Htet Phyo Wai

ECN 367

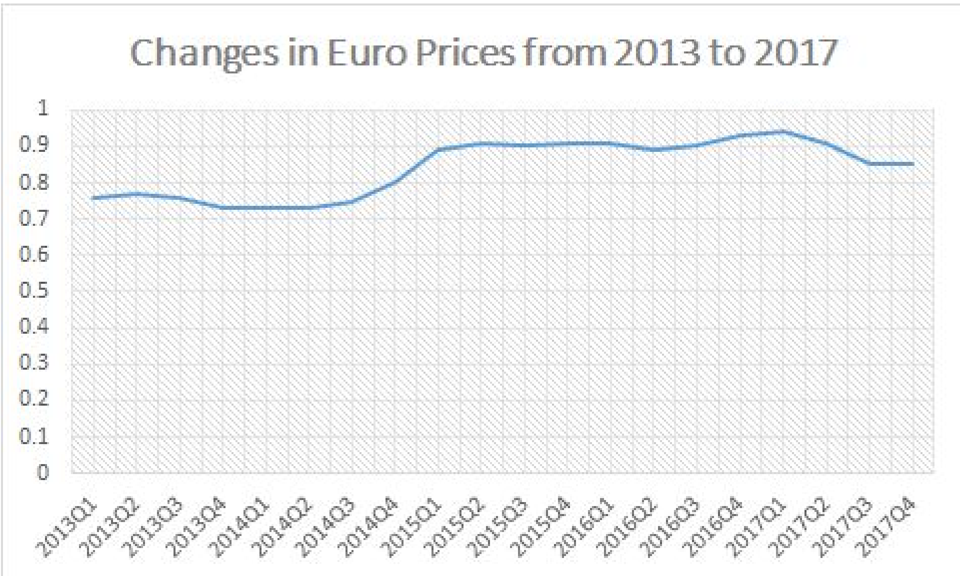
Final Research Paper

May 2, 2018

The Determinants of USD-EURO Exchange Rate

I. Introduction

This paper analyses the main determining factors of USD-Euro exchange rate movement based on the Purchasing Power Parity, the Interest Rate and the Growth Rate models. The Purchasing Power Parity model use the inflation rate differential as an indicator of the consumption level. The interest rate differential and the growth rate differences of US and major Euro-Zone economies are also examined to determine changes in the exchange prices.



Figures 1.1 - Changes in Euro Price (2013 Q1 to 2017 Q4) ; USD = 1

In the above diagram, the change in Euro prices is displayed from 2013 Q1 to 2017 Q4 by setting the US dollar as '1'. The euro dollar price was somewhat stable since 2013 until 2014 following after the quantitative easing of the Federal Reserve in 2012. However, the euro has depreciated significantly between 2014 and 2015 coinciding with the recovery among major economies of Euro regions, and the divergences in monetary policy cycles. (The European Central Bank Report, 2015)

II. Three Models of Exchange Rate

1.Purchasing Power Parity

The Purchasing Power Parity model relates the exchange prices with the inflation rate as an indicator of demand for a particular currency. Under this model, a currency with higher inflation rate is expected to depreciate in comparison to a currency with lower inflation rate. The exchange rate based on inflation rate differential is derived as follow:

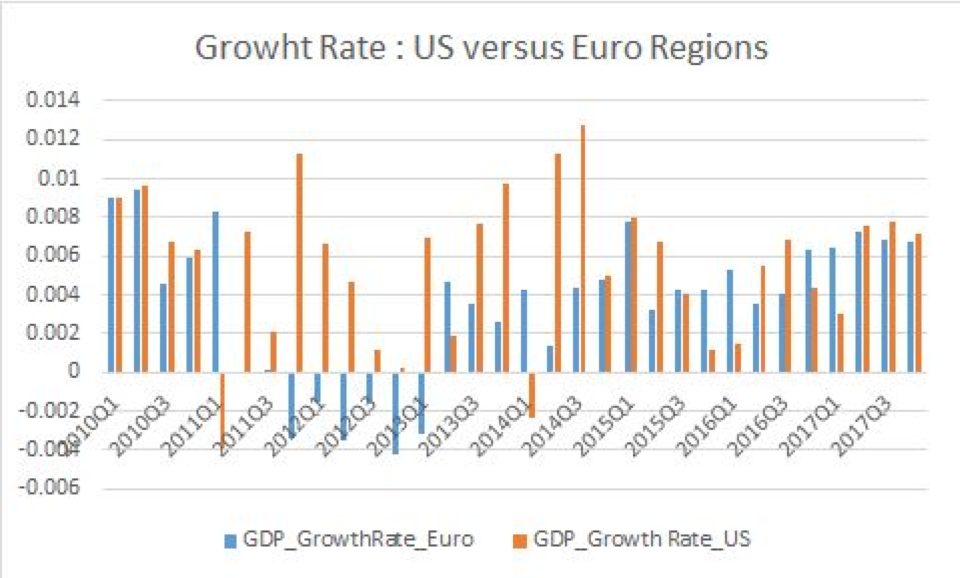
$$\text{Changes in Exchange Rate} = \alpha + \beta\,(Inflation_{Euro} - Inflation_{US})$$

```
Model : OLS, using observations 2010:1-2017:4 (T = 32)
Dependent variable: USEuroDifference
                        Coefficient    std. error      t-ratio  p-value
  ------------------------------------------------------------
  const                0.136756       0.0183077    7.470   2.52e-08 ***
  InflationDiffere~   0.00540440   0.00133206   4.057   0.0003   ***

R-squared               0.354293   Adjusted R-squared   0.332770
```

Based on the data from 2010 Q1 to 2017 Q4, the US/Euro exchange rate is regressed against the inflation rate differential. We have the positive coefficient which is in support of the the depreciation hypotheses from the model. However the low RSS value (0.354) implies that some variations in the exchange rate can be explained by other variables in addition to the inflation rate differences. There is no heteroscedasticity in this model. (Appendix A)

2.Growth Rate Differential



In this model, the high growth rate has inverse relationship with the low exchange prices. Compared to the Euro Zone, the US GDP growth is higher in the past 7 years and thus the demand for the Euro must increase accordingly(i.e positive coefficients in the Growth rate differential).

$$\text{Changes in Exchange Rate} = \alpha + \beta\ (\mathit{Growth\ rate}_{US} - \mathit{Growth\ rate}_{Euro})$$

Model : OLS, using observations 2010:1-2017:4 (T = 32)

Dependent variable: USEuroDifference

	coefficient	std. error	t-ratio	p-value	
const	0.184225	0.0143912	12.80	1.09e-013	***
GrowthRateDiffer~	5.02518	2.52124	1.993	0.0554	*

R-squared	0.116935	Adjusted R-squared	0.087500
F(1, 30)	3.972589	P-value(F)	0.055410

There is no heteroscedasticity in this model. (Appendix A)

3.Interest Rate Parity Model

The Interest Rate model is also proposed to compare with the Purchasing Power Parity and Growth Rate model.(Hauner, IMF paper) In this model, the exchange rate price are derived based on the differences of the interest rate between two states. It is expected that the increase in the interest rate make the demand for that currency to increase and the exchange rate to be decrease (i.e. negative coefficient). The following analysis used 10-year Long Term bonds of US and EU Dollar and indicates that the coefficient of beta is significant.

$$\text{Changes in Exchange Rate} = \alpha + \beta\ (\,Interest\ Rate_{\,US} - InterestRate_{\,Euro})$$

