FE 5217: Seminar in Risk Management and Alternative Investment: Algorithmic Trading and Quantitative Strategies–Assignment 4, Solutions

Yin Teng

A0068164B, DSAP, NUS

1 Solutions of Problem 1

1.1 Q1.1

Table 1 presents monthly average returns of the first quartile and fourth quartile portfolio as well as their difference.

No. of Month	First Quartile	Fourth Quartile	Difference
1	-0.00361	-0.00024	0.00337
2	0.01011	0.00963	-0.00048
3	-0.00404	0.00325	0.00729
4	0.00943	0.01504	0.00561
5	-0.00850	0.00071	0.00920
6	0.00842	-0.00589	-0.01431
7	0.03199	-0.01484	-0.04683
8	-0.01639	-0.00569	0.01070
9	-0.00853	-0.01310	-0.00456
10	0.01892	0.02752	0.00860
11	0.00311	-0.00044	-0.00355
12	-0.01040	0.00163	0.01202
13	0.01294	-0.00408	-0.01703
14	-0.02091	-0.02137	-0.00046
15	-0.07065	-0.02203	0.04862

16	0.00095	-0.01748	-0.01843
17	0.02304	0.00113	-0.02191
18	0.01408	0.00452	-0.00956
19	0.00370	-0.01034	-0.01404
20	0.01428	0.00541	-0.00887
21	0.00490	-0.00554	-0.01044
22	-0.01374	0.00481	0.01855
23	0.00483	-0.00856	-0.01339
24	-0.02014	-0.01256	0.00759
25	-0.02063	-0.01404	0.00658
26	0.01794	0.00206	-0.01588
27	0.00018	-0.00512	-0.00529
28	0.01971	0.02655	0.00684
29	0.01762	0.01821	0.00059
30	-0.00272	-0.00624	-0.00352
31	-0.01146	-0.00801	0.00344
32	-0.00918	-0.01031	-0.00113
33	0.01191	0.00943	-0.00248
34	0.01938	0.01502	-0.00436
35	0.00788	0.00884	0.00096
36	0.00883	0.00255	-0.00628
37	0.00304	0.00237	-0.00067
38	-0.00019	0.00155	0.00174
39	-0.00097	0.00084	0.00181
40	-0.00537	0.01427	0.01964
41	0.00084	0.00223	0.00139
42	0.01439	0.01179	-0.00260

43	0.01048	0.00108	-0.00940
44	0.01178	-0.00009	-0.01187
45	-0.00942	-0.00464	0.00478
46	-0.00101	-0.01293	-0.01192
47	0.00411	-0.00230	-0.00641
48	0.00314	0.00481	0.00167
49	0.00132	0.00283	0.00151
50	-0.00826	0.00218	0.01043
51	0.00592	0.00091	-0.00502
52	-0.01359	-0.00244	0.01115
53	0.00888	0.01090	0.00202
54	0.00773	-0.00310	-0.01083
55	-0.00992	-0.00499	0.00493
56	0.00910	0.00683	-0.00227
57	-0.01648	-0.00280	0.01368
58	-0.00059	-0.00765	-0.00706
59	0.00912	0.00468	-0.00444
60	0.00663	-0.00278	-0.00941
61	0.01284	0.00399	-0.00885
62	-0.00782	0.00197	0.00979
63	-0.00204	-0.00150	0.00054
64	0.01040	-0.00570	-0.01610
65	0.00572	0.00990	0.00419

Table 1: Monthly average returns of the first quartile and fourth quartile portfolio as well as their difference

1.2 Q1.2

Table 2 presents monthly average returns of the first quartile and fourth quartile portfolio as well as the difference for January. Table 3 presents monthly average returns

January	First Quartile	Fourth Quartile	Difference
1	0.03199	-0.01484	-0.04683
2	0.00370	-0.01034	-0.01404
3	-0.01146	-0.00801	0.00344
4	0.01048	0.00108	-0.00940
5	-0.00992	-0.00499	0.00493

Table 2: Monthly average returns of the first quartile and fourth quartile portfolio as well as the difference for January

of the first quartile and fourth quartile portfolio as well as the difference for non-January

non-January	First Quartile	Fourth Quartile	Difference
1	-0.00361	-0.00024	0.00337
2	0.01011	0.00963	-0.00048
3	-0.00404	0.00325	0.00729
4	0.00943	0.01504	0.00561
5	-0.00850	0.00071	0.00920
6	0.00842	-0.00589	-0.01431
7	-0.01639	-0.00569	0.01070
8	-0.00853	-0.01310	-0.00456
9	0.01892	0.02752	0.00860
10	0.00311	-0.00044	-0.00355
11	-0.01040	0.00163	0.01202
12	0.01294	-0.00408	-0.01703

13	-0.02091	-0.02137	-0.00046
14	-0.07065	-0.02203	0.04862
15	0.00095	-0.01748	-0.01843
16	0.02304	0.00113	-0.02191
17	0.01408	0.00452	-0.00956
18	0.01428	0.00541	-0.00887
19	0.00490	-0.00554	-0.01044
20	-0.01374	0.00481	0.01855
21	0.00483	-0.00856	-0.01339
22	-0.02014	-0.01256	0.00759
23	-0.02063	-0.01404	0.00658
24	0.01794	0.00206	-0.01588
25	0.00018	-0.00512	-0.00529
26	0.01971	0.02655	0.00684
27	0.01762	0.01821	0.00059
28	-0.00272	-0.00624	-0.00352
29	-0.00918	-0.01031	-0.00113
30	0.01191	0.00943	-0.00248
31	0.01938	0.01502	-0.00436
32	0.00788	0.00884	0.00096
33	0.00883	0.00255	-0.00628
34	0.00304	0.00237	-0.00067
35	-0.00019	0.00155	0.00174
36	-0.00097	0.00084	0.00181
37	-0.00537	0.01427	0.01964
38	0.00084	0.00223	0.00139
39	0.01439	0.01179	-0.00260

