New York University

Tandon School of Engineering

Financial Econometrics – FRE6083

Personal Project: Exchange Rate Regime Analysis for the Chinese Yuan

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1. PRESENTATION OF THE REFERENCE ARTICLE

1.1 Purpose of the Article

We reviewed the 2010 article "Exchange Rate Regime Analysis for the Chinese Yuan " published by Achim Zeileis, Ajay Shah and Ila Patnaik.

This chosen article investigates the exchange rate regime from 2005-07-25 till 2009-07-31 for the Chinese Yuan CNY which was fixed to the US dollar USD in the years leading up to mid-2005. In July 2005, China announced a small appreciation of CNY, and, in addition, a reform of the exchange rate regime. This reform involved a shift away from the fixed exchange rate to a basket of currencies with greater flexibility. This paper would like to find out if it is true that China is moving away from a USD peg.

1.2 Methodology

The main outcome variable of interest or dependent variable, is the log return of exchange rate of CNY based on CHF. The independent variables are log return of exchange rate of USD based on CHF , log return of exchange rate of JPY based on CHF log return of exchange rate of EUR based on CHF and log return of exchange rate of GBP based on CHF. These independent variables are chosen as a basket of the most important floating currencies (USD, JPY, EUR, GBP).

The specific linear regression model fitted to the data was:

$$\text{CNY} = b_0 + b_1(\text{USD}) + b_2(\text{JPY}) + b_3(\text{EUR}) + b_4(\text{GBP})$$

Where b_0 is a constant, b_1, b_2, ... b_4 are coefficients or estimates for the parameters.

1.3 Data Source

This article used a large data set derived from exchange rates available online from the US Federal Reserve provided in the FXRatesCHF data set in fxregime.

1.4 Data Analysis

To begin this investigation, this article start from an analysis from autumn 2005: Using daily returns for the first three months after the announcement and established a stable exchange regression and monitored it in the subsequent months.

And the outcome is as following:

```
> summary(cny_lm)

Call:

fxlm(formula = CNY ~ USD + JPY + EUR + GBP, data = window(cny,

   end = as.Date("2005-10-31")))
```

```
Residuals:
      Min        1Q    Median        3Q       Max
-0.065697 -0.021036  0.001147  0.021440  0.069985

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.004782   0.003688  -1.297    0.199
USD          0.999653   0.008779 113.868   <2e-16 ***
JPY          0.004668   0.010669   0.437    0.663
EUR         -0.014238   0.026516  -0.537    0.593
GBP         -0.007744   0.014568  -0.532    0.597
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.02953 on 63 degrees of freedom
Multiple R-squared:  0.9979,  Adjusted R-squared:  0.9978
F-statistic:  7577 on 4 and 63 DF,  p-value: < 2.2e-16
```

A very clear USD peg is signaling here.

Then to capture the fluctuation in the parameters, the associated empirical fluctuation process is computed showed in figure 1:

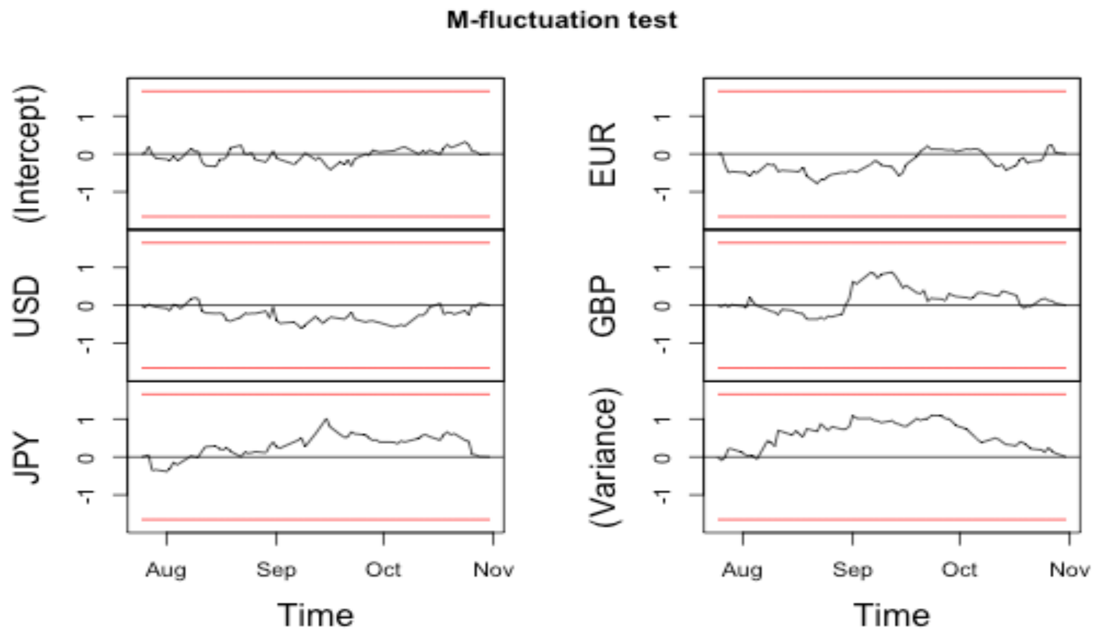
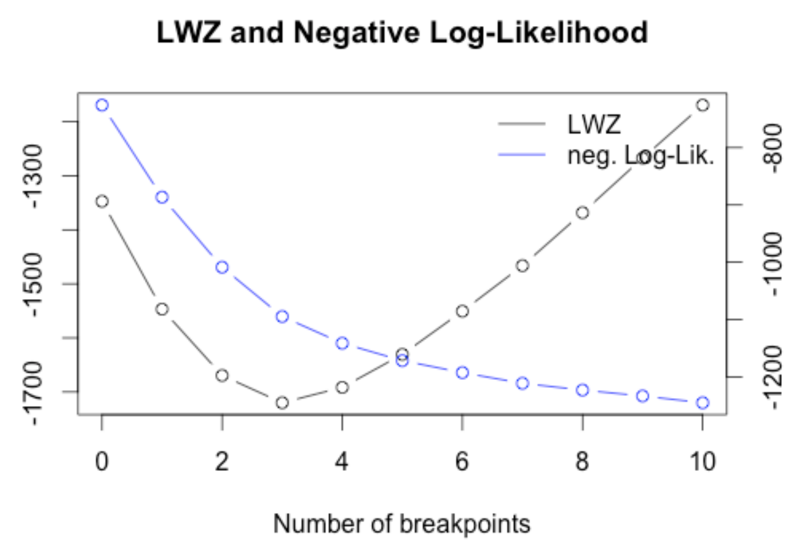


Figure 1 shows that the fluctuation in the parameters during this history period is very small and non-significant.

To capture the changes in the China's exchange rate regime, this article fits a segmented exchange rate regression based on the full extended data set which is showed in Figure 2:

```
> cny_reg <- fxregimes(CNY ~ USD + JPY + EUR + GBP, data = cny, h = 20, breaks = 10)
```



In Figure 2, the LWZ criterion that assumes its minimum is for 3 breaks so a 3-break (or 4-segment) model is chosen. And the breakpoints dates are computed as following:

```
Corresponding to breakdates:
       5 % breakpoints       95 %
1 2006-02-21  2006-03-14 2006-03-15
2 2008-07-31  2008-08-22 2008-08-25
3 2008-12-30  2008-12-31 2009-01-22
```

A complete summary is computed as following:

```
$`2005-07-26--2006-03-14`

Call:
fxlm(formula = object$formula, data = window(object$data, start = sbp[i],
    end = ebp[i]))

Residuals:
      Min        1Q    Median        3Q       Max
-0.106628 -0.015830  0.001518  0.016454  0.090368

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.005033   0.002266  -2.221   0.0278 *
USD          0.999410   0.005421 184.370   <2e-16 ***
JPY          0.005184   0.005230   0.991   0.3231
EUR         -0.015244   0.016588  -0.919   0.3596
GBP          0.006839   0.008257   0.828   0.4088
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.02841 on 153 degrees of freedom
Multiple R-squared:  0.9979,  Adjusted R-squared:  0.9978
F-statistic: 1.788e+04 on 4 and 153 DF,  p-value: < 2.2e-16


$`2006-03-15--2008-08-22`

Call:
fxlm(formula = object$formula, data = window(object$data, start = sbp[i],
    end = ebp[i]))

Residuals:
     Min       1Q   Median       3Q      Max
-0.44652 -0.06071  0.01135  0.06138  0.45665

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.024993   0.004300  -5.812 9.92e-09 ***
USD          0.969398   0.011533  84.054  < 2e-16 ***
JPY         -0.009322   0.010450  -0.892    0.373
EUR          0.025594   0.022943   1.116    0.265
GBP         -0.012868   0.012147  -1.059    0.290
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1067 on 615 degrees of freedom
Multiple R-squared:  0.9649,  Adjusted R-squared:  0.9646
F-statistic:  4223 on 4 and 615 DF,  p-value: < 2.2e-16
```

```
$`2008-08-25--2008-12-31`

Call:
fxlm(formula = object$formula, data = window(object$data, start = sbp[i],
    end = ebp[i]))

Residuals:
     Min       1Q   Median       3Q      Max
-0.97806 -0.11418 -0.01290  0.09812  0.87997

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.014770   0.029756  -0.496    0.621
USD          1.030744   0.043672  23.602   <2e-16 ***
JPY         -0.026479   0.030149  -0.878    0.382
EUR          0.048853   0.058852   0.830    0.409
GBP          0.007187   0.035289   0.204    0.839
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2713 on 83 degrees of freedom
Multiple R-squared:  0.9562,  Adjusted R-squared:  0.954
F-statistic: 452.6 on 4 and 83 DF,  p-value: < 2.2e-16


$`2009-01-02--2009-07-31`

Call:
fxlm(formula = object$formula, data = window(object$data, start = sbp[i],
    end = ebp[i]))

Residuals:
      Min        1Q    Median        3Q       Max
-0.225789 -0.021239 -0.000453  0.019380  0.145003

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.001351   0.003734   0.362   0.7179
USD          0.980939   0.005081 193.060   <2e-16 ***
JPY          0.008205   0.004325   1.897   0.0598 .
EUR         -0.007683   0.009480  -0.810   0.4190
GBP          0.008567   0.004464   1.919   0.0570 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.04521 on 143 degrees of freedom
Multiple R-squared:  0.9979,  Adjusted R-squared:  0.9978
F-statistic: 1.699e+04 on 4 and 143 DF,  p-value: < 2.2e-16
```

