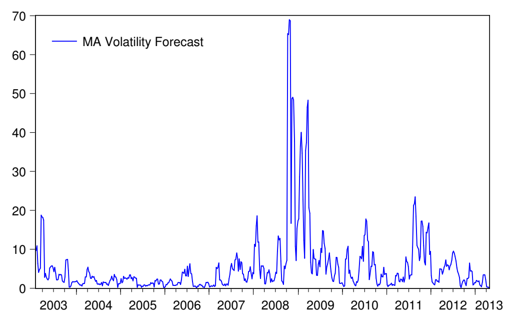


(a) MA / Rolling Window: 20 days

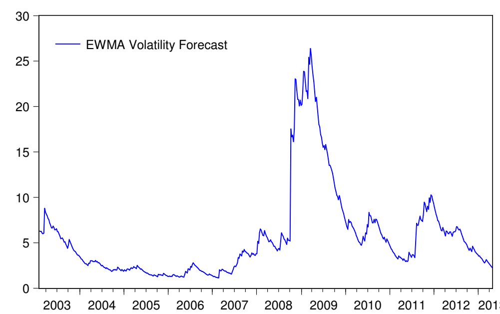


(b) EWMA / $\lambda = 0.95$

Figure 19: 1-step-ahead Volatility Forecast at Daily Frequency

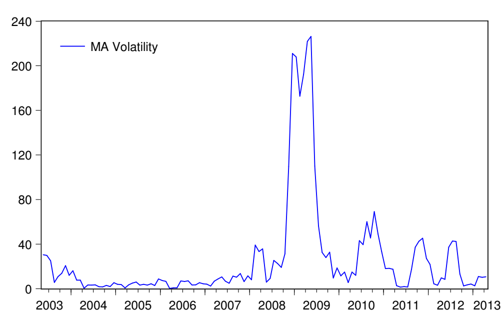


(a) MA / Rolling Window: 4 weeks

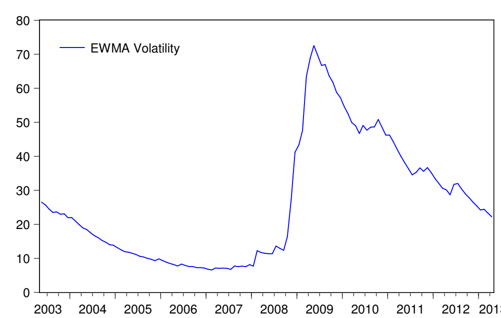


(b) EWMA / $\lambda = 0.95$

Figure 20: 1-step-ahead Volatility Forecast at Weekly Frequency



(a) MA / Rolling Window: 3 months



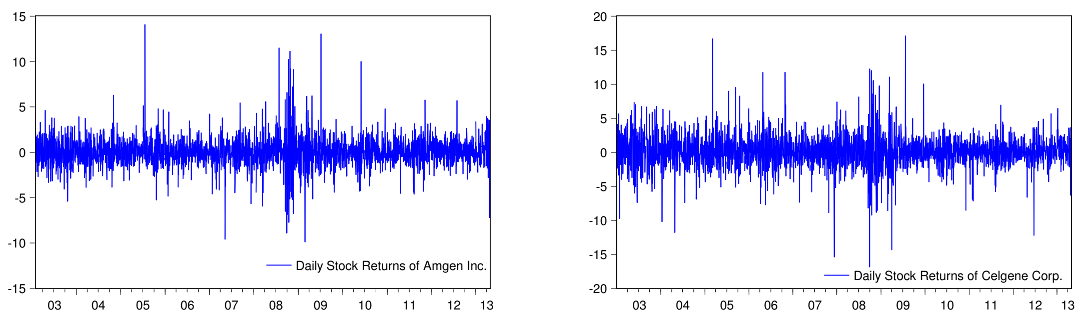
(b) EWMA $/\lambda = 0.95$

Figure 21: 1-step-ahead Volatility Forecast at Monthly Frequency

Exercise 9

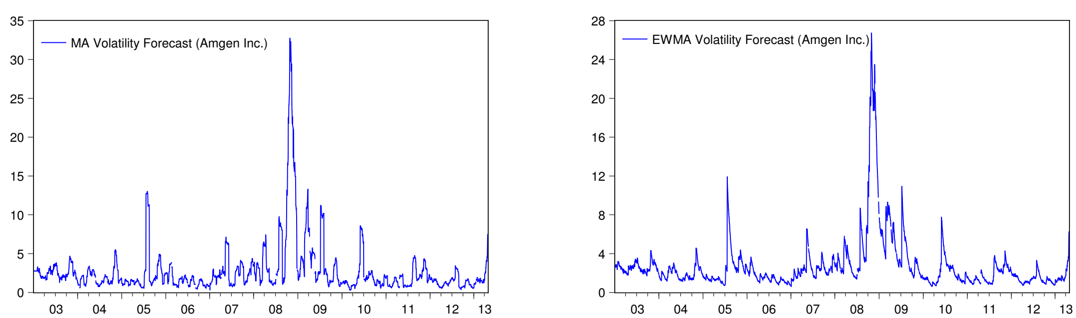
We download the daily stock prices of two biotechnology companies from Yahoo Finance website. The two companies are Amgen Incorporation (AMGN) and Celgene Corporation (CELG), both components of the S&P500 index.

The stock prices are adjusted close prices for dividends and splits, and range from 2003/1/2 to 2013/4/29. The daily stock returns are obtain by taking log differences as $r_t = 100 \times [\log p_t - \log p_{t-1}]$, and are plotted in Figure 22a and 22b respectively. For each series, we compute the 1-step-ahead MA and EWMA volatility forecasts; for MA we choose a rolling window of 20 trading days and for EWMA we choose $\lambda = 0.95$. The volatility forecasts are shown in Figures 23 and 24. Though the volatility profiles of both companies are similar, CELG is more volatile than AMGN, and CELG was more exposed to the 2008 shock than AMGN. In comparison with the daily volatility forecasts of S&P500 returns, 19, both companies are more volatile, they have their own idiosyncratic shocks and they only share with the market the 2008 global volatility shock but not the 2011 episode. The profile of AMGEN volatility is more similar to the SP500 volatility than that of CELG; the former has a larger weight in the index than the latter.