40	0.01178	-0.00009	-0.01187
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43	0.00411	-0.00230	-0.00641
44	0.00314	0.00481	0.00167
45	0.00132	0.00283	0.00151
46	-0.00826	0.00218	0.01043
47	0.00592	0.00091	-0.00502
48	-0.01359	-0.00244	0.01115
49	0.00888	0.01090	0.00202
50	0.00773	-0.00310	-0.01083
51	0.00910	0.00683	-0.00227
52	-0.01648	-0.00280	0.01368
53	-0.00059	-0.00765	-0.00706
54	0.00912	0.00468	-0.00444
55	0.00663	-0.00278	-0.00941
56	0.01284	0.00399	-0.00885
57	-0.00782	0.00197	0.00979
58	-0.00204	-0.00150	0.00054
59	0.01040	-0.00570	-0.01610
60	0.00572	0.00990	0.00419

Table 3: Monthly average returns of the first quartile and fourth quartile portfolio as well as the difference for nonJanuary

1.3 Q1.3

CAMP model is

$$E(R_i) = R_f + \beta(E(R_M) - R_f)$$

Where R_i is the portfolio return; R_M is SP500 return; R_f is risk free rate, which is assumed to be 2%. TableCAMP presents the results From Table 4 we know the spread

	Estimate	Std.Error	t Value	p-value
β	0.1618	0.1234	1.312	0.194

Table 4: CAPM model

between winner and loser can not be explained by CAMP model.

1.4 Q1.4

Table 5 presents results of previous questions in a table similar to table I in Jegadeesh and Titman (2001).

	2000-2005
Q1 (First Quartile)	0.09
Q4 (Fourth Quartile)	1.01
Q4-Q1	0.01
t statistic	3.09

Table 5: Monthly average returns

1.5 Q1.5

Comparing table 5 to Table I in Jegadeesh and Titman (2001), we see our winner portfolio has less return than the first 10 percent of the stocks in Jegadeesh and Titman (2001). Our return is 1.01% whereas their return is 1.65%. However, our loser has similar return as their loser. Our t statistic is 3.09.

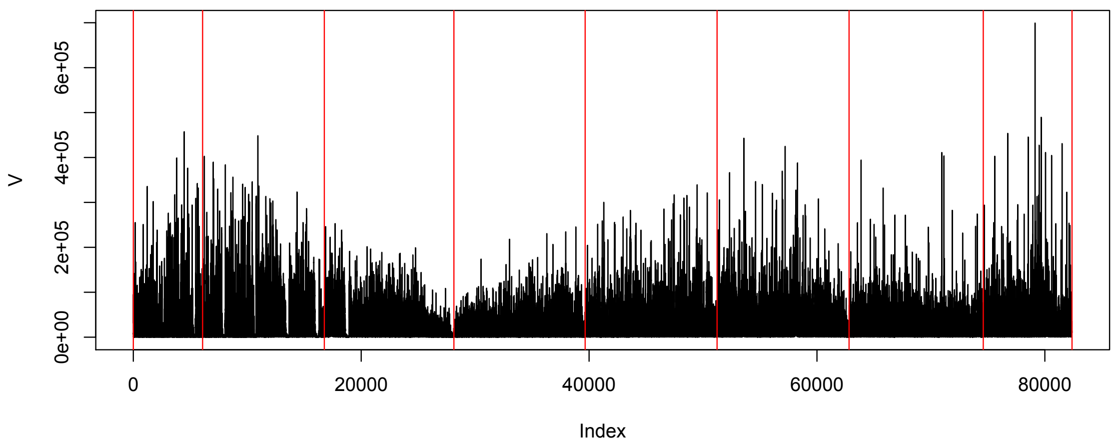

Figure 1: Plot of time series of the 30-min volume

2 Solutions of Problem 2

2.1 Q2.1

In the first place, we develop ARMA time series model for the 30-min volume. Figure 1 shows the plot of time series of the 30-min volume. The red vertical lines separate years. From Figure 1, we can see there exist seasonality for the 30-min volume. The volume is high in the middle of the year and is low at the beginning or the end of the year.

In order to build ARMA model, we need to determine the order of the model. Figure 2 and 3 show the autocorrelation coefficients and partial autocorrelation coefficients of 30-min volume data. The autocorrelations are significant for a large number of lags, but perhaps the autocorrelations at lags 2 and above are merely due to the propagation of the autocorrelation at lag 1. This is confirmed by the PACF plot (Figure 3). Note that the PACF plot has a significant spike only at lag 1, meaning that all the higher-order autocorrelations are effectively explained by the lag-1 autocorrelation. Therefore, we