Then several conclusions about the Chinese exchange rate regime after spring 2006 are concluded:

- CNY was still closely linked to USD. The exchange rate regime got much more flexible increasing from $\sigma = 0.028$ to 0.106 which is still very low, even compared with other pegged exchange rate regimes like India.
- Till 2008-08-22 the intercept was clearly smaller than 0, reflecting a slow appreciation of the CNY and thus signaling a modest liberation of the rigid

USD peg in spring 2006. Towards the end of 2008, the modest liberation was abandoned again and since 2009 ,after the financial cirises occurred ,the exchange rate regime is again an extremely tight USD peg without appreciation.

1.5 Results and Summary

For the Chinese Yuan, a 4-segment model is found for the time after July 2005 to July 2009 when China gave up on a fixed exchange rate to the USD. While being closely linked to USD in all periods, there had been small increased flexibility while the weight of the USD in the currency basket slightly decreased. However, these steps were reversed again towards the end of 2008.

2. PRESENTAION OF REPRODUCTION WITH UPDATED DATA

In order to carry forward this study and to determined:

- For any given period after 2009-08-01, what is the implicit reference basket for the Chinese currency?
- Has the reference basket changed over time?

We continue to regress changes in the target currency (CNY) on changes in the values of reference currencies in the reference basket (USD,JPY,EUR,GBP)

To apply this methodology we express the dollar-based exchange rates using another currency, the Swiss Franc, the same currency as our reference paper choose. This allows currency moves of the dollar to be used to explain moves in the Yuan. The choice of Swiss Franc is consistent with evaluations with respect to a stable, developed-market currency.

2.1 PRESENTATION OF THE DATASET

The exchange rates we used are download from Bloomberg and we subset the data from 2005-07-25 till 2016-04-29

Then we calculate the log return of the exchange rate.

First, Let us take a close look at the return data

>summary(ret2)

CNY	USD	JPY	EUR	GBP
Min. :-19.25931	Min. :-19.383353	Min. :-18.49511	Min. :-20.787703	Min. :-19.739693
1st Qu.: -0.38225	1st Qu.: -0.365039	1st Qu.: -0.39977	1st Qu.: -0.142557	1st Qu.: -0.339471
Median : 0.00000	Median : 0.000000	Median : -0.01227	Median : -0.006661	Median : -0.006356
Mean : -0.00306	Mean : -0.006131	Mean : -0.01292	Mean : -0.018586	Mean : -0.013797
3rd Qu.: 0.38790	3rd Qu.: 0.363150	3rd Qu.: 0.38242	3rd Qu.: 0.114455	3rd Qu.: 0.335659
Max. : 9.07247	Max. : 9.088893	Max. : 8.11091	Max. : 8.391494	Max. : 8.009727

From this summary, we can observe that all the mean value of these 5 currency is negative which shows that all these five currencies somehow depreciated compared with CHF yet the Chinese Yuan depreciated least that makes Chinese Yuan appreciated compared with those 4 reference currencies during 2009 to 2016.

Also the standard deviation of those returns are similar:

> lapply(ret2,sd)

$CNY[1] 0.8239813

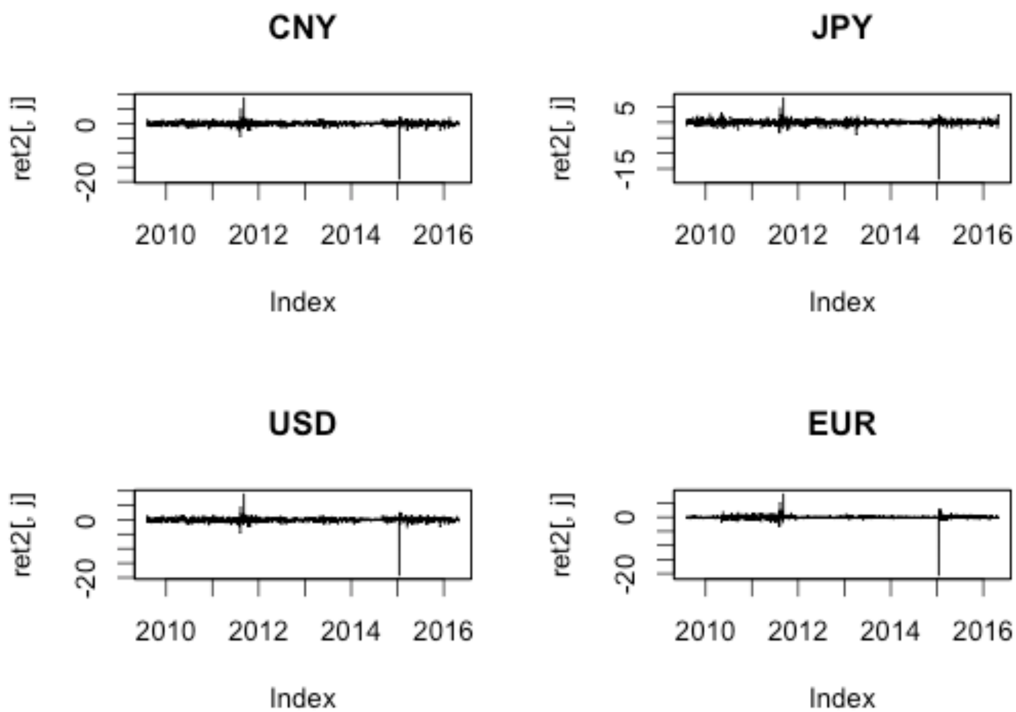
$USD[1] 0.8169411

$JPY[1] 0.8519066

$EUR[1] 0.7090731

$GBP[1] 0.7942843

The plot of the return is shown as following in Figure 3:



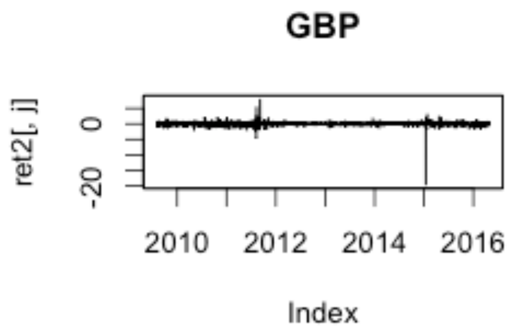
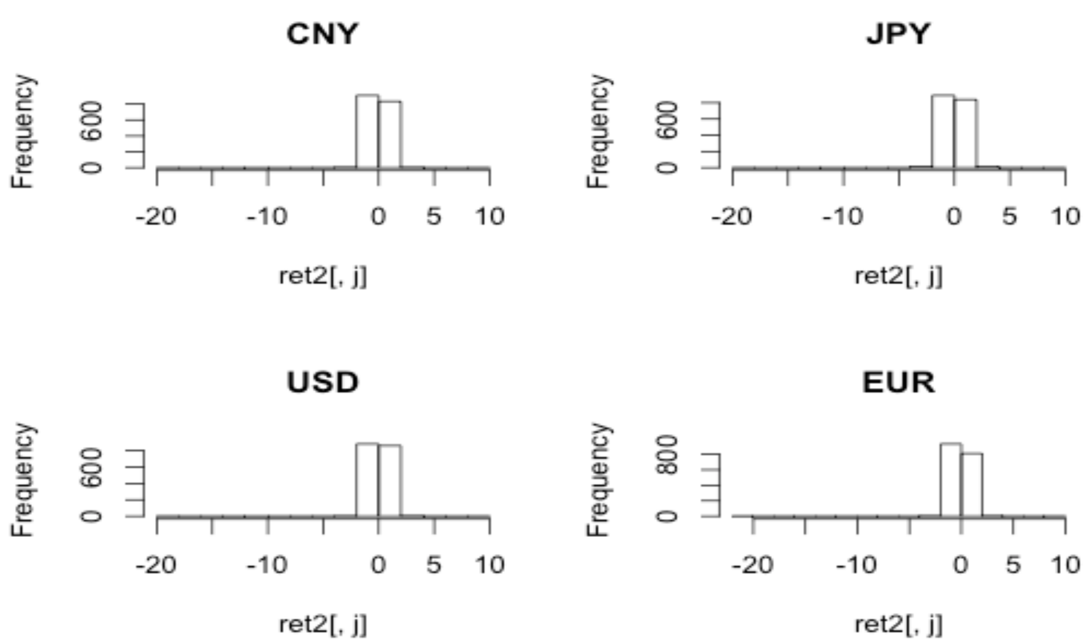
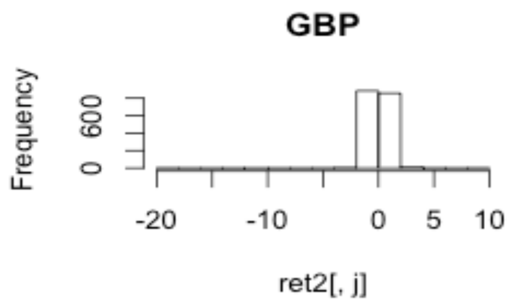


Figure 3 shows a similar pattern of return in these 5 currencies.