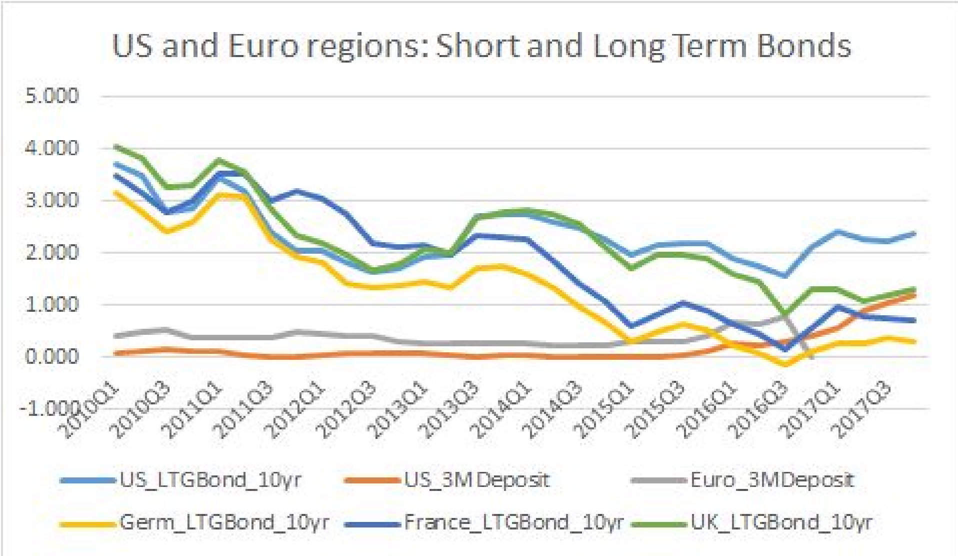
Model : OLS, using observations 2010:1-2017:4 (T = 32)

Dependent variable: USEuroDifference

	coefficient	std. error	t-ratio	p-value	
const	0.250970	0.0106066	23.66	5.83e-021	***
InterestRate_Dif~	−0.100227	0.0124019	−8.082	5.08e-09	***

R-squared 0.685243 Adjusted R-squared 0.674751

We have also tested whether different maturity level of US federal bonds and major Euro-zone economies (UK, France, Germany) will make any difference. In the following diagram, the Long Term bonds rates are decreasing whereas the short term rates increase steadily over the period. When there is a decrease in the Interest Rate, the demand for a particular currency relative to other currency will decrease. Based on our analysis, the individual bonds rates are not as significant to derive the exchange rate changes. (Appendix B) One thing to remember is that the major economies in the Euro-zone may prefer their own currencies and see the Euro as a substitute. Thus, the short term real interest rates might not be as significant as one might expect.



III. The New Model

We have seen that three models of the exchange rates can be improved by introducing new variables since the RSS values in each model is relatively low(RSS value is 0.34 in the PPP model, and 0.15 in the growth rate differential model) We will try to incorporate all three variables together to explain the exchange rate changes.

Unrestricted Model

$$\text{Changes in ExchangeRate} = \alpha + \beta_1 \textit{Inflation Difference} + \beta_2 \textit{ Interest Rate Diff}(\textit{Long Term}) + \beta_3 \textit{ GrowthRate Difference} + u$$

Model : OLS, using observations 2010:1-2017:4 (T = 32)

Dependent variable: USEuroDifference

	coefficient	std. error	t-ratio	p-value	
const	0.234514	0.0227594	10.30	4.95e-011	***
InterestRate_Dif~	−0.0904839	0.0171345	−5.281	1.29e-05	***
InflationDiffere~	0.000887398	0.00125020	0.7098	0.4837	
GrowthRateDiffer~	−0.707253	1.65017	−0.4286	**0.6715**	

R-squared 0.693264 Adjusted R-squared 0.660400

F(3, 28)	21.09459	P-value(F)	2.39e-07

Since the p-value for Growth Rate Differential is relatively high, we will drop that variable to improve our model.