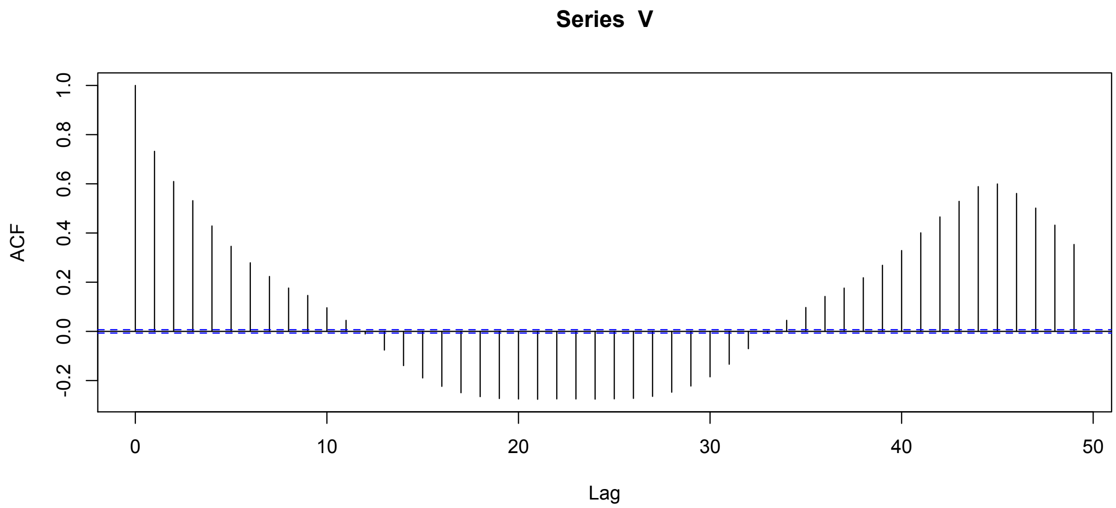

Figure 2: ACF of time series of the 30-min volume

choose first order autocorrelation model. We also choose order 1 for moving average model. The ARMA (1,1) model for 30-min volume data is

$$V_t = 3302 + 0.8397V_{t-1} - 0.2396\epsilon_{t-1} + \epsilon_t$$

where $\epsilon_t \sim N(0, \sigma^2)$ and $\sigma^2 = 441178023$.

In addition, we also build ARMA model for daily data. Figure 4 shows the plot of time series for daily volume data. Figure 5 and 6 show the autocorrelation coefficients and partial autocorrelation coefficients of daily volume data. Similar to 30-min volume data, we build ARMA (1,1), which is

$$V_t = 0.9921V_{t-1} - 0.6116\epsilon_{t-1} + \epsilon_t$$

where $\epsilon_t \sim N(0, \sigma^2)$ and $\sigma^2 = 1.123 \times 10^{11}$.