The histogram of the data is as following in Figure 4:





2.2 ECONOMETRIC MODEL AND DIAGNOSTIC TESTS

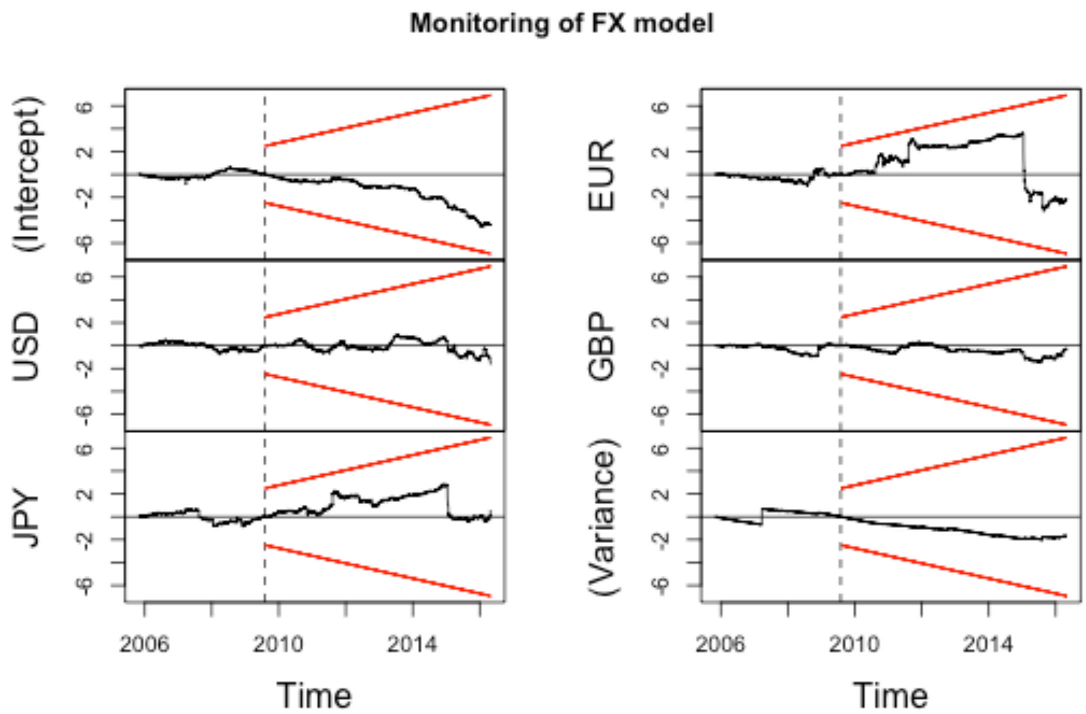
To begin with our analysis, we start to check whether future observations still conform to the established model of reference article. Using a linear boundary, derived at 5% significance level (for potentially monitoring up to T = 4), this can be performed via

```
>ret_mon <- fxmonitor(CNY ~ USD + JPY + EUR + GBP,

           data = window(ret3),

           start = as.Date("2009-08-01"), end = 4)
```

and yielding the visualization as following in Figure 5:

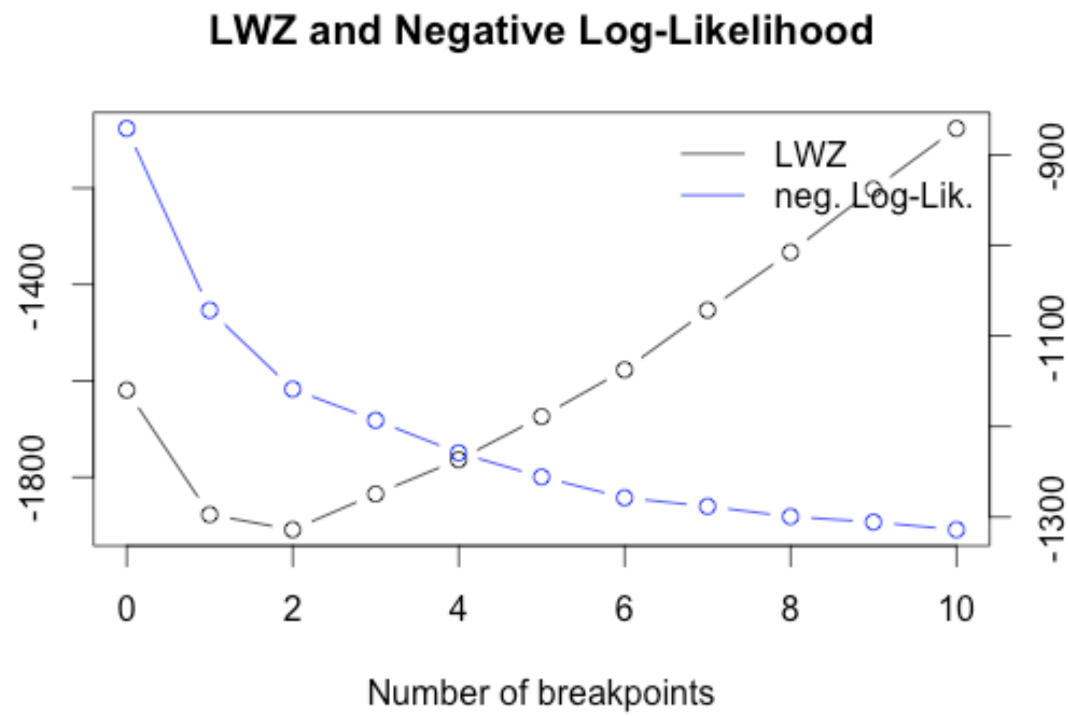


This is showing that none of the coefficients deviates significantly from its zero mean, signaling that there was no significant change in the currency weights. Also there is only small fluctuation in variance signaling no departure from the previously established model, which indicates a USD peg.

To capture the changes in the China's exchange rate regime more formally, we fit a segmented exchange rate regression based on the full extended data set:

```
>ret_reg2 <- fxregimes(CNY ~ USD + JPY + EUR + GBP, data=ret2,h=60,breaks=10)
```

We determine the optimal breakpoints for 1, . . . , 10 breaks with a minimal segment size of 60 observations and compute the associated segmented negative log-likelihood (NLL) and LWZ criterion in Figure 6.



As Figure 6 shows, NLL decreases with every additional break but with a marked decrease only for going from 0 to 1 break. The LWZ criterion that assumes its minimum is for 2 breaks so a 2-break (or 3-segment) model is chosen. And the breakpoints dates are computed as following:

```
> confint(ret_reg, level = 0.9)

         Confidence intervals for breakpoints

         of optimal 3-segment partition:



Call:

confint.fxregimes(object = ret_reg, level = 0.9)



Breakpoints at observation number:

  5 % breakpoints 95 %

1  202        220  221

2 1544        1571 1574
```

Corresponding to breakdates:

```
       5 % breakpoints      95 %
1 2010-05-11  2010-06-04 2010-06-07
2 2015-07-02  2015-08-10 2015-08-13
```

These two dates collides with the date that China implemented the second exchange rate reform (June 2010) and the big crash of China's stock market (Aug. 2015)

A complete summary is computed as following:

```
> cny_rf2 <- refit(ret_reg2)

> lapply(cny_rf2, summary)

$`2009-08-03--2010-06-04`


Call:

fxlm(formula = object$formula, data = window(object$data, start = sbp[i],

   end = ebp[i]))

Residuals:

     Min        1Q    Median        3Q       Max

-0.134603 -0.023690  0.000564  0.022161  0.141712

Coefficients:

            Estimate Std. Error t value Pr(>|t|)

(Intercept)  5.670e-04  2.651e-03   0.214    0.831

USD          9.921e-01  6.016e-03 164.922   <2e-16 ***

JPY          4.064e-03  3.882e-03   1.047    0.296

EUR         -1.397e-03  9.531e-03  -0.147    0.884

GBP          7.831e-05  5.023e-03   0.016    0.988

---

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


Residual standard error: 0.03881 on 215 degrees of freedom
```

```
Multiple R-squared:  0.9954,  Adjusted R-squared:  0.9953
F-statistic: 1.171e+04 on 4 and 215 DF,  p-value: < 2.2e-16
```