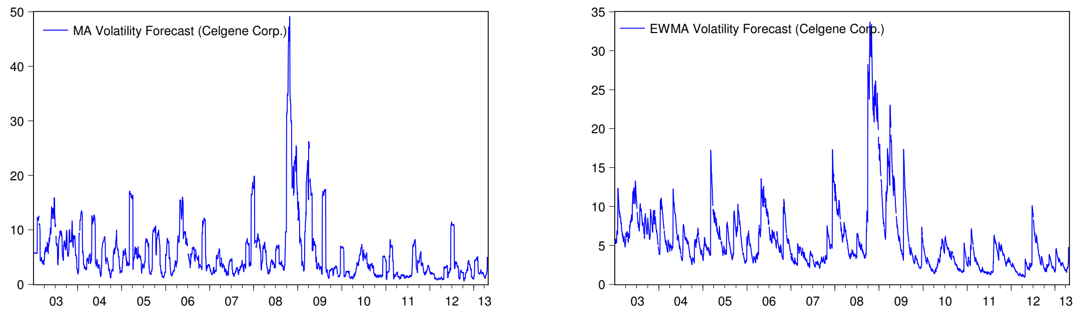
(a) Amgen Inc. (AMGN), Thousand Oaks, CA (b) Celgene Corp. (CELG), Summit, NJ

Figure 22: Daily Stock Returns of Two Biotechnological Companies



(a) MA / Rolling Window: 20 days (b) EWMA / $\lambda = 0.95$

Figure 23: 1-step-ahead Volatility Forecast for AMGN



(a) MA / Rolling Window: 20 days (b) EWMA / $\lambda = 0.95$

Figure 24: 1-step-ahead Volatility Forecast for CELG

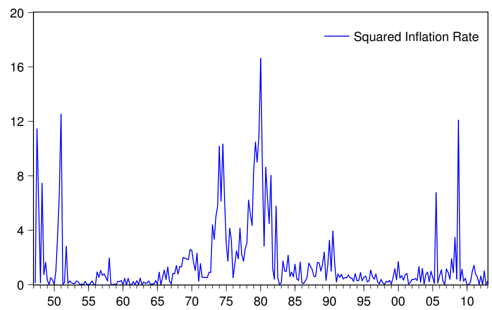
Exercise 10

We compute and plot the squared values, the absolute values, and the range (for stock returns) of the variables in Exercises 6 to 9 and their corresponding autocorrelograms in Figures 25 – 33.

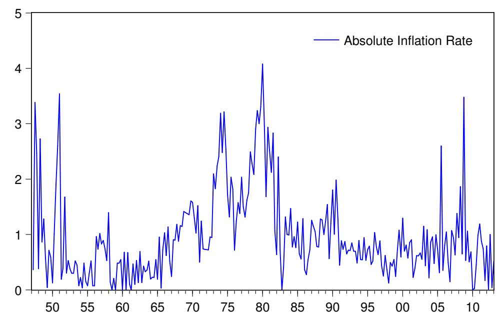
We find substantial time dependence in the squared and absolute values of the quarterly U.S. inflation rate in Figure 25, indicating that the the conditional variance is time varying. The profiles of the ACF and PACF point towards an autoregressive structure in volatility. In contrast, there is very little dependence in squared and absolute growth rates of real GDP in Figure 26.

The absolute values of the quarterly growth rate of the house price indexes in Miami and Chicago exhibit more dependence than the squared values. There is a more pronounced seasonality in the absolute values of the Chicago series than in those of Miami, though Miami shows a more time dependent process that points to an autoregressive model in volatility being measured by the absolute value of the series. See Figures 27 and 28.

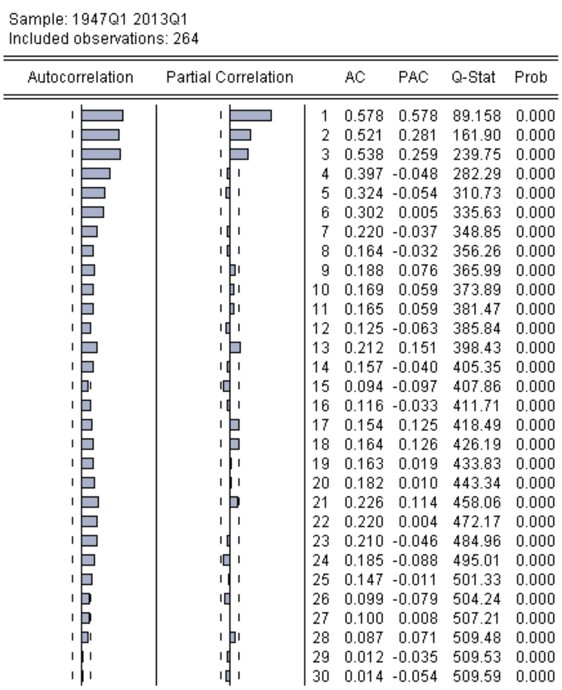
For the returns to the SP500 series, Figures 29, 30, and 31, observe that the time dependence in volatility fades as a function of the frequency so that the lower the frequency the weaker the dependence is. There are two commonalities across the three frequencies, first, the range is more dependent than the absolute and squared values, and second, all the profiles of the ACF and PACF seem to point out towards an autoregressive model in volatility. We also observe the same common behavior in the two individual stocks, AMGN and CELG, in Figures 32 and 33.



(a) Squared Value



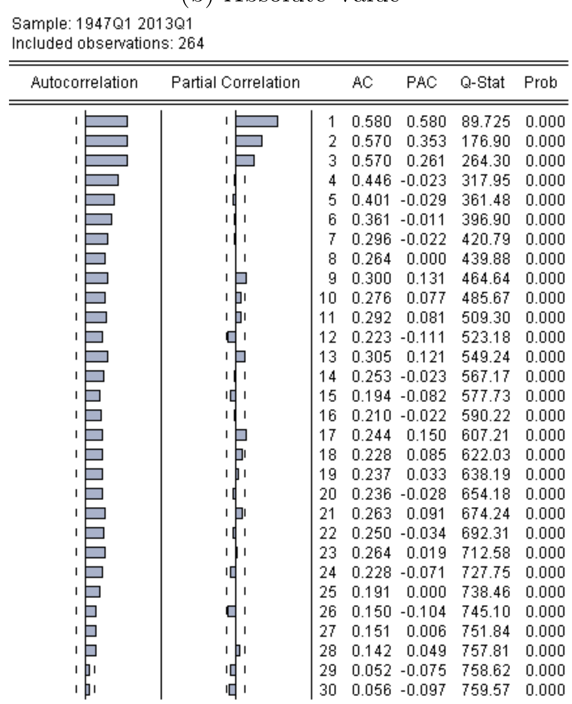
(b) Absolute Value



Sample: 1947Q1 2013Q1
Included observations: 264

Lag	AC	PAC	Q-Stat	Prob
1	0.578	0.578	89.158	0.000
2	0.521	0.281	161.90	0.000
3	0.538	0.259	239.75	0.000
4	0.397	-0.048	282.29	0.000
5	0.324	-0.054	310.73	0.000
6	0.302	0.005	335.63	0.000
7	0.220	-0.037	348.85	0.000
8	0.164	-0.032	356.26	0.000
9	0.188	0.076	365.99	0.000
10	0.169	0.059	373.89	0.000
11	0.165	0.059	381.47	0.000
12	0.125	-0.063	385.84	0.000
13	0.212	0.151	398.43	0.000
14	0.157	-0.040	405.35	0.000
15	0.094	-0.097	407.86	0.000
16	0.116	-0.033	411.71	0.000
17	0.154	0.125	418.49	0.000
18	0.164	0.126	426.19	0.000
19	0.163	0.019	433.83	0.000
20	0.182	0.010	443.34	0.000
21	0.226	0.114	458.06	0.000
22	0.220	0.004	472.17	0.000
23	0.210	-0.046	484.96	0.000
24	0.185	-0.088	495.01	0.000
25	0.147	-0.011	501.33	0.000
26	0.099	-0.079	504.24	0.000
27	0.100	0.008	507.21	0.000
28	0.087	0.071	509.48	0.000
29	0.012	-0.035	509.53	0.000
30	0.014	-0.054	509.59	0.000