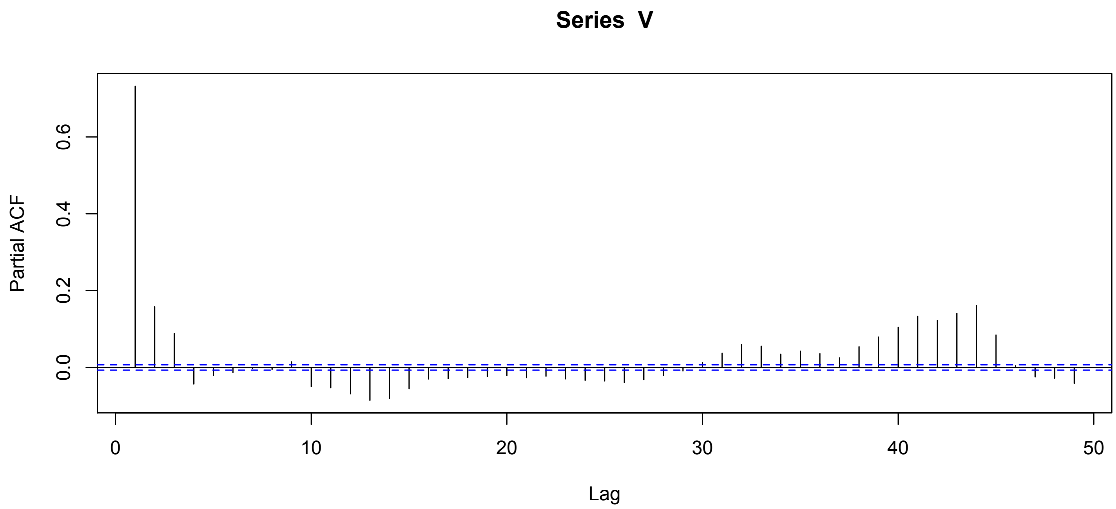

Figure 3: PACF of time series of the 30-min volume

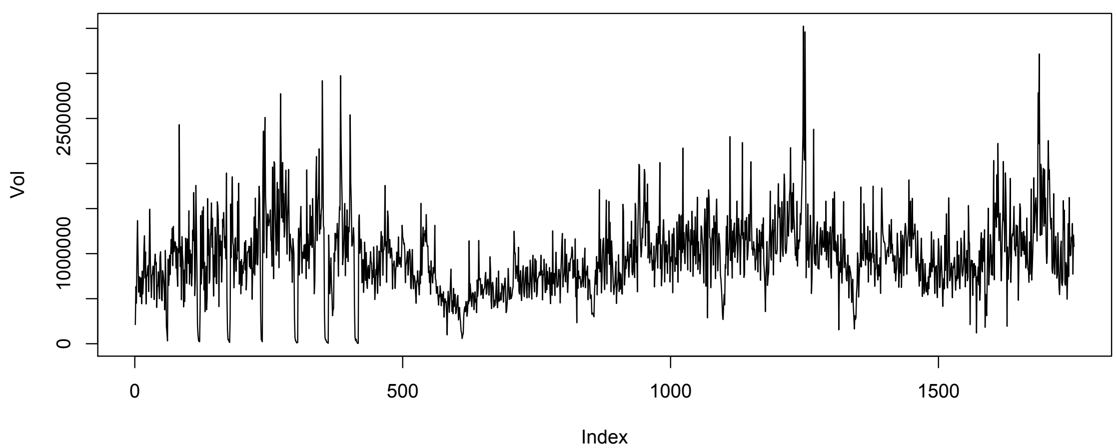

Figure 4: Plot of time series of the 30-min volume

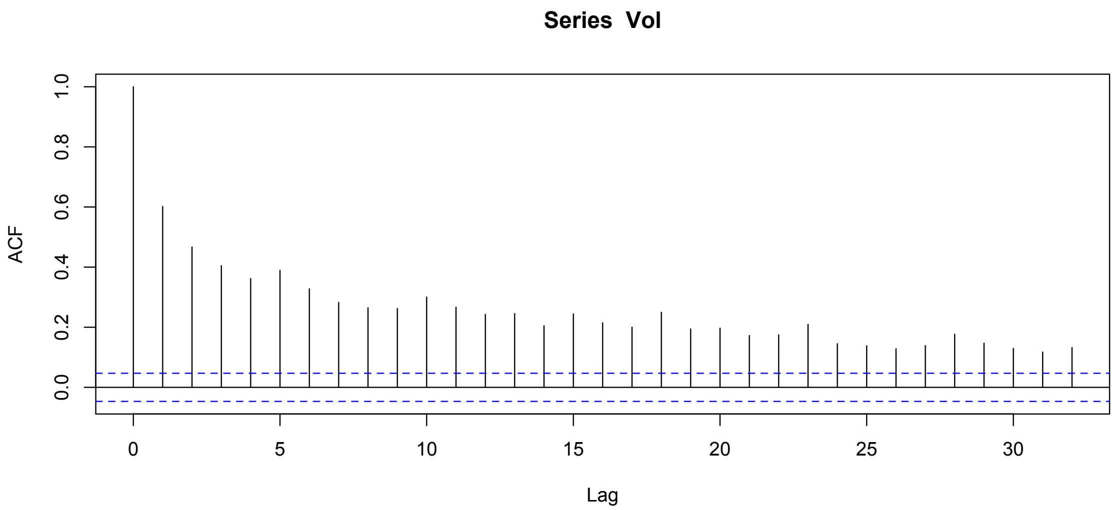

Figure 5: ACF of time series of the daily volume

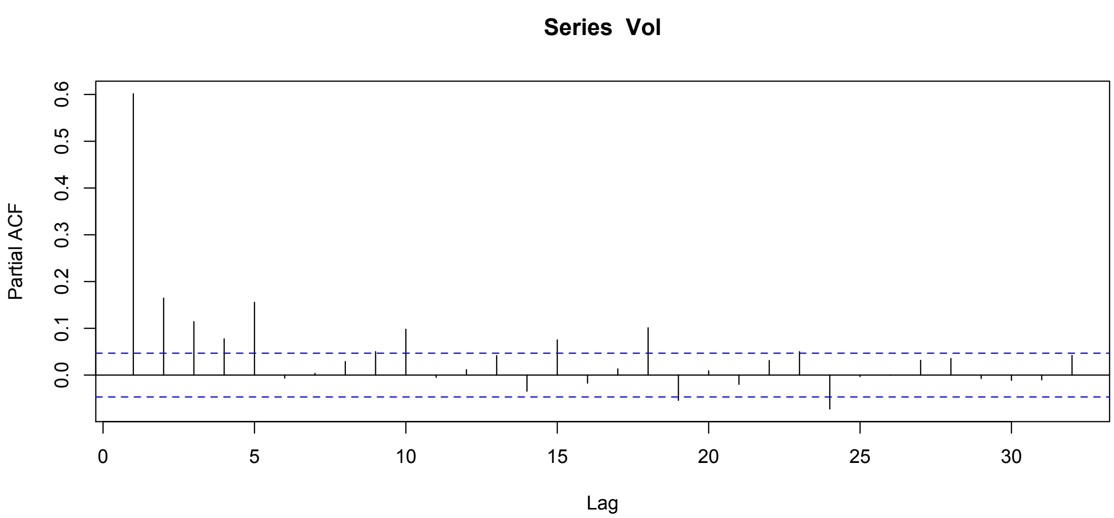

Figure 6: PACF of time series of the daily volume

```
> summary(arma(V,c(1,1)))

Call:
arma(x = V, order = c(1, 1))

Model:
ARMA(1,1)

Residuals:
      Min        1Q    Median        3Q       Max 
-328090.9   -5518.5   -3852.7     707.5  488144.5 

Coefficient(s):
            Estimate  Std. Error  t value Pr(>|t|)    
ar1        8.397e-01   2.518e-03   333.48   <2e-16 ***
ma1       -2.396e-01   4.501e-03   -53.23   <2e-16 ***
intercept  3.302e+03   7.602e+01    43.44   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Fit:
sigma^2 estimated as 441178023,  Conditional Sum-of-Squares = 3.634557e+13,  AIC = 
1873675

>  summary(arma(Vol,c(1,1),include.intercep=F))

Call:
arma(x = Vol, order = c(1, 1), include.intercept = F)

Model:
ARMA(1,1)

Residuals:
     Min       1Q   Median       3Q      Max 
-1762798  -172604     5034   188501  1652163 

Coefficient(s):
     Estimate  Std. Error  t value Pr(>|t|)    
ar1  0.992105    0.003271   303.28   <2e-16 ***
ma1 -0.611605    0.028553   -21.42   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Fit:
sigma^2 estimated as 1.123e+11,  Conditional Sum-of-Squares = 1.973936e+14,  AIC = 
49582.79

> 
```

2.2 Q2.2

The volatility measure is computed as

$$\sigma_t^2 = 0.5[\ln(\frac{H_t}{L_t})]^2 - 0.368[\ln(\frac{C_t}{O_t})]^2$$

Figure 7 and 8 present the volatility for both levels. Compare the volatility for micro and macro level, we can see clearly it is bigger for micro level.