During this period only the USD coefficient differing significantly from 0 (but not significantly from 1), thus signaling a very clear USD peg. The R2 of the regression is 99.5% due to the extremely low standard deviation of σ = 0.03881. This result shows that the trend of tight US peg resumes during and after 2008 Financial Crises

```
$`2010-06-07--2015-08-10`

Call:
fxlm(formula = object$formula, data = window(object$data, start = sbp[i],
    end = ebp[i]))

Residuals:
     Min       1Q   Median       3Q      Max
-0.99394 -0.06175 -0.00032  0.06537  0.88277

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.006994   0.003764   1.858   0.0634 .
USD         0.983047   0.009407 104.502   <2e-16 ***
JPY         0.001991   0.007048   0.282   0.7776
EUR         0.007720   0.008693   0.888   0.3747
GBP         0.002387   0.010292   0.232   0.8166
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1381 on 1346 degrees of freedom
Multiple R-squared:  0.9753,  Adjusted R-squared:  0.9753
```

```
F-statistic: 1.331e+04 on 4 and 1346 DF,  p-value: < 2.2e-16
```

Still only the USD coefficient differing significantly from 0, thus signaling a very clear USD peg. Yet the R2 of the regression is decreasing due to the standard deviation increased from 0.03881 to 0.1381. This result shows that during the period that the global economy was recovering from the 2008 Financial Crises and after China's second exchange rate reform, there exists a slightly increased flexibility of CNY yet CNY is still highly related to USD.

```
$`2015-08-11--2016-04-29`

Call:
fxlm(formula = object$formula, data = window(object$data, start = sbp[i],
    end = ebp[i]))

Residuals:
     Min       1Q   Median       3Q      Max
-1.81543 -0.09992 -0.00151  0.10090  1.15380

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.02004    0.01869  -1.073   0.2849
USD          0.93284    0.04101  22.746   <2e-16 ***
JPY          0.02453    0.03553   0.690   0.4908
EUR         -0.01407    0.06131  -0.229   0.8188
GBP          0.09024    0.03848   2.345   0.0201 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2537 on 184 degrees of freedom
```

Multiple R-squared: 0.8541, Adjusted R-squared: 0.851

F-statistic: 269.3 on 4 and 184 DF, p-value: < 2.2e-16

This outcome shows small steps in the direction that add flexibility to Chinese Yuan exchange rate while the weight of the USD in the currency basket decreased. The adjusted R square decreased from 0.97 to 0.85. The standard deviation kept increased from 0.14 to 0.25.

To capture the fluctuation in the parameters during these 3 historical periods, the associated empirical fluctuation process is computed in Figure 7:

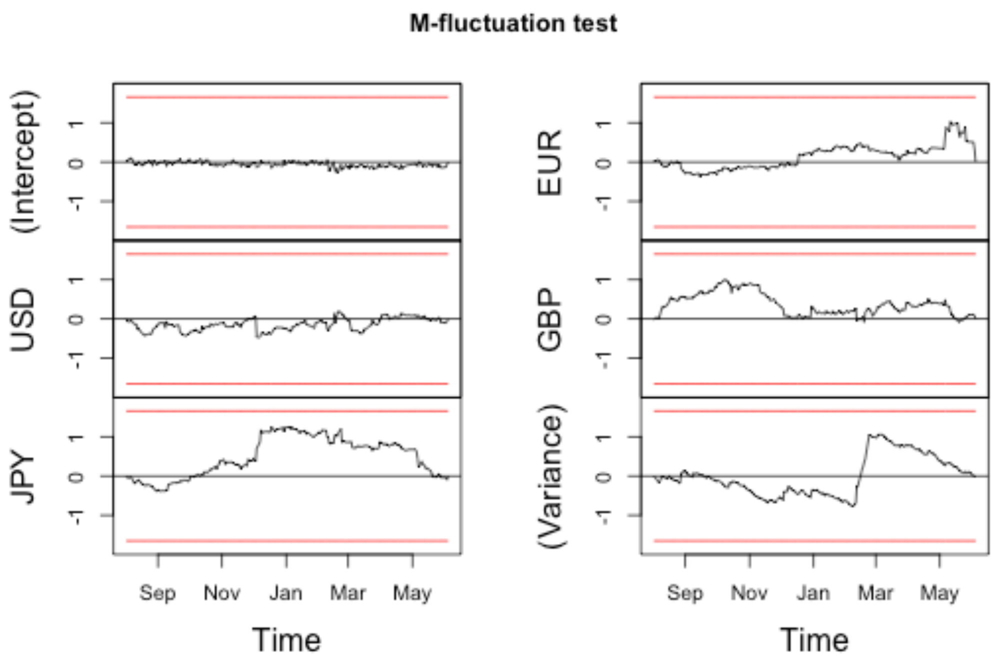


Figure 7 shows that the fluctuation in the parameters during 2009-08-03/2010-06-04.

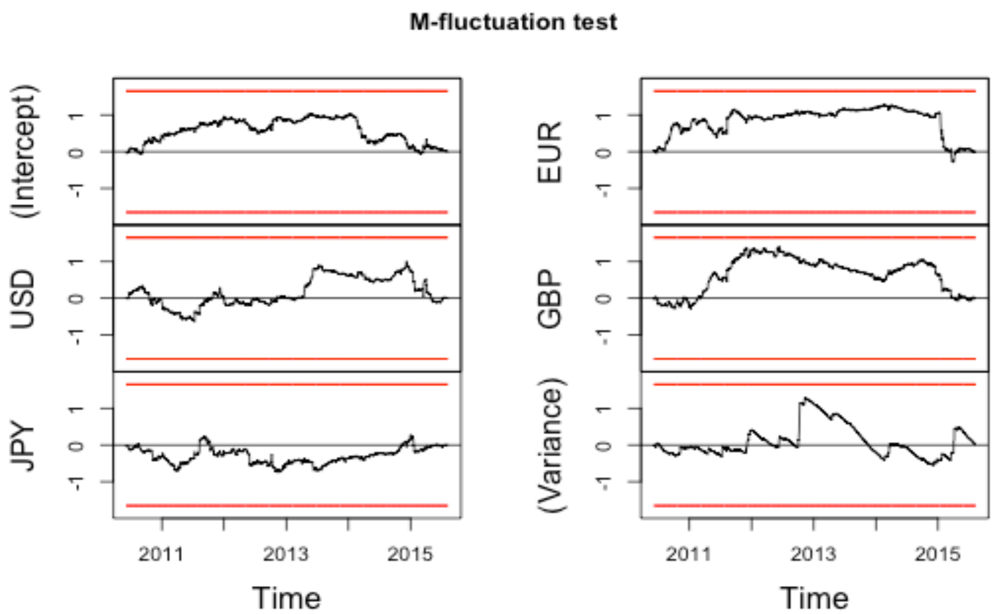


Figure 8 shows that the fluctuation in the parameters during 2010-06-07/2015-08-10

.

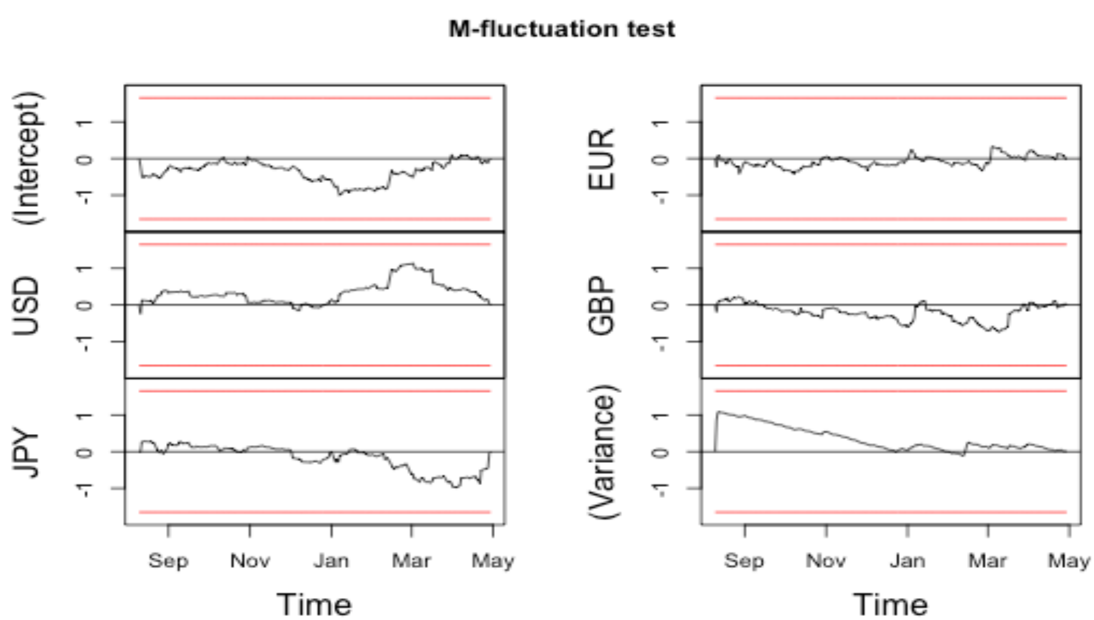


Figure 9 shows that the fluctuation in the parameters during 2015-08-11/2016-04-29

All these three periods the fluctuation is very small and non-significant.