(c) Correlogram of Squared Value

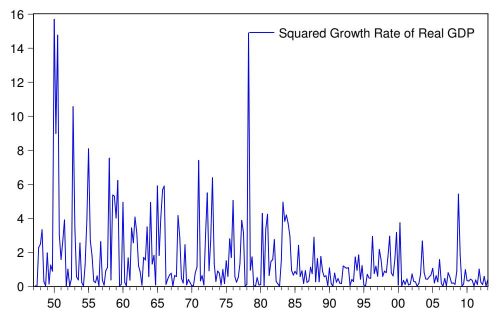


Sample: 1947Q1 2013Q1
Included observations: 264

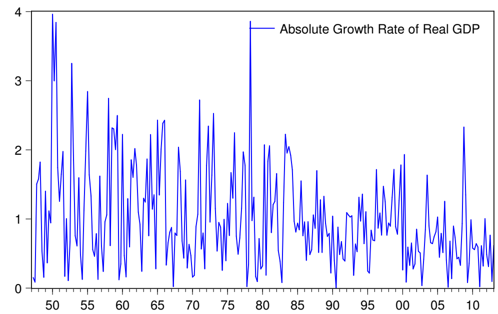
Lag	AC	PAC	Q-Stat	Prob
1	0.580	0.580	89.725	0.000
2	0.570	0.353	176.90	0.000
3	0.570	0.261	264.30	0.000
4	0.446	-0.023	317.95	0.000
5	0.401	-0.029	361.48	0.000
6	0.361	-0.011	396.90	0.000
7	0.296	-0.022	420.79	0.000
8	0.264	0.000	439.88	0.000
9	0.300	0.131	464.64	0.000
10	0.276	0.077	485.67	0.000
11	0.292	0.081	509.30	0.000
12	0.223	-0.111	523.18	0.000
13	0.305	0.121	549.24	0.000
14	0.253	-0.023	567.17	0.000
15	0.194	-0.082	577.73	0.000
16	0.210	-0.022	590.22	0.000
17	0.244	0.150	607.21	0.000
18	0.228	0.085	622.03	0.000
19	0.237	0.033	638.19	0.000
20	0.236	-0.028	654.18	0.000
21	0.263	0.091	674.24	0.000
22	0.250	-0.034	692.31	0.000
23	0.264	0.019	712.58	0.000
24	0.228	-0.071	727.75	0.000
25	0.191	0.000	738.46	0.000
26	0.150	-0.104	745.10	0.000
27	0.151	0.006	751.84	0.000
28	0.142	0.049	757.81	0.000
29	0.052	-0.075	758.62	0.000
30	0.056	-0.097	759.57	0.000

(d) Correlogram of Absolute Value

Figure 25: Quarterly U.S. Inflation Rate



(a) Squared Value



(b) Absolute Value

Sample: 1947Q1 2013Q1
Included observations: 264

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.265	0.265	18.707	0.000
		2	0.191	0.130	28.466	0.000
		3	0.036	-0.046	28.815	0.000
		4	0.050	0.029	29.477	0.000
		5	0.005	-0.010	29.485	0.000
		6	-0.036	-0.050	29.847	0.000
		7	-0.073	-0.056	31.304	0.000
		8	0.092	0.149	33.646	0.000
		9	0.173	0.156	41.894	0.000
		10	0.100	-0.012	44.671	0.000
		11	0.133	0.075	49.564	0.000
		12	0.032	-0.037	49.842	0.000
		13	0.017	-0.039	49.922	0.000
		14	-0.004	0.000	49.927	0.000
		15	0.045	0.088	50.486	0.000
		16	0.026	0.028	50.674	0.000
		17	0.012	-0.040	50.715	0.000
		18	0.062	0.054	51.822	0.000
		19	0.088	0.034	54.018	0.000
		20	0.213	0.153	67.101	0.000
		21	0.115	0.028	70.924	0.000
		22	-0.006	-0.097	70.934	0.000
		23	-0.022	-0.029	71.070	0.000
		24	0.086	0.104	73.246	0.000
		25	0.050	0.030	73.983	0.000
		26	0.063	0.037	75.155	0.000
		27	0.005	-0.003	75.163	0.000
		28	0.054	-0.005	76.024	0.000
		29	0.143	0.052	82.147	0.000
		30	0.039	-0.045	82.596	0.000

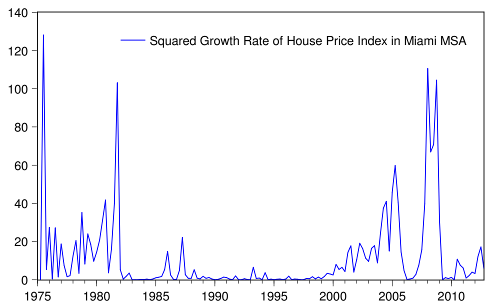
(c) Correlogram of Squared Value

Sample: 1947Q1 2013Q1
Included observations: 264

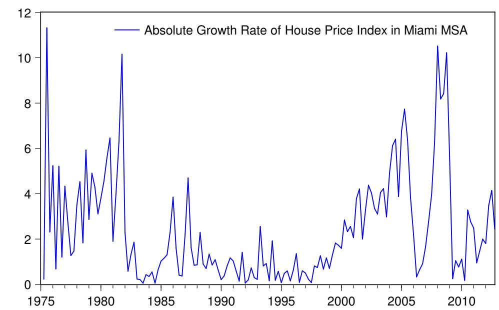
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.268	0.268	19.108	0.000
		2	0.156	0.091	25.634	0.000
		3	0.027	-0.038	25.834	0.000
		4	0.043	0.034	26.345	0.000
		5	0.015	0.000	26.409	0.000
		6	-0.019	-0.034	26.507	0.000
		7	-0.069	-0.062	27.815	0.000
		8	0.086	0.135	29.839	0.000
		9	0.118	0.090	33.693	0.000
		10	0.116	0.042	37.419	0.000
		11	0.078	0.025	39.113	0.000
		12	0.054	0.011	39.941	0.000
		13	0.035	-0.002	40.292	0.000
		14	0.030	0.008	40.551	0.000
		15	0.052	0.064	41.300	0.000
		16	0.056	0.041	42.198	0.000
		17	-0.004	-0.049	42.203	0.001
		18	0.049	0.039	42.876	0.001
		19	0.115	0.096	46.670	0.000
		20	0.189	0.128	57.003	0.000
		21	0.086	-0.019	59.128	0.000
		22	-0.017	-0.076	59.211	0.000
		23	-0.059	-0.063	60.227	0.000
		24	0.042	0.057	60.740	0.000
		25	0.031	0.026	61.021	0.000
		26	0.080	0.087	62.886	0.000
		27	-0.009	-0.043	62.913	0.000
		28	0.076	0.023	64.636	0.000
		29	0.110	0.038	68.256	0.000
		30	0.028	-0.065	68.483	0.000