2.3 Q2.3

Figure 9 and 10 present the predictions of volatility for both levels.

2.4 Q2.4

In this question, strategies in Note1.pdf are followed.

2.4.1 Price information only

We use Moving average strategy, that is

$$\text{If } P_t < \text{Moving average of } P_{t-1}, \ldots, P_{t-m} \quad \text{Buy the stock}$$

$$\text{If } P_t > \text{Moving average of } P_{t-1}, \ldots, P_{t-m} \quad \text{Sell the stock}$$

Where P_t is close price. We also assume the initial investment is 1\$. We choose $m = 20$. Figure 11 presents the value of our investment for 30-min data and Figure 12 presents the value of our investment for daily data

From Figure 11 we know if we use Moving average strategy, our final value of investment is 1.205488\$. That is we have over 20% profit. If we use daily data, the final value of investment is 1.185087\$.

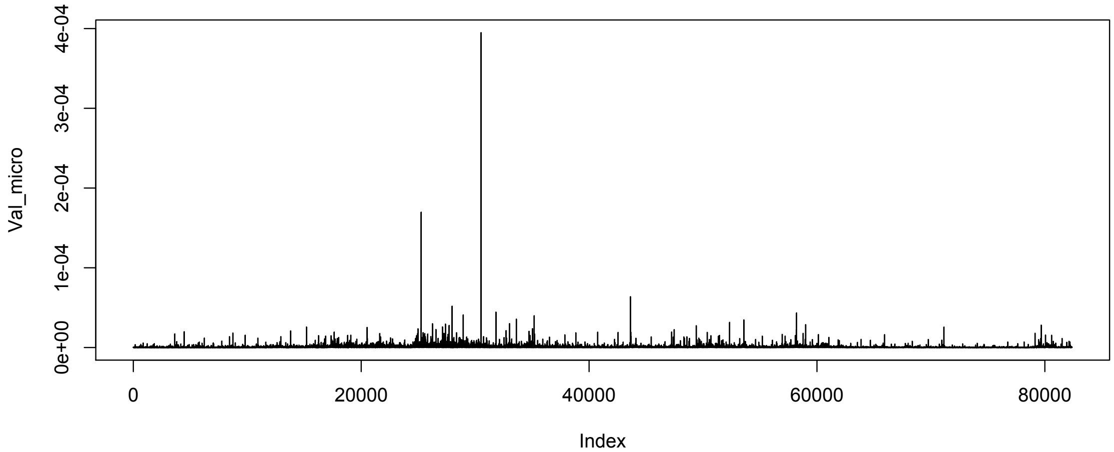

Figure 7: Volatility measure for micro level

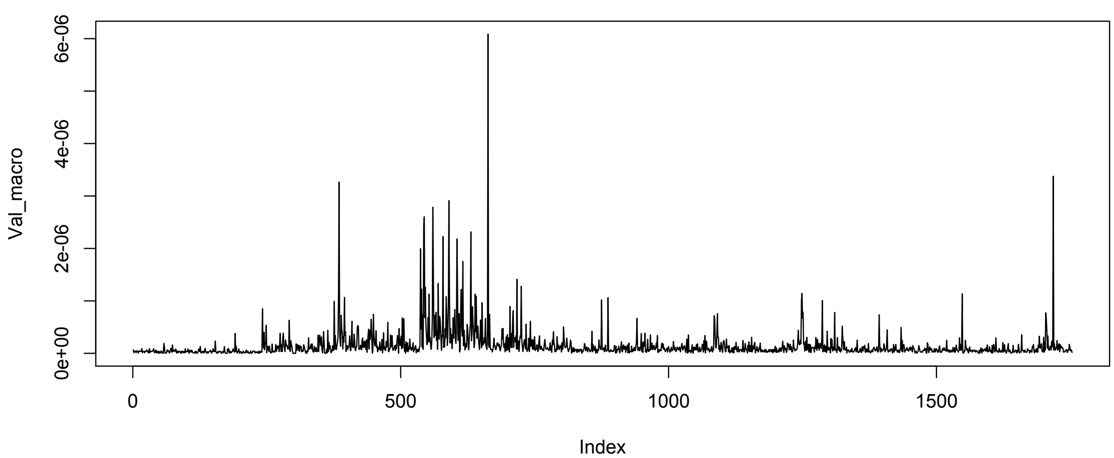

Figure 8: Volatility measure for macro level

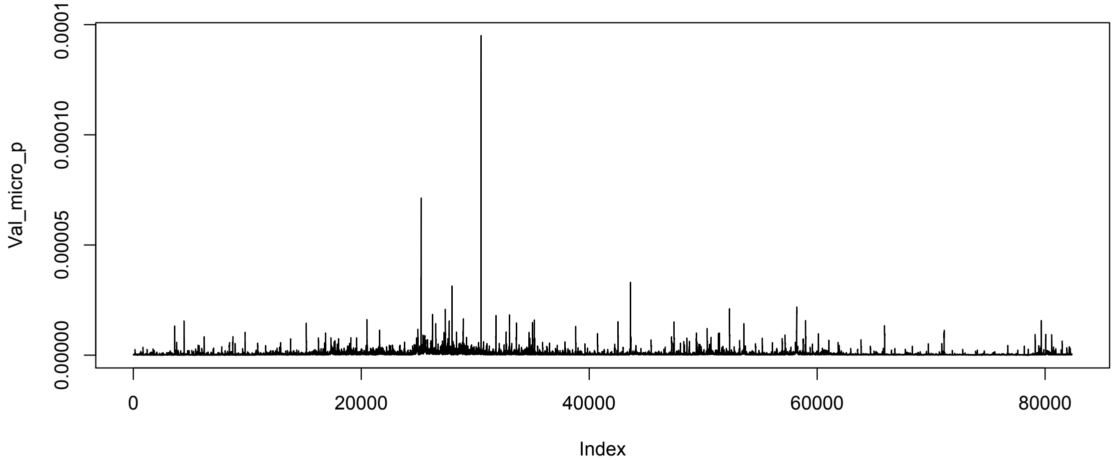

Figure 9: Prediction of volatility for micro level

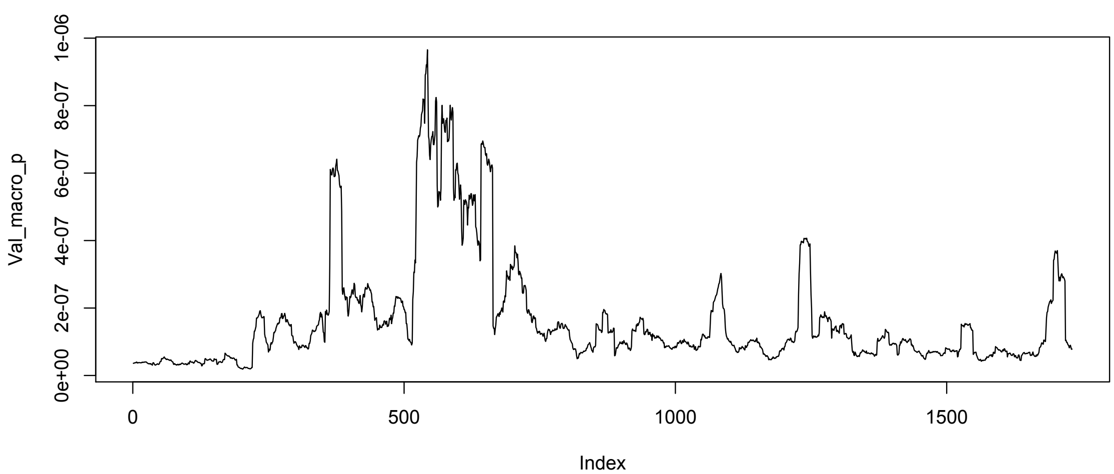

Figure 10: Prediction of volatility for macro level

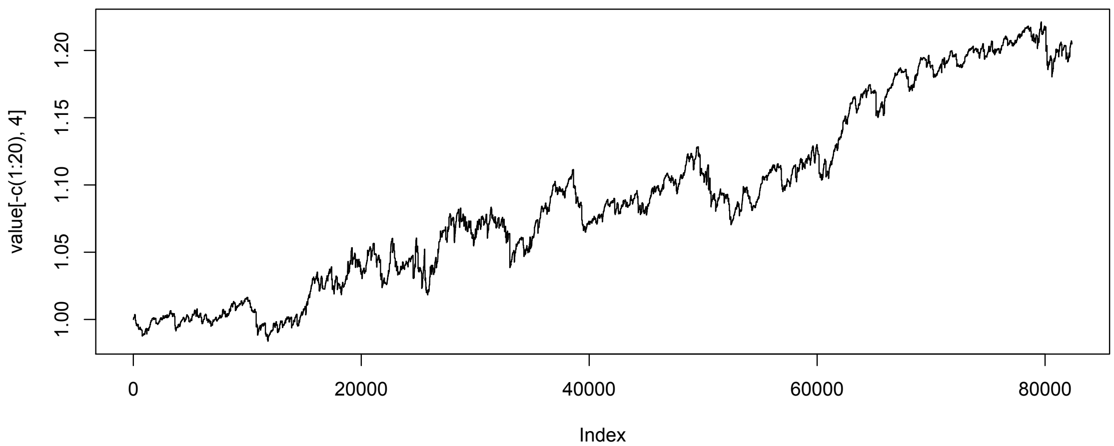

Figure 11: Value of trading strategies only incorporate price information (30-min data)