From these three periods we can clearly observed that:

- CNY still remains USD peg during the past years from 2009 to 2016 with the weights of USD slightly decreasing after 2010 July, the second exchange rate reform.
- The residual standard error of the model keep increased from 0.03881 to 0.2537 which shows that there might exists other independent variable that can contribute to the Chinese Yuan exchange rate regime

2.3 COMPARISON OF RESULTS AND CRITIQUE

From our data and analysis it is clear that the model doesn't change much from the reference paper to ours. CNY still remains USD peg during the past years with the weights of USD slightly decreasing after China's second exchange rater reform.

The residual standard error of the model keep increased from 0.03881 to 0.2537. In order to make our research further and to estimate the Chinese Yuan exchange rate better, we decide to dig further of our regression model with the domestic economic data .

3. IMPACT OF MACRO-ECONOMIC FACTORS ON THE EXCHANGE RATE

3.1 General Model

This part studies practical factors of RMB exchange rate, with econometrics to establish multiple linear regression model, analyze the size of the role of quantitative of the determinants of exchange rate changes and predict the trend of exchange rate.
The following regression equation to test the impact of macro-economic factors on the exchange rates is used:

$$EXCH = \alpha + \beta 1GOV + \beta 2M2 + \beta 3INT + \beta 4CPI + \beta 5TRD + \beta 6EXP + \beta 7IMP + \beta 8FER + \beta 9FGDP + \beta 10BOP + \varepsilon$$

Where, EXCH is the foreign exchange of Chinese yuan to USD from January 2000 to December 2013 quarterly, α is the constant, β1 to β10 are the parameters to be estimated, GOV is the government spending, M2 is the money supply, INT is the interest rate, CPI is the inflation rate, TRD is the trade balance, EXP is the export, IMP is the import, FER is foreign exchange reserves, GDP is the growth rate of GDP, BOP is the balance of international payment, ε is the random error term.

3.2 Data

The sample period for this paper on the impact of macro-economic factors on the exchange rates extends from January 2000 to December 2013 based on quarterly data. This study uses following macro-economic factors: inflation, interest rate, trade balance, foreign exchange reserves, money supply, and GDP to examine the foreign exchange rate movements between USA and China. The data on the macro-economic are obtained from IMF, Worldbank, Bloomberg, State Administration of Foreign Exchange and the Unites States Census Bureau Websites.

3.2.1 Descriptive Statistics

Table 1 summarizes the descriptive statistics of the variables used in this research paper. There are totally 10 independent variables, which represent for 7 macro-economic factors, inflation, interest rate, trade balance, public debt, international reserves, and foreign direct investment (BOP) and gross domestic product (GDP). Besides, there is one dependent variable CNY/USD, which is collected quarterly from January 2000 to December 2013.

Table 1. Descriptive of variables

	N	Minimum	Maximum	Mean	Std.Deviation	Skewness	Kurtosis
CNY/USD	56	0.13	0.13	0.12	0.02	0.42	-1.48
GOV	56	413.67	2188.67	1017.98	546.21	0.65	-0.93
M2	56	12483.03	110652.50	45739.56	29906.98	0.73	-0.81
INT	56	5.31	7.47	5.88	0.61	1.16	0.66
CPI	56	-1.40	5.00	2.40	1.33	-0.59	0.77
TRD	56	-8595.00	114450.00	35747.65	30032.67	0.42	-0.91
EXP	56	51700.00	594977.00	271252.76	168015.88	0.31	-1.24

IMP	56	46472.00	504804.32	235505.11	146463.12	0.41	-1.20
FER	56	1568.20	38213.15	15149.61	12193.17	0.43	-1.36
GDP	56	-0.20	0.15	0.04	0.11	-0.95	-0.78
BOP	56	-9.00	1331.00	411.45	340.34	0.67	-0.53

3.2.2 CNY/USD

The assumption of variables type was met because the outcome CNY/USD and 10 predictors are continuous. The independence of observation was also assumed. The assumption of Non-Zero variance was met because there are standard deviations of the predictors are unequal to 0. Based on the Figure 1, the assumption of Normally-distributed errors was met. Because the histogram followed the normal distribution and the Normal P-P plot followed a straight line.

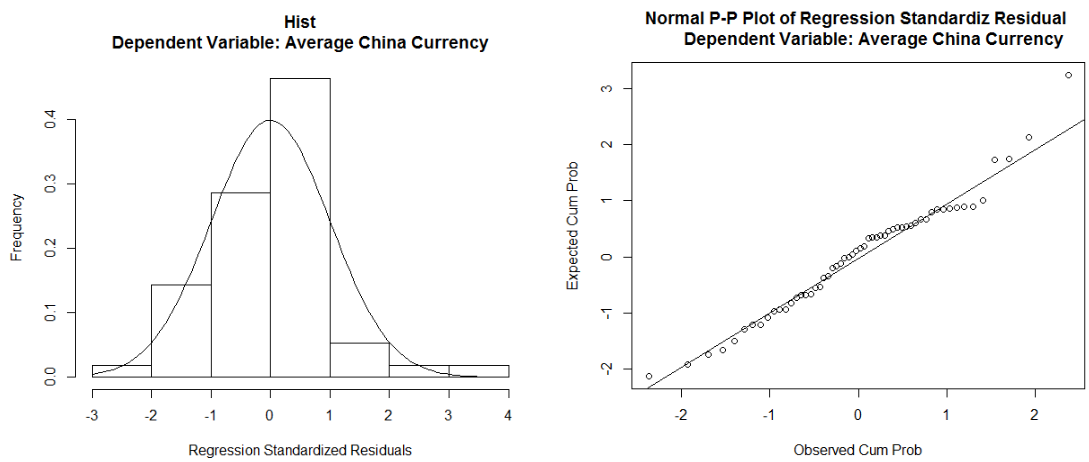


Figure 10. Histogram and normal P-P plot of the outcome CNY/USD

Table 2 shows that government spending, interest rate, money supply, foreign exchange reserve, trade balance, export and import have a strong relationship with the USD/CNY exchange rate. However, inflation rate, export and import have a negative correlation.

Table 2. Pearson correlations among variables of CNY/USD

	CNYUSD	GOV	M2	INT	CPI	TRD	EXP	IMP	FER	GDP	BOP
CNYUSD	1.0000000	0.97690620	0.96936234	0.33970045	-0.29736946	0.6624025	0.9532496	0.95769747	0.98784752	0.02749470	0.46327129
GOV	0.9769062	1.00000000	0.99525436	0.31382585	-0.24025058	0.6455123	0.9734400	0.98432229	0.99113521	0.04268501	0.40503021
M2	0.9693623	0.99525436	1.00000000	0.24777103	-0.27173980	0.6090926	0.9573071	0.97328332	0.98614058	0.03369643	0.36030861
INT	0.3397004	0.31382585	0.24777103	1.00000000	0.37959869	0.4248143	0.4140177	0.38783301	0.30904659	0.04375984	0.50773219
CPI	-0.2973695	-0.24025058	-0.27173980	0.37959869	1.00000000	-0.2385098	-0.1724796	-0.14895376	-0.25058713	0.02051998	-0.08706001
TRD	0.6624025	0.64551234	0.60909257	0.42481434	-0.23850982	1.0000000	0.7609893	0.66791986	0.64907381	0.30630523	0.87091948
EXP	0.9532496	0.97343997	0.95730705	0.41401765	-0.17247964	0.7609893	1.0000000	0.99111189	0.97167254	0.13696397	0.56637516
IMP	0.9576975	0.98432229	0.97328332	0.38783301	-0.14895376	0.6679199	0.9911119	1.00000000	0.98156449	0.09431015	0.47113557
FER	0.9878475	0.99113521	0.98614058	0.30904659	-0.25058713	0.6490738	0.9716725	0.98156449	1.00000000	0.03703772	0.44628786
GDP	0.0274947	0.04268501	0.03369643	0.04375984	0.02051998	0.3063052	0.1369640	0.09431015	0.03703772	1.00000000	0.22087755
BOP	0.4632713	0.40503021	0.36030861	0.50773219	-0.08706001	0.8709195	0.5663752	0.47113557	0.44628786	0.22087755	1.00000000

3.3 Macro-economic Determinants of USD/CNY

The Multiple Regression excluded the import due to its too high VIF and Tolerance. In Table 3, there is a statistical significance of the regression model because of p-value = 0 (< 0.01). It suggests that selected macro-economic factors have 98% explanatory power on CNY/USD exchange rate movements.

Table 3. Model summary of multiple regression of USD/CNY

Model Summary			
R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
0.990	0.9883	0.986	0.001882

However, some variables are highly correlated with each other and not significant as their p values is high in the table 4. To optimize the linear regression model, government spending, interest rate, money supply, GDP, export, import, trading balance and balance of payment are removed.