(d) Correlogram of Absolute Value

Figure 26: Quarterly Growth Rate of U.S. Real GDP



(a) Squared Value



(b) Absolute Value

Sample: 1975Q1 2012Q4
Included observations: 151

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.459	0.459	32.471	0.000
		2	0.369	0.201	53.625	0.000
		3	0.244	0.021	62.908	0.000
		4	0.217	0.062	70.292	0.000
		5	0.039	-0.149	70.528	0.000
		6	-0.001	-0.048	70.528	0.000
		7	-0.029	-0.002	70.660	0.000
		8	-0.026	0.010	70.766	0.000
		9	0.015	0.086	70.803	0.000
		10	0.081	0.099	71.888	0.000
		11	0.147	0.102	75.459	0.000
		12	0.150	0.024	79.181	0.000
		13	0.173	0.029	84.188	0.000
		14	0.182	0.035	89.771	0.000
		15	0.177	0.030	95.089	0.000
		16	0.088	-0.054	96.429	0.000
		17	0.095	0.040	98.001	0.000
		18	0.089	0.053	99.370	0.000
		19	0.066	0.014	100.12	0.000
		20	0.030	-0.003	100.28	0.000
		21	0.097	0.082	101.96	0.000
		22	0.031	-0.071	102.13	0.000
		23	0.052	0.005	102.61	0.000
		24	0.042	-0.006	102.94	0.000
		25	0.148	0.118	106.97	0.000
		26	0.000	-0.136	106.97	0.000
		27	-0.013	-0.068	107.00	0.000
		28	-0.028	-0.021	107.15	0.000
		29	-0.012	-0.016	107.18	0.000
		30	-0.036	0.016	107.42	0.000

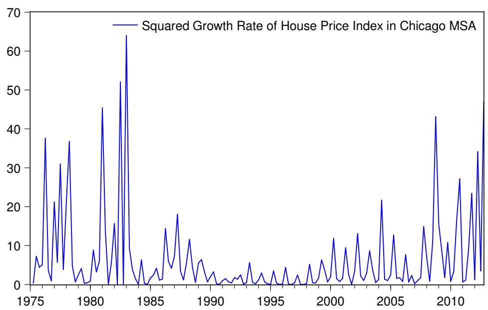
(c) Correlogram of Squared Value

Sample: 1975Q1 2012Q4
Included observations: 151

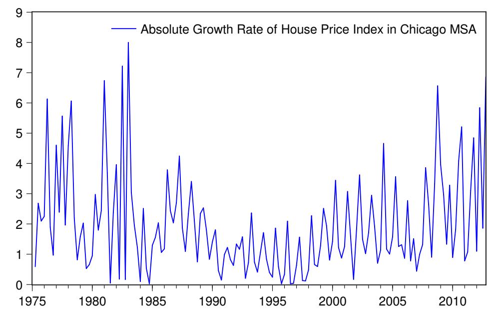
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.601	0.601	55.607	0.000
		2	0.525	0.256	98.297	0.000
		3	0.360	-0.048	118.51	0.000
		4	0.391	0.182	142.49	0.000
		5	0.195	-0.191	148.49	0.000
		6	0.142	-0.054	151.73	0.000
		7	0.103	0.079	153.42	0.000
		8	0.114	0.010	155.51	0.000
		9	0.153	0.168	159.29	0.000
		10	0.195	0.110	165.53	0.000
		11	0.239	0.059	174.92	0.000
		12	0.235	0.016	184.14	0.000
		13	0.271	0.038	196.43	0.000
		14	0.274	0.040	209.12	0.000
		15	0.252	-0.008	219.92	0.000
		16	0.167	-0.071	224.71	0.000
		17	0.167	0.051	229.52	0.000
		18	0.176	0.086	234.91	0.000
		19	0.130	-0.051	237.85	0.000
		20	0.067	-0.051	238.64	0.000
		21	0.127	0.118	241.52	0.000
		22	0.087	-0.111	242.88	0.000
		23	0.095	0.003	244.51	0.000
		24	0.062	-0.002	245.20	0.000
		25	0.083	-0.061	246.45	0.000
		26	0.031	-0.024	246.62	0.000
		27	0.009	-0.065	246.64	0.000
		28	0.001	-0.010	246.64	0.000
		29	0.015	0.041	246.68	0.000
		30	-0.034	-0.086	246.90	0.000

(d) Correlogram of Absolute Value

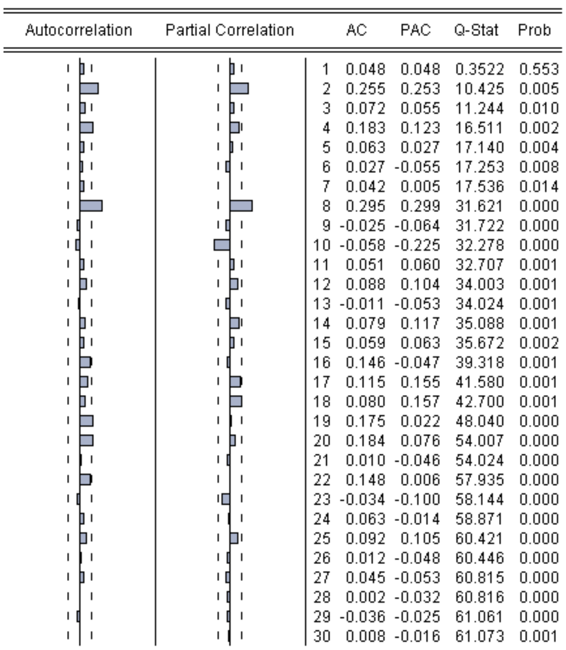
Figure 27: Quarterly Growth Rate of House Price Index in Miami MSA