Restricted Model

Changes in ExchangeRate $= \alpha + \beta_1 \mathit{Inflation\ Difference} + \beta_2\ \mathit{Interest\ Rate\ Diff(\ Long\ Term)} + u$

Null hypothesis: the regression parameter is zero for GrowthRateDifferential

Test statistic: F(1, 28) = 0.183694, p-value 0.671497

Model 7: OLS, using observations 2010:1-2017:4 (T = 32)

Dependent variable: USEuroDifference

	coefficient	std. error	t-ratio	p-value	
const	0.236587	0.0219244	10.79	1.14e-011	***
InterestRate_Dif~	−0.0922477	0.0163972	−5.626	4.47e-06	***
InflationDiffere~	0.000923801	0.00122963	0.7513	0.4585	

Mean dependent var	0.194687	S.D. dependent var	0.079352
Sum squared resid	0.060267	S.E. of regression	0.045587
R-squared	0.691252	Adjusted R-squared	0.669959

Wald Test

$H_0: \quad \beta_4 = 0$

$H_1: \quad \beta_4 \neq 0$

There is one restrictions and 28 degrees of freedom.

Since it has a F-distribution,

$$F_c = \frac{(ESS_R - ESS_U)/1}{ESS_U/28} = 0.183 < F(1,20) = 19.45 \text{ (5\%significance level)}$$

Therefore the null hypothesis is accepted and concluded that the selected variable of the growth rate Differential is not significant in the incorporated model. We can also see that the inflation differential is not very significant (with p-value around 40%) compared to the interest rate differential.

Although the GDP growth rate, the consumer prices (the inflation rate) and real interest rates are all important factors of determining the exchange rates, the recession and economic recovery in both US and Euro Zone in the past years require government interventions which make the long term real interest rate as the best explanatory variable for the exchange rates. Therefore, the Interest Rate Model is preferred over any other exchange rate models.

IV. Testing for Heteroskedasticity and Serial Correlation in the Interest Rate Model

The Interest Rate Model is given as follow:

$$\text{Changes in Exchange Rate} = \alpha + \beta\,(\,Interest\ Rate_{US} - InterestRate_{Euro})$$

In Appendix A, we have seen that there is no heteroscedasticity among the error terms in the interest rate model.

To conduct White Test:

$$\sigma^2 = \gamma_1 + \gamma_2\, InterestRateDiff + \gamma_3\, InterestrateDiff^2$$

H_0: $\gamma_2 = \gamma_3 = 0$

H_1 : at least one of them is non zero

The following steps are taken:

Step 1) Use the Interest Rate Model to regress Changes in Exchange Rate using OLS

Step 2) Obtain u = *Changes'Exchange* - $\alpha - \beta$ *Interest RateDifference*

Step 3) Regress *u^2* against *Exchange Rate Changes* and (*Exchange Rate Changes*)^2 for the auxiliary regression

Step 4)

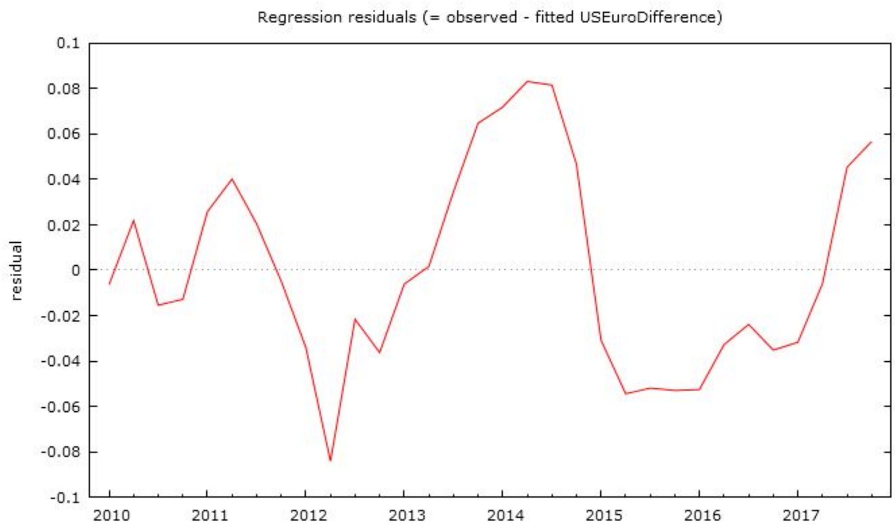
Since it has a Chi-squared distribution with degree of freedom = 2,

$$n.\ R^2 = 4.04 < X^2(2) = 5.99$$

Thus, the null hypothesis is accepted and there is no heteroscedasticity in the Interest Rate model at 5% significance level.