Table 4. Coefficient results of the multiple regression of USD/CNY

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	1.032e-01	3.350e-03	30.802	< 2e-16	***
GOV	7.590e-06	1.018e-05	0.745	0.459828	
FER	1.636e-06	2.130e-07	7.682	8.73e-10	***
M2	-2.216e-08	1.320e-07	-0.168	0.867427	
INT	2.805e-03	7.148e-04	3.924	0.000289	***
CPI	-6.515e-04	2.732e-04	-2.384	0.021285	*
TRD	5.675e-08	3.218e-08	1.763	0.084499	.
GDP	2.598e-03	2.780e-03	0.934	0.355016	
BOP	3.849e-07	2.673e-06	0.144	0.886111	
EXP	-5.884e-08	1.508e-08	-3.901	0.000311	***
IMP	NA	NA	NA	NA	

Note. IMP and EXP are highly correlated so that estimate of IMP is not shown by the system.

The model will be modified to the following format:
$EXCH = \alpha + \beta 1FER + \beta 2INT + \beta 3CPI + \varepsilon$

Table 5. Coefficient results of the multiple regression of CNY/USD

```
lm(formula = CNYUSD ~ FER + INT + CPI, data = dm)

Residuals:
       Min         1Q     Median         3Q        Max
-0.0040994 -0.0010752 -0.0001126  0.0012158  0.0056589

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.070e-01  2.899e-03  36.917  < 2e-16 ***
FER          1.224e-06  2.688e-08  45.529  < 2e-16 ***
INT          2.231e-03  5.581e-04   3.998 0.000203 ***
CPI         -1.140e-03  2.535e-04  -4.497  3.9e-05 ***
---
Signif. codes:  0 ?**?0.001 ?*?0.01 ??0.05 ??0.1 ??1

Residual standard error: 0.0021 on 52 degrees of freedom
```

```
Multiple R-squared:  0.9835,	Adjusted R-squared:  0.9826 
F-statistic:  1036 on 3 and 52 DF,  p-value: < 2.2e-16
```

3.3.1 ADF Test

To examine the stationary of the variables, Augmented Dickey-Fuller (ADF) test is used. The residuals of the model are stationary.

Table 6. ADF Test Result

```
Title:
 Augmented Dickey-Fuller Test

Test Results:
  PARAMETER:
    Lag Order: 1
  STATISTIC:
    Dickey-Fuller: -3.0878
  P VALUE:
    0.01
```

3.3.2 ARIMA model and Prediction

To predict CNY/USD trend from January 2014 to December 2015 quarterly, ARIMA model will be used and this report will hence distinguish seasonal ARIMA terms from simultaneously exploring an ACF and PACF.

For the non seasonal behavior, the PACF in Figure.2 shows a clear spike at lag 1 and not much else. This is accompanied by a tapering pattern in the early lags of the ACF. A non-seasonal AR(1) may be a useful part of the model. For the seasonal behavior, we look at what's going on around lags 12, 24, and so on. In the ACF, there's a cluster of (negative) spikes around lag 12 and then not much else. The PACF tapers not much else except on lag 1.

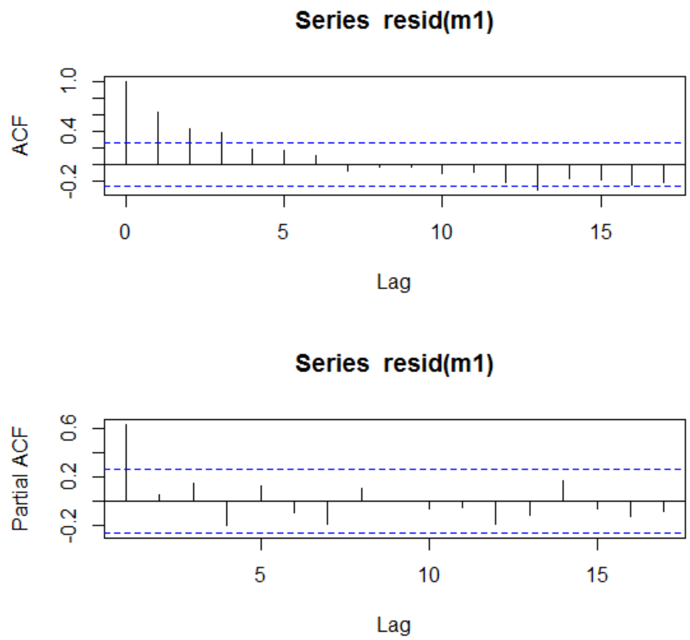


Figure 11. ACF and PACF of Residuals of Model

In general, ARIMA(1,0,0) model will be applied to forecasting. As shown in Figure.3, the forecasting well matches the actual exchange rate between China and USA. The root mean square error is 0.004168038.

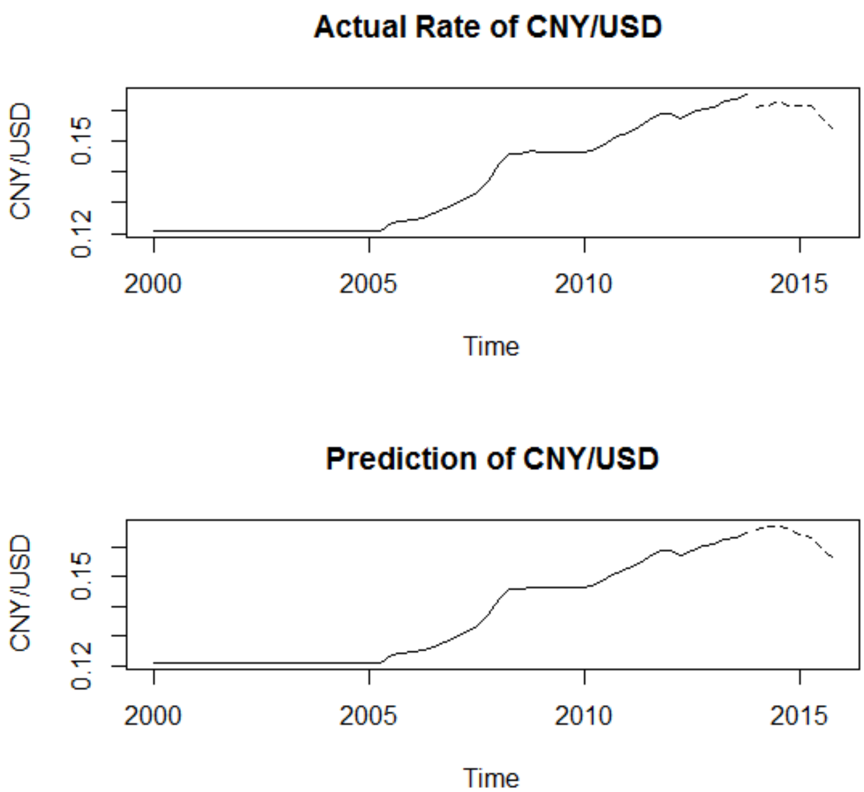


Figure 12. Original Trend(top) and Forecasting Result(bottom)

3.3.3 The relationship between RMB exchange rate and each independent Variable

- Government Spending

The change in government spending may not directly cause the exchange rate change apparently since when there is more or less government spending, government may use the different monetary policy affect the exchange rate in another way.

- Interest Rate

The interest rate differential is significantly positive related to Chinese Yuan exchange rate. The positive relationship to exchange rate means that the increase of interest rate of China leads to more Chinese Yuan exchange for 1 U.S. Dollar, so Chinese Yuan depreciate.

- Trade Balance

The trade balance of China is not significantly related to Chinese RMB exchange rate. The change in trade balance may not directly cause the exchange rate change apparently since when there is trade surplus or deficit the different monetary policy would affect the exchange rate in other way. That's why the export and import are highly negatively related to exchange rate.

- Foreign Exchange Reserve

The foreign exchange reserve is significantly negative related to Chinese Yuan exchange rate. This implies that the foreign exchange reserve will be one of the important sign to predict the Chinese RMB exchange rate. The negative relationship to exchange rate means that the increase of foreign exchange reserve in China led to less Chinese Yuan exchange for 1 U.S. Dollar, so Chinese Yuan appreciate.

- Inflation Rate

The foreign exchange reserve is significantly positive related to Chinese Yuan exchange rate. This implies that the inflation rate differential will be one of the major sign to predict the Chinese RMB exchange rate. The positive relationship to exchange rate means that the increase of inflation rate differential between China and U.S. led to more Chinese Yuan exchange for 1 U.S. Dollar, so Chinese Yuan depreciate.

- Money Supply, Balance of Payment and GDP Growth Rate

They are not significantly related to Chinese Yuan exchange rate.

3.4 Dynamic Linear Regression Model

In econometrics, time series regressions are often fitted by OLS. But it may not be well enough to interpret the relationship among dependent variable, its past values and past values of factors in the case of time series data. Because of fitted values or residuals, the time series properties are by default not preserved (start end frequency) and lags or differences can not directly be specified in the model formula. The use of dynlm() which tries to overcome these problems.

This part will study the dynamic regression model of exchange rate using its five past value and five past values of factors. In other words, the lags will be 1 to 5.