(a) Squared Value



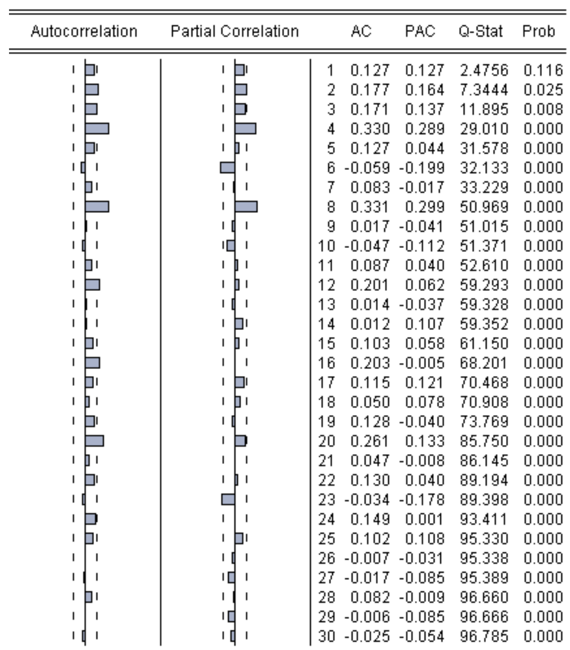
(b) Absolute Value



Sample: 1975Q1 2012Q4
Included observations: 151

Lag	AC	PAC	Q-Stat	Prob
1	0.048	0.048	0.3522	0.553
2	0.255	0.253	10.425	0.005
3	0.072	0.055	11.244	0.010
4	0.183	0.123	16.511	0.002
5	0.063	0.027	17.140	0.004
6	0.027	-0.055	17.253	0.008
7	0.042	0.005	17.536	0.014
8	0.295	0.299	31.621	0.000
9	-0.025	-0.064	31.722	0.000
10	-0.058	-0.225	32.278	0.000
11	0.051	0.060	32.707	0.001
12	0.088	0.104	34.003	0.001
13	-0.011	-0.053	34.024	0.001
14	0.079	0.117	35.088	0.001
15	0.059	0.063	35.672	0.002
16	0.146	-0.047	39.318	0.001
17	0.115	0.155	41.580	0.001
18	0.080	0.157	42.700	0.001
19	0.175	0.022	48.040	0.000
20	0.184	0.076	54.007	0.000
21	0.010	-0.046	54.024	0.000
22	0.148	0.006	57.935	0.000
23	-0.034	-0.100	58.144	0.000
24	0.063	-0.014	58.871	0.000
25	0.092	0.105	60.421	0.000
26	0.012	-0.048	60.446	0.000
27	0.045	-0.053	60.815	0.000
28	0.002	-0.032	60.816	0.000
29	-0.036	-0.025	61.061	0.000
30	0.008	-0.016	61.073	0.001

(c) Correlogram of Squared Value

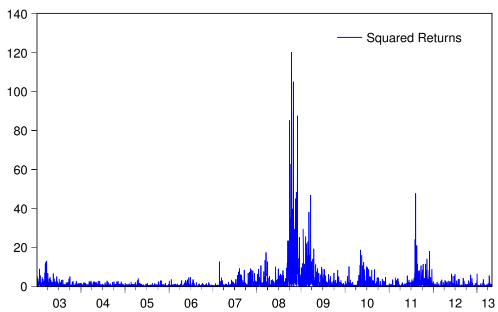


Sample: 1975Q1 2012Q4
Included observations: 151

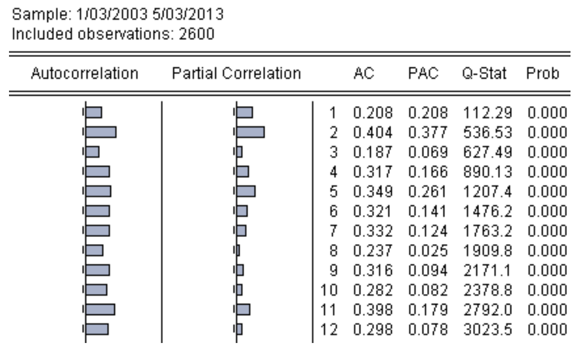
Lag	AC	PAC	Q-Stat	Prob
1	0.127	0.127	2.4756	0.116
2	0.177	0.164	7.3444	0.025
3	0.171	0.137	11.895	0.008
4	0.330	0.289	29.010	0.000
5	0.127	0.044	31.578	0.000
6	-0.059	-0.199	32.133	0.000
7	0.083	-0.017	33.229	0.000
8	0.331	0.299	50.969	0.000
9	0.017	-0.041	51.015	0.000
10	-0.047	-0.112	51.371	0.000
11	0.087	0.040	52.610	0.000
12	0.201	0.062	59.293	0.000
13	0.014	-0.037	59.328	0.000
14	0.012	0.107	59.352	0.000
15	0.103	0.058	61.150	0.000
16	0.203	-0.005	68.201	0.000
17	0.115	0.121	70.468	0.000
18	0.050	0.078	70.908	0.000
19	0.128	-0.040	73.769	0.000
20	0.261	0.133	85.750	0.000
21	0.047	-0.008	86.145	0.000
22	0.130	0.040	89.194	0.000
23	-0.034	-0.178	89.398	0.000
24	0.149	0.001	93.411	0.000
25	0.102	0.108	95.330	0.000
26	-0.007	-0.031	95.338	0.000
27	-0.017	-0.085	95.389	0.000
28	0.082	-0.009	96.660	0.000
29	-0.006	-0.085	96.666	0.000
30	-0.025	-0.054	96.785	0.000

(d) Correlogram of Absolute Value

Figure 28: Quarterly Growth Rate of House Price Index in Chicago MSA



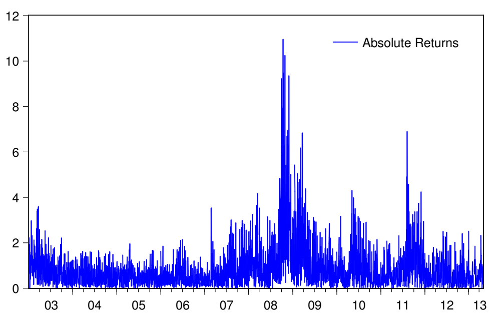
(a) Squared Return



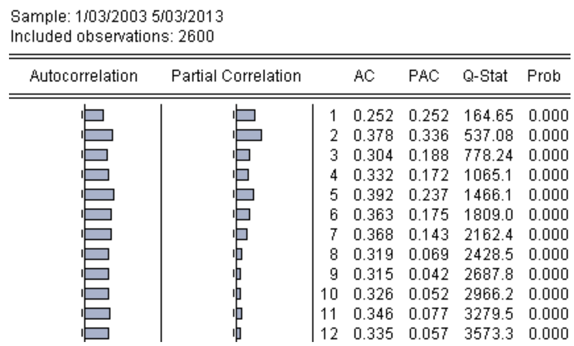
Sample: 1/03/2003 5/03/2013
Included observations: 2600

	AC	PAC	Q-Stat	Prob
1	0.208	0.208	112.29	0.000
2	0.404	0.377	536.53	0.000
3	0.187	0.069	627.49	0.000
4	0.317	0.166	890.13	0.000
5	0.349	0.261	1207.4	0.000
6	0.321	0.141	1476.2	0.000
7	0.332	0.124	1763.2	0.000
8	0.237	0.025	1909.8	0.000
9	0.316	0.094	2171.1	0.000
10	0.282	0.082	2378.8	0.000
11	0.398	0.179	2792.0	0.000
12	0.298	0.078	3023.5	0.000

(b) Correlogram of Squared Return



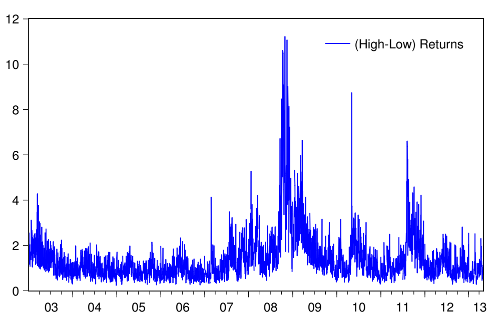
(c) Absolute Return



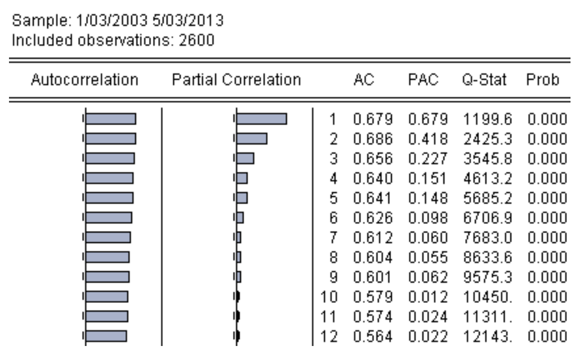
Sample: 1/03/2003 5/03/2013
Included observations: 2600