<u>Testing for Serial Correlation using Breusch-Godfrey LM Test</u>

Since there is a pattern in the residuals of the Interest Rate Model, it is suspected that there could be a serial correlation.



We will use 4th order of autoregressive process since it is a quarterly data.

Let , $\mu_t = \rho_1\mu_{t-1} + \rho_2\mu_{t-2} + \rho_3\mu_{t-3} + \rho_4\mu_{t-4} + \varepsilon_t$

We have a new equation:

$$ChangesInExchange = \alpha + \beta\, InterestRDiff + \rho_1 \mu_{t-1} + \rho_2 \mu_{t-2} + \rho_3 \mu_{t-3} + \rho_4 \mu_{t-4} + \varepsilon_t$$

H_0 : $\rho_i = 0$ (i = 1 to 4) (no serial correlation)

H_1 : at least one of them is non zero

In Appendix D1, we regress the residual against interest rate difference $\mu_{t-1}, \mu_{t-2}, \mu_{t-3}, and\ \mu_{t-4}$. Since it has a Chi-squared distribution,

(n-p)(R^2) = (0.68) (28) = 13.86 > $X^2_{0.05}$ (4) = 9.48

Therefore, the null hypothesis is rejected and concluded that there is a serial correlation among the dependent variable.

We can improve the correlation problem by using General-Order Autoregressive Methods (with iterated values of ρ_i) as follow -

<u>General AR form</u>

Let *N.Exchange* = Changes in Exchange rate; *InterestRDiff* = Interest Rate Differential

$$N.Exchange_t - \rho_1 N.exchange_{t-1} - \rho_2 N.exchange_{t-2} - \rho_3 N.exchange_{t-3} - \rho_4 N.exchange_{t-4}$$
$$= \alpha(1 - \rho_1 - \rho_2 - \rho_3 - \rho_4) + \beta\,[\,(InterestRDiff)_t - \rho_1 (InterestRDiff)_{t-1}$$
$$- \rho_2 (InterestRDiff)_{t-2} - \rho_3 (InterestRDiff)_{t-3} - \rho_4 (InterestRDiff)_{t-4}] + \varepsilon_t$$

We derive the value of that corresponds with the smallest values of ESS through the iteration process and obtain the final coefficient β equal to -0.042 (significant at 5%) which is going to be unbiased, consistent and efficient. (Appendix D3)

Engel ARCH Test

In Appendix D2, we have also examine the conditional heteroscedasticity of the error terms using Engel ARCH test by setting this model-

$$\sigma^2_t = \alpha_0 + \alpha_1 \mu^2_{t-1} + \alpha_2 \mu^2_{t-2} + \alpha_3 \mu^2_{t-3} + \alpha_4 \mu^2_{t-4}$$

We obtain the LM test value of 6.04 which is smaller than the significant value ($X^2_{0.05}(4) = 9.48$) and the null hypothesis of no conditional heteroscedasticity is therefore accepted.

V.Conclusion

We conclude that the Interest Rate model can explain the changes in the exchange rate between US Dollar and Euro dollar better than the Purchasing Power Parity or the Growth Rate Differential model. It could be because both US and Euro-zones have experienced recession and recovery recently and the government policies on the real interest rate have direct impacts on the economic performances and the flow of currency over the years. To improve the Interest Rate Model, Government bond rates with different maturity level and real GDP growth rates of both US and Euro were considered but found to be insignificant individually. Since it is a time-series data, the serial correlation of error terms remain as a limitation in the Interest Rate model which could be improved by General Order Autoregressive Method.