After applying the regression model, only CNY/USD at lag 1, CNY/USD at lag 2 and FER at lag 4 are significant. Then the model is simplified to the following format:

$$EXCH = \alpha + \beta 1lag(EXCH,-1) + \beta 2lag(EXCH,-2) + \beta 3FER + \varepsilon$$

3.4.1 ADF Test

To examine the stationary of the variables, Augmented Dickey-Fuller (ADF) test is used. The residuals of the model are stationary.

Table 7. ADF Test Result

```
Title:
 Augmented Dickey-Fuller Test

Test Results:
  PARAMETER:
```

```
    Lag Order: 1
  STATISTIC:
    Dickey-Fuller: -5.3534
  P VALUE:
    0.01
```

3.4.2 ARIMA model and Prediction
From figure, it can be concluded that there is no non-seasonal or seasonal behavior in ACF and PACF analysis. Similar to the prediction of last part, ARIMA model will applied to predict exchange rate from January 2014 to December 2015.

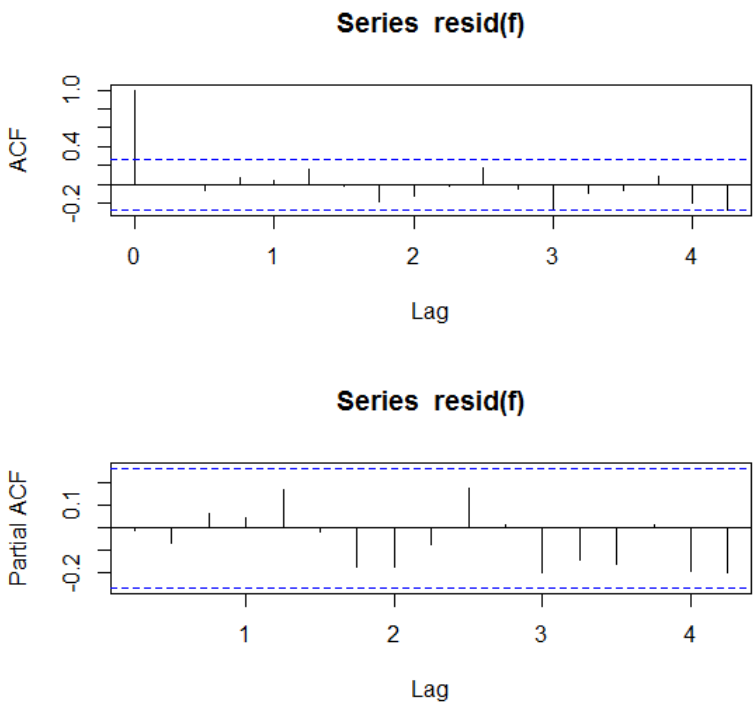


Figure 13. ACF and PACF of Residuals of Dynamic Regression Model

As shown in Figure.5, the forecasting well matches the actual exchange rate between Chi na and USA. The root mean square error is 0.001237622.

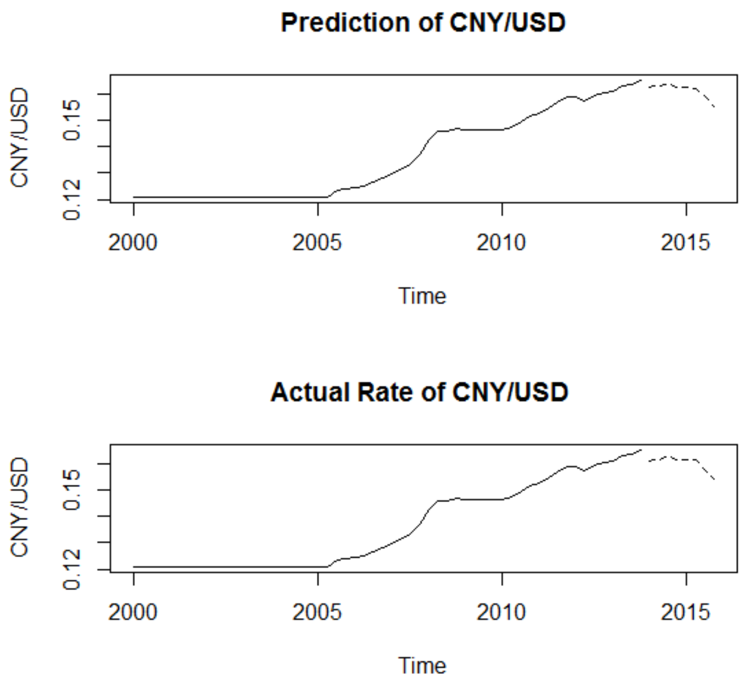


Figure 14. Forecasting Result(Top) and Original Trend(bottom)

After running the regression, the Heteroskedasticity is checked by using the White's General Test and found that the null hypothesis cannot be rejected. Thus, there is no Heteroskdasticity. In checking for the Serial Correlation, the Breusch-Godfrey Test is used where finding identified that the null hypothesis cannot be rejected, so there is no Serial Correlation.

3.4.3 Interpretation of Model

Exchange rate in the dynamic model is highly correlated to its past price and still to foreign exchange reserve. From the equation, it can be concluded that the rate is most correlated to price of previous quarter and the quarter before the previous one.