	AC	PAC	Q-Stat	Prob
1	0.252	0.252	164.65	0.000
2	0.378	0.336	537.08	0.000
3	0.304	0.188	778.24	0.000
4	0.332	0.172	1065.1	0.000
5	0.392	0.237	1466.1	0.000
6	0.363	0.175	1809.0	0.000
7	0.368	0.143	2162.4	0.000
8	0.319	0.069	2428.5	0.000
9	0.315	0.042	2687.8	0.000
10	0.326	0.052	2966.2	0.000
11	0.346	0.077	3279.5	0.000
12	0.335	0.057	3573.3	0.000

(d) Correlogram of Absolute Return



(e) Range of Return

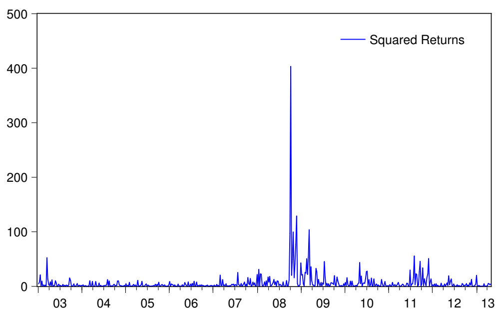


Sample: 1/03/2003 5/03/2013
Included observations: 2600

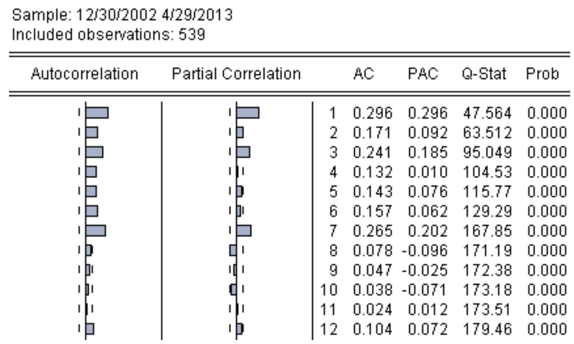
	AC	PAC	Q-Stat	Prob
1	0.679	0.679	1199.6	0.000
2	0.686	0.418	2425.3	0.000
3	0.656	0.227	3545.8	0.000
4	0.640	0.151	4613.2	0.000
5	0.641	0.148	5685.2	0.000
6	0.626	0.098	6706.9	0.000
7	0.612	0.060	7683.0	0.000
8	0.604	0.055	8633.6	0.000
9	0.601	0.062	9575.3	0.000
10	0.579	0.012	10450.	0.000
11	0.574	0.024	11311.	0.000
12	0.564	0.022	12143.	0.000

(f) Correlogram of Range of Return

Figure 29: Daily Returns of S&P500 Index

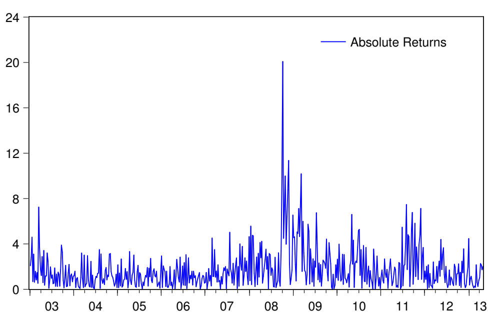


(a) Squared Return

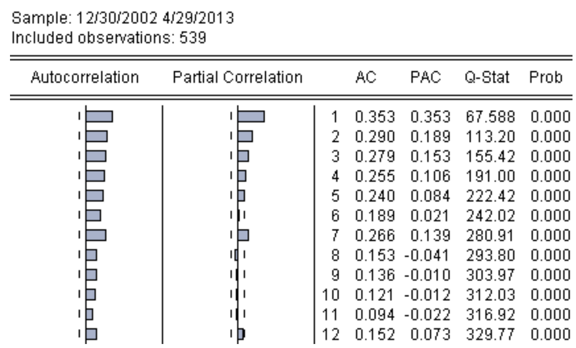

Sample: 12/30/2002 4/29/2013
Included observations: 539

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.296	0.296	47.564	0.000
		2	0.171	0.092	63.512	0.000
		3	0.241	0.185	95.049	0.000
		4	0.132	0.010	104.53	0.000
		5	0.143	0.076	115.77	0.000
		6	0.157	0.062	129.29	0.000
		7	0.265	0.202	167.85	0.000
		8	0.078	-0.096	171.19	0.000
		9	0.047	-0.025	172.38	0.000
		10	0.038	-0.071	173.18	0.000
		11	0.024	0.012	173.51	0.000
		12	0.104	0.072	179.46	0.000

(b) Correlogram of Squared Return

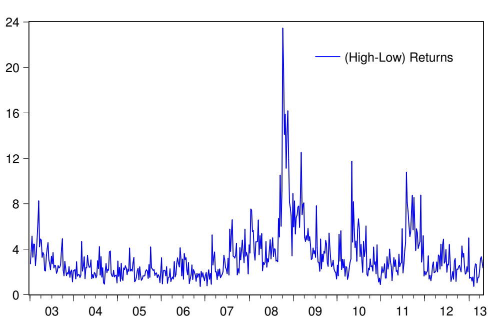


(c) Absolute Return

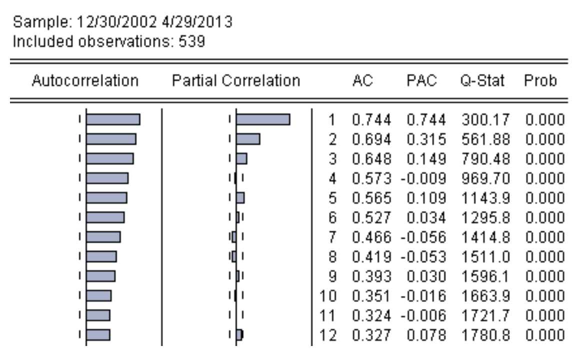

Sample: 12/30/2002 4/29/2013
Included observations: 539

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.353	0.353	67.588	0.000
		2	0.290	0.189	113.20	0.000
		3	0.279	0.153	155.42	0.000
		4	0.255	0.106	191.00	0.000
		5	0.240	0.084	222.42	0.000
		6	0.189	0.021	242.02	0.000
		7	0.266	0.139	280.91	0.000
		8	0.153	-0.041	293.80	0.000
		9	0.136	-0.010	303.97	0.000
		10	0.121	-0.012	312.03	0.000
		11	0.094	-0.022	316.92	0.000
		12	0.152	0.073	329.77	0.000