Bibliography

Hauner, David, et al. "In Which Exchange Rate Models Do Forecasters Trust?" *IMF Working Paper*, International Monetary Fund, www.imf.org/external/pubs/ft/wp/2011/wp11116.pdf.

"The International Role of Euro : July 2015 Report." *The European Central Bank.* https://www.ecb.europa.eu/pub/pdf/other/euro-international-role-201507.en.pdf

*The data used in this paper is from the St. Louis Federal Reserve Economic Online Database https://fred.stlouisfed.org/series/IRLTCT01DEQ156N#0

Appendix A1: Testing for Heteroskedasticity in Simple Models

$$\sigma^2 = \gamma_1 + \gamma_2\, InflationDiff + \gamma_3\, InflationDiff^2$$

$$H_0: \quad \gamma_2 = \gamma_3 = 0$$

H_1 : at least one of them is non zero

We have obtain the test statistic of 5.47 which is smaller than the critical value of $X^2(2)$ =5.99

Therefore, accept the null and there is no heteroscedsiticity.

```
White's test for heteroskedasticity
OLS, using observations 2010:1-2017:4 (T = 32)
Dependent variable: uhat^2

                    coefficient   std. error   t-ratio  p-value
  ------------------------------------------------------------
  const              0.00398258   0.00136044    2.927   0.0066  ***
  InflationDiffere~  0.000394757  0.000276068   1.430   0.1634
  sq_InflationDiff~ −2.26333e-05  1.14176e-05  −1.982   0.0570  *

  Unadjusted R-squared = 0.171196

Test statistic: TR^2 = 5.478266,
with p-value = P(Chi-square(2) > 5.478266) = 0.064626
```

Appendix A2

$$\sigma^2 = \gamma_1 + \gamma_2\, InterestRateDiff + \gamma_3\, InterestrateDiff^2$$

$H_0: \quad \gamma_2 = \gamma_3 = 0$ H_1 : at least one of them is non zero

We have obtain the test statistic of 4.04 which is smaller than the critical value of $X^2(2)$ =5.99

Therefore, accept the null and there is no heteroscedsiticity.

```
White's test for heteroskedasticity
OLS, using observations 2010:1-2017:4 (T = 32)
Dependent variable: uhat^2

                    coefficient  std. error   t-ratio  p-value
  -----------------------------------------------------------
  const              0.00177215  0.000474011   3.739   0.0008  ***
  InterestRate_Dif~   0.00292702  0.00143173    2.044   0.0501  *
  sq_InterestRate_~  −0.00204505  0.00110888   −1.844   0.0754  *
```

```
  Unadjusted R-squared = 0.126318

Test statistic: TR^2 = 4.042188,
with p-value = P(Chi-square(2) > 4.042188) = 0.132510
```

Appendix A-3

$$\sigma^2 = \gamma_1 + \gamma_2 \, Growth\ Rate\ Diff + \gamma_3 \, Growth\ Rate\ Diff^{\,2}$$

$$H_0 : \quad \gamma_2 = \gamma_3 = 0$$

H_1 : at least one of them is non zero

We have obtain the test statistic of 18.17 which is larger than the critical value of $X^2(2)$=5.99

Therefore, reject the null hypothesis and there is a heteroscedsiticity.

```
White's test for heteroskedasticity
OLS, using observations 2010:1-2017:4 (T = 32)
Dependent variable: uhat^2

                  coefficient   std. error   t-ratio  p-value
  ---------------------------------------------------------------
  const              0.00572757   0.000791019   7.241   5.67e-08 ***
  GrowthRateDiffer~    0.836584     0.135744      6.163   1.02e-06 ***
  sq_GrowthRateDif~   42.9934      14.7128       2.922   0.0067   ***

  Unadjusted R-squared = 0.567975

Test statistic: TR^2 = 18.175185,
with p-value = P(Chi-square(2) > 18.175185) = 0.000113
```