APPENDIX

```
#######PERSONAL PROJECT FOR FINANCIAL ECONOMETIRCS

##THIS PART IS FOR PRECESSING THE DATA FOR PART 1 & 2


library("fxregime")

library("xlsx")

library("xts")


setwd("/Users/quya/Google Drive/FEco/project")



#get the data of ex rate from 2005-07-25/2009-07-31

data("FXRatesCHF", package = "fxregime")

cny <- fxreturns("CNY", frequency = "daily",start = as.Date("2005-07-25"),

        end = as.Date("2009-07-31"),

        other = c("USD", "JPY", "EUR", "GBP"), data = FXRatesCHF)



##Get the data for the whole period


CNY <- read.xlsx(file="CNYCHF.xlsx",1)

USD <- read.xlsx(file="USDCHF.xlsx",1)

JPY <- read.xlsx(file="JPYCHF.xlsx",1)

EUR <- read.xlsx(file="EURCHF.xlsx",1)
```

```
GBP <- read.xlsx(file="GBPCHF.xlsx",1)



transform <- function(cur){
  in_dex <-as.Date(cur[,1])
  cur <- zoo(cur[,2],order.by=in_dex)
}



USD <- transform(USD)
USD <- window(USD,start=as.Date("2005-07-25"))
CNY <- transform(CNY)
CNY <- window(CNY,start=as.Date("2005-07-25"))
JPY <- transform(JPY)
JPY <- window(JPY,start=as.Date("2005-07-25"))
EUR <- transform(EUR)
EUR <- window(EUR,start=as.Date("2005-07-25"))
GBP <- transform(GBP)
GBP <- window(GBP,start=as.Date("2005-07-25"))

#formed the whole exchange rate table
CUR <- merge(CNY,USD,JPY,EUR,GBP)



#get the log return
```

```
ret <- diff(log(CUR))*100

save(CUR,ret,file="project.RData")



###THIS PART IS FOR PERFORM THE REGRESSION AND TEST FOR PART 1 & 2


##PART 1


library("fxregime")

data("FXRatesCHF", package = "fxregime")


cny <- fxreturns("CNY", frequency = "daily",start = as.Date("2005-07-25"),

        end = as.Date("2009-07-31"),

        other = c("USD", "JPY", "EUR", "GBP"), data = FXRatesCHF)


#LM between 2005-07-25/2005-10-31


cny_lm <- fxlm(CNY ~ USD + JPY + EUR + GBP,

       data = window(cny, end = as.Date("2005-10-31")))

summary(cny_lm)


cny_efp <- gefp(cny_lm, fit = NULL)

plot(cny_efp, aggregate = FALSE, ylim = c(-1.85, 1.85))


sctest(cny_efp)
```

```
cny_mon <- fxmonitor(CNY ~ USD + JPY + EUR + GBP,
          data = window(cny, end = as.Date("2006-05-31")),
          start = as.Date("2005-11-01"), end = 4)
plot(cny_mon, aggregate = FALSE)
cny_mon

cny_reg <- fxregimes(CNY ~ USD + JPY + EUR + GBP, data=cny,h=20,breaks=10)

plot(cny_reg)

confint(cny_reg, level = 0.9)
coef(cny_reg)

## regression from 2005-07-25/2009-07-31

cny_rf <- refit(cny_reg)
lapply(cny_rf, summary)


##PART 2

load("Project.RData")

ret3 <- window(ret,start=as.Date("2005-11-01"))
```

```
ret2 <- window(ret,start=as.Date("2009-08-01"))

##Presenting the data

par(mfcol=c(2,2))
for (j in (1:ncol(ret2))){
  plot(ret2[,j],main=colnames(ret2)[j])}

for (j in (1:ncol(ret2))){
  hist(ret2[,j],main=colnames(ret2)[j])}

summary(ret2)

lapply(ret2,sd)

#monitor the further data

ret_mon <- fxmonitor(CNY ~ USD + JPY + EUR + GBP,
                  data = window(ret3),
                  start = as.Date("2009-08-01"), end = 4)
plot(ret_mon, aggregate = FALSE)
ret_mon

#determine the breakpoints
```

```
par(mfcol=c(1,1))

ret_reg2 <- fxregimes(CNY ~ USD + JPY + EUR + GBP, data=ret2,h=60,breaks=10)
plot(ret_reg2)
confint(ret_reg2, level = 0.9)

#performing the LM on 3 segment
cny_rf2 <- refit(ret_reg2)
lapply(cny_rf2, summary)

#plot the gefp
gefp_2 <- lapply(cny_rf2,gefp,fit=NULL)
lapply(gefp_2,plot,aggregate = FALSE, ylim = c(-1.85, 1.85))


##PART 3

###library
library(dyn)
library("dynlm")
library(psych)
library(forecast)
library(vars)
library(het.test)
library(car)
```

```
library(caret) # for box-cox transformation

library(lmtest) # bptest for testing heteroscedasticity

library(gvlma) # global validation of linear model assumptions


###Read data

dm<-read.csv("data1.csv",header = T)

dm2<-read.csv("data2.csv",header = T)

dm=dm[,-1]

dm2=dm2[,-1]



CNYUSD<-ts(dm$CNYUSD,start=2000,freq=4)

INT<-ts(dm$INT,start=2000,freq=4)

FER<-ts(dm$FER,start=2000,freq=4)

CPI<-ts(dm$CPI,start=2000,freq=4)

GDP<-ts(dm$GDP,start=2000,freq=4)

GOV<-ts(dm$GOV,start=2000,freq=4)

M2<-ts(dm$M2,start=2000,freq=4)

TRD<-ts(dm$TRD,start=2000,freq=4)

BOP<-ts(dm$BOP,start=2000,freq=4)

EXP<-ts(dm$EXP,start=2000,freq=4)

IMP<-ts(dm$IMP,start=2000,freq=4)



###1 Simple linear regression
```

```
##Statistical test and economical test

lm_CNYUSD=lm(CNYUSD~GOV+FER+M2+INT+CPI+TRD+GDP+BOP+EXP+IMP)

summary(lm_CNYUSD)


###2 Descriptive Statistics

describe(dm)


qqnorm(rstandard(lm_CNYUSD),

        ylab="Expected Cum Prob",

        xlab="Observed Cum Prob",

        main="Normal P-P Plot of Regression Standardiz Residual

    Dependent Variable: Average China Currency")

qqline(rstandard(lm_CNYUSD))


hist(rstandard(lm_CNYUSD), freq = FALSE, ylab="Frequency", xlab="Regression
Standardized Residuals", main="Hist

Dependent Variable: Average China Currency")

curve(dnorm, add = TRUE)


###3 Multicollinearity test

cor_data<- dm

head(cor_data)

cor(cor_data)


###4 Multicollinearity Correction
```

```
##remove M2 since M2 is highly correlated with others
m1=lm(CNYUSD~FER+INT+CPI, data=dm)

par(mfcol=c(2,1))
acf(resid(m1))
pacf(resid(m1))

###4 adf test
adfTest(m1$residuals)

###ARIMA model and prediction
best.order<-c(0,0,0)
best.aic<-Inf
for (i in 0:5) for (j in 0:5){
 fit.aic<-AIC(arima(resid(m1), order = c(i,0,j)))
 if (fit.aic<best.aic){
  best.order<-c(i,0,j)
  best.arma<-arima(resid(m1), order=best.order)
  best.aic<-fit.aic
 }
}

best.order
acf(resid(best.arma))
pacf(resid(best.arma))
```

```
m2=ar(m1$residuals,method='mle')

m2$order



m3=arima(resid(m1),order=c(1,0,0))

m3


ts<-ts(dm$CNYUSD, frequency = 4, start = c(2000, 1))

Time<-1:length(ts)

Imth<-cycle(ts)


new.INT<-dm2$INT

new.FER<-dm2$FER

new.CPI<-dm2$CPI

new.data<-data.frame(INT=new.INT,FER=new.FER,CPI=new.CPI,Imth=rep(1:4,1))

predict.lm<-predict(m1,new.data)

predict.arma<-predict(m3, n.ahead=8)

m.pred<-ts(predict.lm+predict.arma$pred, start=2014, freq=4)

ts.plot(cbind(ts, m.pred), lty=1:2,ylab="CNY/USD",main="Prediction of CNY/USD")

m_ori<-ts(dm2$CNYUSD,start=2014,freq=4)

ts.plot(cbind(ts,m_ori),lty=1:2,ylab="CNY/USD",main="Actual Rate of CNY/USD ")


accuracy(m.pred,m_ori)
```

```
##########################################
###dyn
library(dyn)
library("dynlm")
dCNYUSD<-ts(dm$CNYUSD,start=2000,freq=4)
dINT<-ts(dm$INT,start=2000,freq=4)
dFER<-ts(dm$FER,start=2000,freq=4)
dCPI<-ts(dm$CPI,start=2000,freq=4)
dGDP<-ts(dm$GDP,start=2000,freq=4)
dGOV<-ts(dm$GOV,start=2000,freq=4)
dM2<-ts(dm$M2,start=2000,freq=4)
dTRD<-ts(dm$TRD,start=2000,freq=4)
dBOP<-ts(dm$BOP,start=2000,freq=4)
dEXP<-ts(dm$EXP,start=2000,freq=4)
#dGDPG<-ts(dm$GDPGrowth,start=2000,freq=4)

acf(dCNYUSD)
pacf(dCNYUSD)
acf(dINT)
acf(dFER)
acf(dCPI)

f<-dynlm(dCNYUSD~
```

```
 dINT+lag(dINT,-1)+lag(dINT,-2)+lag(dINT,-3)+lag(dINT,-4)+lag(dINT,-5)

 +dFER+lag(dFER,-1)+lag(dFER,-2)+lag(dFER,-3)+lag(dFER,-4)+lag(dFER,-5)

 +dCPI+lag(dCPI,-1)+lag(dCPI,-2)+lag(dCPI,-3)+lag(dCPI,-4)+lag(dCPI,-5)

 +lag(dCNYUSD,-1)+lag(dCNYUSD,-2)+lag(dCNYUSD,-3)+lag(dCNYUSD,-
4)+lag(dCNYUSD,-5))

 #+dEXP+lag(dEXP,-1)+lag(dEXP,-2)+lag(dEXP,-3)+lag(dEXP,-4)+lag(dEXP,-5))

 #+dGDP+lag(dGDP,-1)+lag(dGDP,-2)+lag(dGDP,-3)+lag(dGDP,-4)+lag(dGDP,-5)

 #+dGOV+lag(dGOV,-1)+lag(dGOV,-2)+lag(dGOV,-3)+lag(dGOV,-4)+lag(dGOV,-5)

 #+dM2+lag(dM2,-1)+lag(dM2,-2)+lag(dM2,-3)+lag(dM2,-4)+lag(dM2,-5)

 #+dTRD+lag(dTRD,-1)+lag(dTRD,-2)+lag(dTRD,-3)+lag(dTRD,-4)+lag(dTRD,-
5)

 #+dBOP+lag(dBOP,-1)+lag(dBOP,-2)+lag(dBOP,-3)+lag(dBOP,-4)+lag(dBOP,-5)

 #+dGDPG+lag(dGDPG,-1)+lag(dGDPG,-2)+lag(dGDPG,-3)+lag(dGDPG,-
4)+lag(dGDPG,-5))

summary(f)


f<-dynlm(dCNYUSD~lag(dCNYUSD,-1)+lag(dCNYUSD,-2) + dFER)

summary(f)


par(mfcol=c(2,1))

acf(resid(f))

pacf(resid(f))


adf.test(resid(f))


ts<-ts(dm$CNYUSD, frequency = 4, start = c(2000, 1))
```

```
Time<-1:length(ts)
Imth<-cycle(ts)

f2=ar(f$residuals,method='mle')
f2$order

best.order<-c(0,0,0)
best.aic<-Inf
for (i in 0:5) for (j in 0:5){
 fit.aic<-AIC(arima(resid(f), order = c(i,0,j)))
 if (fit.aic<best.aic){
  best.order<-c(i,0,j)
  best.arma<-arima(resid(f), order=best.order)
  best.aic<-fit.aic
 }
}

best.order
acf(resid(best.arma))
pacf(resid(best.arma))

f3=arima(resid(f),order=c(0,0,0))
f3

new.dCNYUSD<-ts(dm2$CNYUSD,start=2000,freq=4)
```

```
new.dCNYUSDLAG<-lag(new.dCNYUSD,-1)
new.dFER<-ts(dm2$FER,start=2000,freq=4)
new.data<-data.frame(dCNYUSD=new.dCNYUSD,dFER=new.dFER,Imth=rep(1:4,1))
predict.dyn<-predict(f,new.data)
predict.arma<-predict(f3, n.ahead=8)
f.pred<-ts(predict.dyn+predict.arma$pred, start=2014, freq=4)
ts.plot(cbind(ts, f.pred), lty=1:2,ylab="CNY/USD",main="Prediction of CNY/USD")
f_ori<-ts(dm2$CNYUSD,start=2014,freq=4)
ts.plot(cbind(ts,f_ori),lty=1:2, ylab="CNY/USD",main="Actual Rate of CNY/USD ")

accuracy(f.pred,f_ori)

###testing heteroscedasticity
bptest(f)
###testing serial correlation
bgtest(f,4)
```

REFERENCE

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