(d) Correlogram of Absolute Return



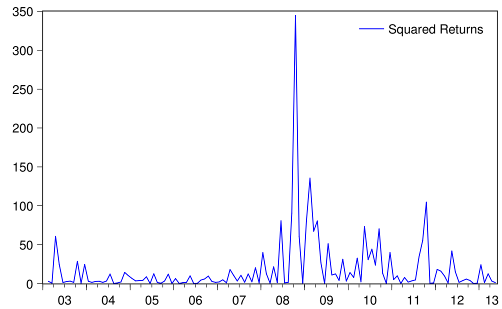
(e) Range of Return


Sample: 12/30/2002 4/29/2013
Included observations: 539

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.744	0.744	300.17	0.000
		2	0.694	0.315	561.88	0.000
		3	0.648	0.149	790.48	0.000
		4	0.573	-0.009	969.70	0.000
		5	0.565	0.109	1143.9	0.000
		6	0.527	0.034	1295.8	0.000
		7	0.466	-0.056	1414.8	0.000
		8	0.419	-0.053	1511.0	0.000
		9	0.393	0.030	1596.1	0.000
		10	0.351	-0.016	1663.9	0.000
		11	0.324	-0.006	1721.7	0.000
		12	0.327	0.078	1780.8	0.000

(f) Correlogram of Range of Return

Figure 30: Weekly Return of S&P500 Index

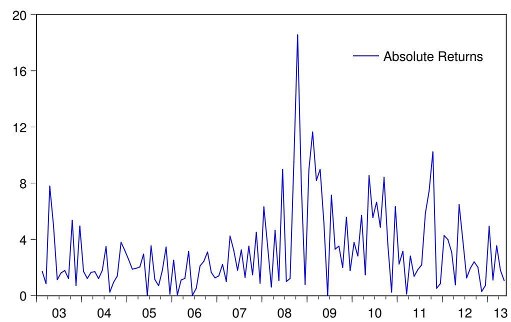


(a) Squared Return

Sample: 2003M01 2013M05
Included observations: 124

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.326	0.326	13.467	0.000
		2	0.062	-0.049	13.967	0.001
		3	0.183	0.199	18.304	0.000
		4	0.400	0.324	39.094	0.000
		5	0.170	-0.053	42.909	0.000
		6	0.134	0.122	45.299	0.000
		7	0.042	-0.142	45.531	0.000
		8	0.024	-0.110	45.606	0.000
		9	0.104	0.097	47.085	0.000
		10	0.016	-0.157	47.121	0.000
		11	-0.035	0.057	47.294	0.000
		12	-0.038	-0.027	47.497	0.000

(b) Correlogram of Squared Return

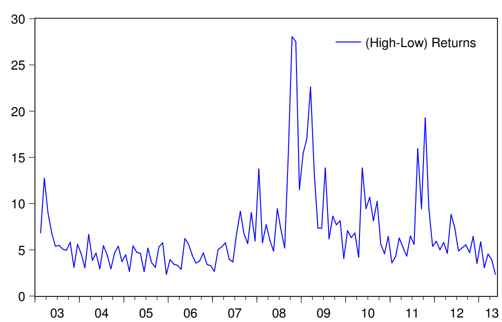


(c) Absolute Return

Sample: 2003M01 2013M05
Included observations: 124

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.284	0.284	10.218	0.001
		2	0.136	0.060	12.587	0.002
		3	0.190	0.150	17.270	0.001
		4	0.375	0.314	35.617	0.000
		5	0.220	0.050	41.981	0.000
		6	0.150	0.043	44.963	0.000
		7	0.109	-0.025	46.535	0.000
		8	0.085	-0.092	47.498	0.000
		9	0.144	0.054	50.313	0.000
		10	0.086	-0.030	51.317	0.000
		11	0.005	-0.062	51.320	0.000
		12	0.044	0.044	51.591	0.000

(d) Correlogram of Absolute Return



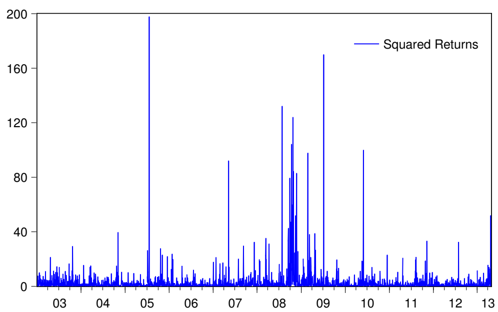
(e) Range of Return

Sample: 2003M01 2013M05
Included observations: 124

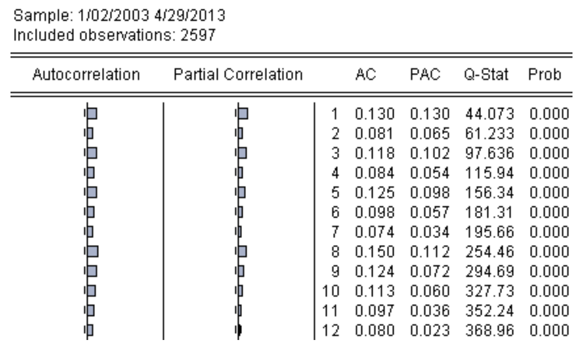
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.626	0.626	49.728	0.000
		2	0.482	0.149	79.523	0.000
		3	0.371	0.035	97.312	0.000
		4	0.435	0.260	122.00	0.000
		5	0.332	-0.078	136.44	0.000
		6	0.200	-0.142	141.74	0.000
		7	0.135	0.012	144.17	0.000
		8	0.169	0.067	148.00	0.000
		9	0.160	0.004	151.45	0.000
		10	0.183	0.137	156.06	0.000
		11	0.096	-0.089	157.34	0.000
		12	0.120	0.029	159.34	0.000

(f) Correlogram of Range of Return

Figure 31: Monthly Return of S&P500 Index



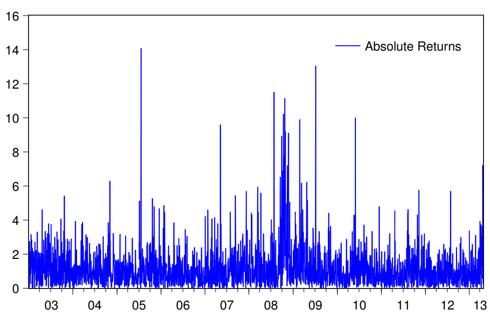
(a) Squared Return



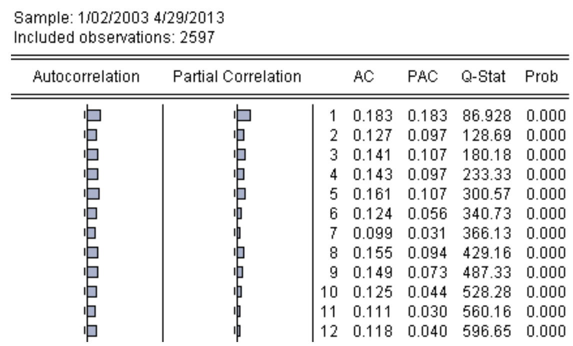
Sample: 1/02/2003 4/29/2013
Included observations: 2597