Appendix B: Comparing Short term and Long term rates

```
Model : OLS, using observations 2010:1-2016:4 (T = 28)

Dependent variable: USEuroDifference

                              coefficient   std. error   t-ratio   p-value

  ---------------------------------------------------------------------------------------------------

  const                        0.178533     0.0847269     2.107    0.0473  **

  Germ_LTGBond_10yr      0.0113894    0.0632822     0.1800   0.8589

  France_LTGBond_10r      0.0373956    0.0420638     0.8890   0.3841
```

UK_LTGBond_10yr	0.0533268	0.0693648	0.7688	0.4506
US_LTGBond_10yr	-0.0676764	0.0678132	-0.9980	0.3296
Euro_3MDeposit	-0.0514950	0.0557569	-0.9236	0.3662
US_3MDeposit	-0.110877	0.111863	-0.9912	0.3329

R-squared 0.795915 Adjusted R-squared 0.737605

F(6, 21) 13.64972 P-value(F) 2.70e-06

Appendix_D1_Higher_Order_Autocorrelation

Breusch-Godfrey test for autocorrelation up to order 4

OLS, using observations 2010:1-2017:4 (T = 32)

Dependent variable: uhat

	coefficient	std. error	t-ratio	p-value	
const	3.64541e-05	0.00644120	0.005660	0.9955	
InterestRate_Dif~	0.00114068	0.00759497	0.1502	0.8818	
uhat_1	0.930149	0.194158	4.791	5.84e-05	***
uhat_2	−0.0576384	0.269971	−0.2135	0.8326	
uhat_3	−0.164025	0.271666	−0.6038	0.5512	
uhat_4	−0.146819	0.205767	−0.7135	0.4819	

Unadjusted R-squared = 0.680880

Test statistic: LMF = 13.868524,

with p-value = P(F(4,26) > 13.8685) = 3.51e-006

Alternative statistic: TR^2 = 21.788165,

with p-value = P(Chi-square(4) > 21.7882) = 0.000221

```
Ljung-Box Q' = 27.5025,
with p-value = P(Chi-square(4) > 27.5025) = 1.57e-005
```

Appendix_D2_Engle's ARCH Test

```
Test for ARCH of order 4

             coefficient   std. error    t-ratio   p-value
  --------------------------------------------------------
  alpha(0)    0.00155458   0.000665961    2.334    0.0287  **
  alpha(1)    0.466722     0.207210       2.252    0.0341  **
  alpha(2)   −0.0334672    0.228418      −0.1465   0.8848
  alpha(3)   −0.0892503    0.232144      −0.3845   0.7042
  alpha(4)   −0.0537627    0.206478      −0.2604   0.7969

  Null hypothesis: no ARCH effect is present
  Test statistic: LM = 6.01731
  with p-value = P(Chi-square(4) > 6.01731) = 0.197859
```

Appendix_D3_Cochrane_Orcutt(General Autoregressive Errors)

```
Generalized Cochrane-Orcutt estimation

          ITER          ESS          % CHANGE

           1          0.136007
           2          0.126456       7.022
           3          0.125488       0.766
           4          0.125376       0.089
           5          0.125362       0.011
```

6 0.125361 0.001

Model 13: AR, using observations 2011:1-2017:4 (T = 28)

Dependent variable: USEuroDifference

	coefficient	std. error	t-ratio	p-value	
InterestRate_Dif~	−0.0424325	0.0331804	−1.279	0.2118	
u_4	0.918867	0.0556313	16.52	1.22e-015	***

Statistics based on the rho-differenced data:

Mean dependent var	−0.001823	S.D. dependent var	0.070148
Sum squared resid	0.125361	S.E. of regression	0.068140
Uncentered R-squared	0.401891	Centered R-squared	0.056452
F(1, 27)	1.615392	P-value(F)	0.214577
rho	0.782215	Durbin-Watson	0.415971