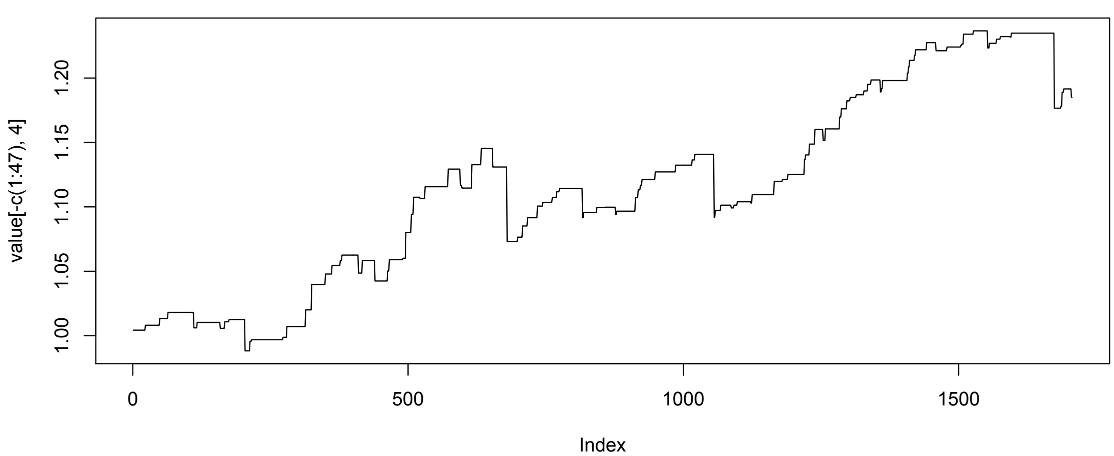

Figure 12: Value of trading strategies only incorporate price information (daily data)

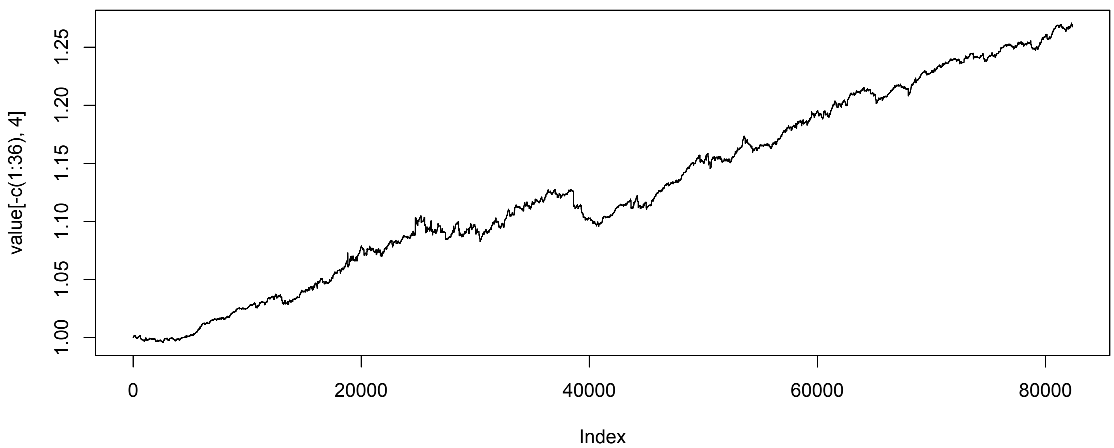

Figure 13: Value of trading strategies only incorporate price and volume information (30-min data)

2.4.2 Price and volume information

The prediction of volume is computed by exponential smoothing. The smoothing constant is 0.25.The trading strategy is

If $P_t <$ Moving average of $P_{t-1}, \ldots, P_{t-m}$ and $\sum_{i=1}^{20} v_{t+1\cdot m} < \sum_{i=1}^{20} \hat{v}_{t+1\cdot m}$ Buy the stock

If $P_t >$ Moving average of $P_{t-1}, \ldots, P_{t-m}$ or $\sum_{i=1}^{20} v_{t+1\cdot m} > \sum_{i=1}^{20} \hat{v}_{t+1\cdot m}$ Sell the stock

If we use daily data, $v_{t+1\cdot m}$ is substituted by v_{t+1} and $\hat{v}_{t+1\cdot m}$ is substituted by $\hat{v}_{t+1}$.

Figure 13 presents the value of our investment. From it we can see, our final value is 1.267507$. If we use daily data and follow same strategy, our final value is 1.334073$ (see Figure 14)

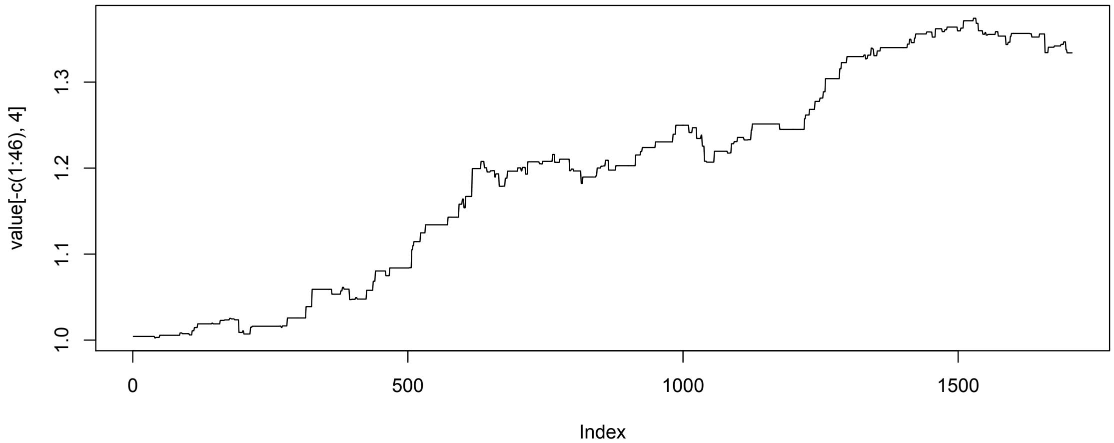

Figure 14: Value of trading strategies incorporate price and volume information (daily data)