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.130	0.130	44.073	0.000
		2	0.081	0.065	61.233	0.000
		3	0.118	0.102	97.636	0.000
		4	0.084	0.054	115.94	0.000
		5	0.125	0.098	156.34	0.000
		6	0.098	0.057	181.31	0.000
		7	0.074	0.034	195.66	0.000
		8	0.150	0.112	254.46	0.000
		9	0.124	0.072	294.69	0.000
		10	0.113	0.060	327.73	0.000
		11	0.097	0.036	352.24	0.000
		12	0.080	0.023	368.96	0.000

(b) Correlogram of Squared Return



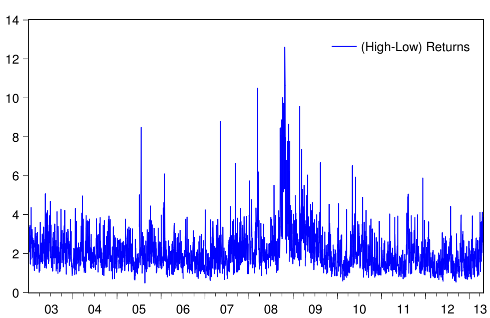
(c) Absolute Return



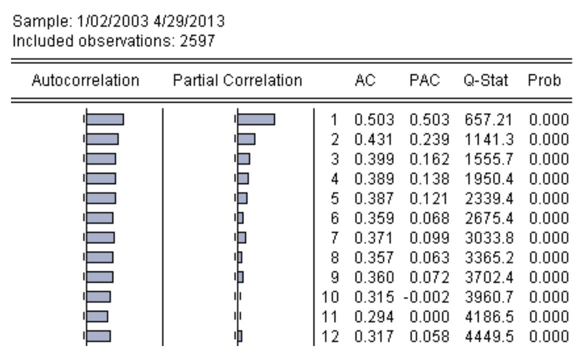
Sample: 1/02/2003 4/29/2013
Included observations: 2597

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.183	0.183	86.928	0.000
		2	0.127	0.097	128.69	0.000
		3	0.141	0.107	180.18	0.000
		4	0.143	0.097	233.33	0.000
		5	0.161	0.107	300.57	0.000
		6	0.124	0.056	340.73	0.000
		7	0.099	0.031	366.13	0.000
		8	0.155	0.094	429.16	0.000
		9	0.149	0.073	487.33	0.000
		10	0.125	0.044	528.28	0.000
		11	0.111	0.030	560.16	0.000
		12	0.118	0.040	596.65	0.000

(d) Correlogram of Absolute Return



(e) Range of Return

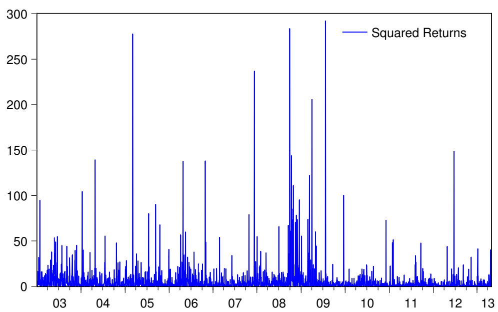


Sample: 1/02/2003 4/29/2013
Included observations: 2597

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.503	0.503	657.21	0.000
		2	0.431	0.239	1141.3	0.000
		3	0.399	0.162	1555.7	0.000
		4	0.389	0.138	1950.4	0.000
		5	0.387	0.121	2339.4	0.000
		6	0.359	0.068	2675.4	0.000
		7	0.371	0.099	3033.8	0.000
		8	0.357	0.063	3365.2	0.000
		9	0.360	0.072	3702.4	0.000
		10	0.315	-0.002	3960.7	0.000
		11	0.294	0.000	4186.5	0.000
		12	0.317	0.058	4449.5	0.000

(f) Correlogram of Range of Return

Figure 32: Daily Stock Return of AMGN

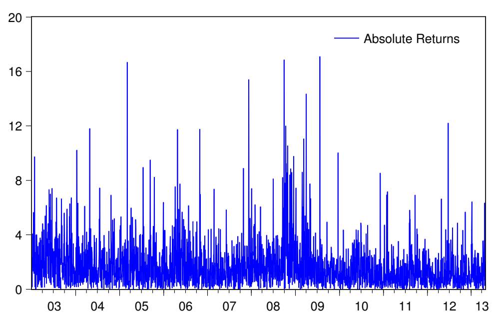


(a) Squared Return

Sample: 1/02/2003 4/30/2013
Included observations: 2598

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.128	0.128	42.310	0.000
		2	0.045	0.029	47.645	0.000
		3	0.049	0.041	53.991	0.000
		4	0.028	0.016	56.003	0.000
		5	0.076	0.069	71.199	0.000
		6	0.050	0.030	77.819	0.000
		7	0.049	0.034	83.963	0.000
		8	0.066	0.049	95.304	0.000
		9	0.071	0.051	108.44	0.000
		10	0.081	0.057	125.68	0.000
		11	0.079	0.052	142.18	0.000
		12	0.058	0.030	151.08	0.000

(b) Correlogram of Squared Return

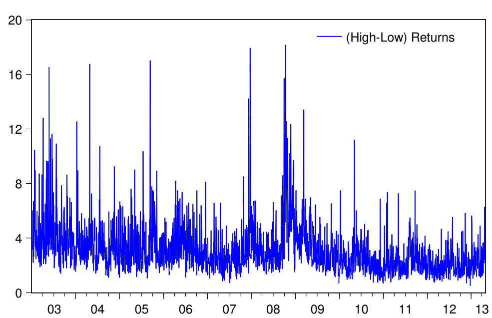


(c) Absolute Return

Sample: 1/02/2003 4/30/2013
Included observations: 2598

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.164	0.164	69.776	0.000
		2	0.121	0.097	107.92	0.000
		3	0.109	0.078	139.01	0.000
		4	0.084	0.047	157.36	0.000
		5	0.114	0.081	191.23	0.000
		6	0.095	0.051	214.73	0.000
		7	0.088	0.044	235.09	0.000
		8	0.103	0.058	262.53	0.000
		9	0.088	0.039	282.92	0.000
		10	0.092	0.042	305.01	0.000
		11	0.114	0.064	339.13	0.000
		12	0.079	0.020	355.30	0.000

(d) Correlogram of Absolute Return



(e) Range of Return

Sample: 1/02/2003 4/30/2013
Included observations: 2598

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.436	0.436	495.55	0.000
		2	0.377	0.230	865.44	0.000
		3	0.352	0.163	1188.1	0.000
		4	0.337	0.127	1484.6	0.000
		5	0.334	0.114	1775.1	0.000
		6	0.293	0.048	1998.8	0.000
		7	0.317	0.100	2261.3	0.000
		8	0.344	0.121	2569.9	0.000
		9	0.320	0.062	2836.9	0.000
		10	0.301	0.039	3073.1	0.000
		11	0.276	0.014	3272.5	0.000
		12	0.276	0.028	3471.8	0.000

(f) Correlogram of Range of Return

Figure 33: Daily Stock Return of CELG