2.4.3 Price, volume and volatility strategy

We use the volatility prediction obtained in the previous question. The prediction of volume is computed by exponential smoothing. The smoothing constant is 0.25.The trading strategy is

$$\begin{aligned}
&\text{If } P_t < \text{Moving average of } P_{t-1}, \ldots, P_{t-m} \\
&\qquad \text{and } \sum_{i=1}^{20} v_{t+1\cdot m} < \sum_{i=1}^{20} \hat{v}_{t+1\cdot m} \quad \text{Buy the stock} \\
&\qquad \text{and } \sigma^2_{t+1\cdot m} < \hat{\sigma}^2_{t+1\cdot m} \\
&\text{If } P_t > \text{Moving average of } P_{t-1}, \ldots, P_{t-m} \\
&\qquad \text{or } \sum_{i=1}^{20} v_{t+1\cdot m} > \sum_{i=1}^{20} \hat{v}_{t+1\cdot m} \quad \text{Sell the stock} \\
&\qquad \text{or } \sigma^2_{t+1\cdot m} > \hat{\sigma}^2_{t+1\cdot m}
\end{aligned}$$

If we use daily data, $\sigma^2_{t+1\cdot m}$ is substituted by σ^2_{t+1} and $\hat{\sigma}^2_{t+1\cdot m}$ is substituted by $\hat{\sigma}^2_{t+1}$.

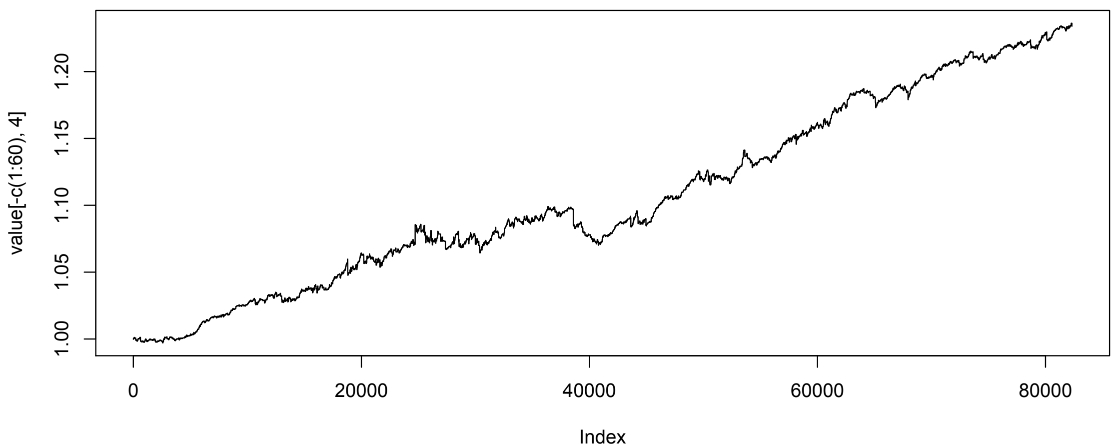

Figure 15: Value of trading strategies only incorporate price and volume information (30-min data)

Figure 15 presents the value of our investment. From it we can see, our final value is 1.233997$. If we use daily data and follow same strategy, our final value is 1.299696$ (see Figure 16)

2.4.4 Conclusion

Table 2.4.4 presents the conclusion of all strategies. We can see that using price and volume information and daily data, we have highest value of initial investment.

Strategy	30-min data ($)	daily ($)
Price information	1.205488	1.185087
Price and volume information	1.267507	1.334073
Price, volume and volatility	1.233997	1.299696

Table 6: Conclusions of three strategies

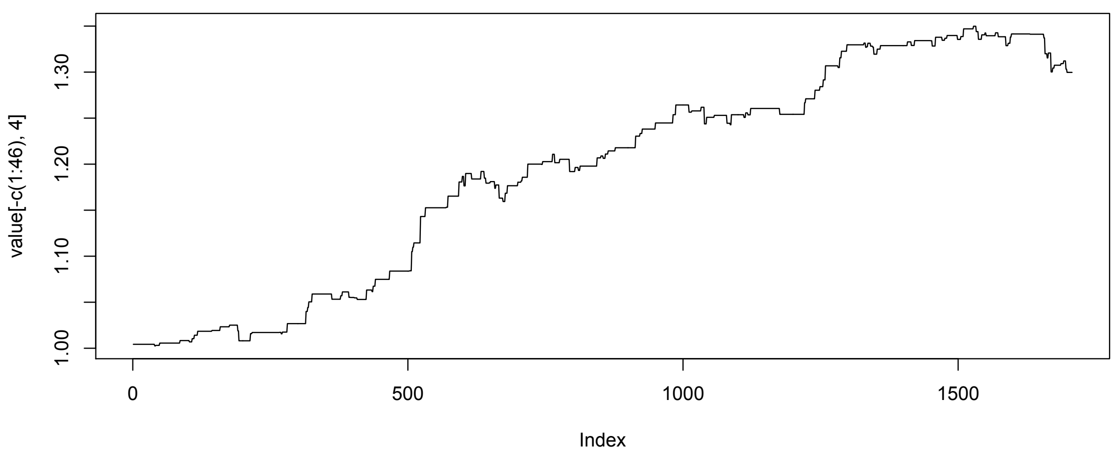

Figure 16: Value of trading strategies incorporate price and volume information (daily data)