How do oil price changes impact economic variables in the period 1990 to 2017: A Replication of the Cologni & Manera paper

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1. Introduction

To replicate the study by Cologni & Manera to find the economic impact of a rise in oil prices.

2. Background

3. Replication methodology & results

4. Step 1: Find the data

As per the paper, the data was sourced where possible from the IMF. However, for the interest rate and exchange rate we sourced the data from Board of Governors of the Federal Reserve System and for inflation from the US Bureau of Labor Statistics. First, we want to use US data and see if we can replicate the results in the study. We need to convert all the data into quarterly. The time period available to reproduce the results of the paper was constrained by the availability of world oil price data: could only find from 1990, therefore had to limit to 1990 onwards. Similarly, restricted time period due to the data availability of money. In the paper they used predominantly seasonally-adjusted data but due to constraints on availability of data, for this replication I used a combination of seasonally-adjusted and not seasonally-adjusted.

Interest Rate= Federal Funds Effective Rate, percent, not seasonally adjusted, monthly Source: Board of Governors of the Federal Reserve System Exchange Rate= Millions of Dollars, Not Seasonally Adjusted, quarterly, source: Board of Governors of the Federal Reserve System (2021) Inflation = Index 1982-1984=100, Seasonally Adjusted, monthly, source U.S. Bureau of Labor Statistics Real GDP
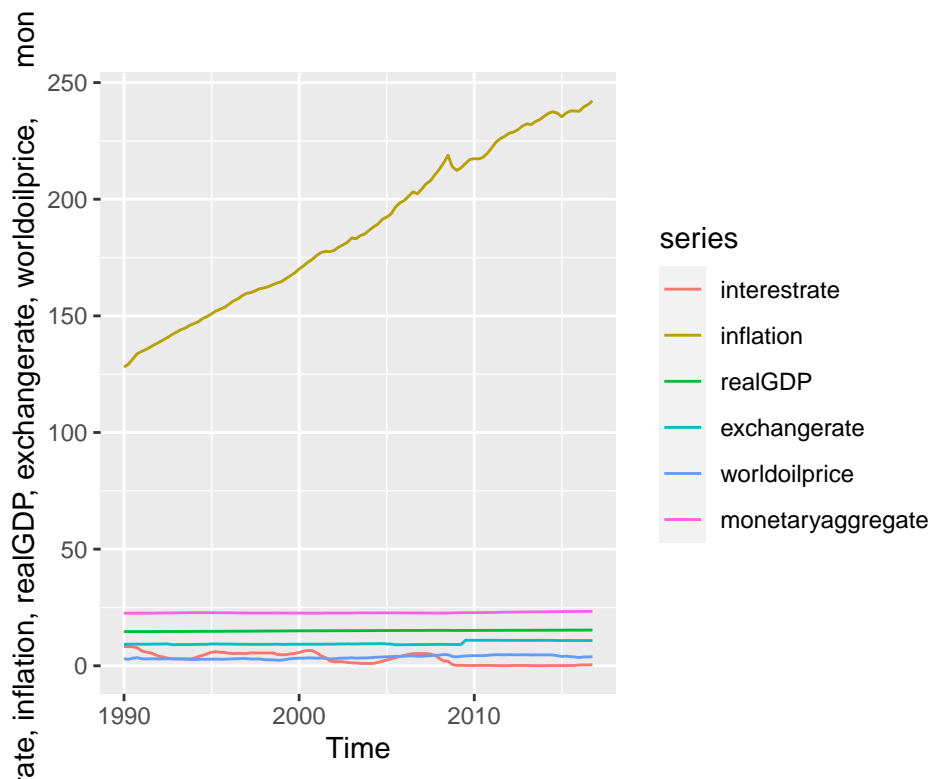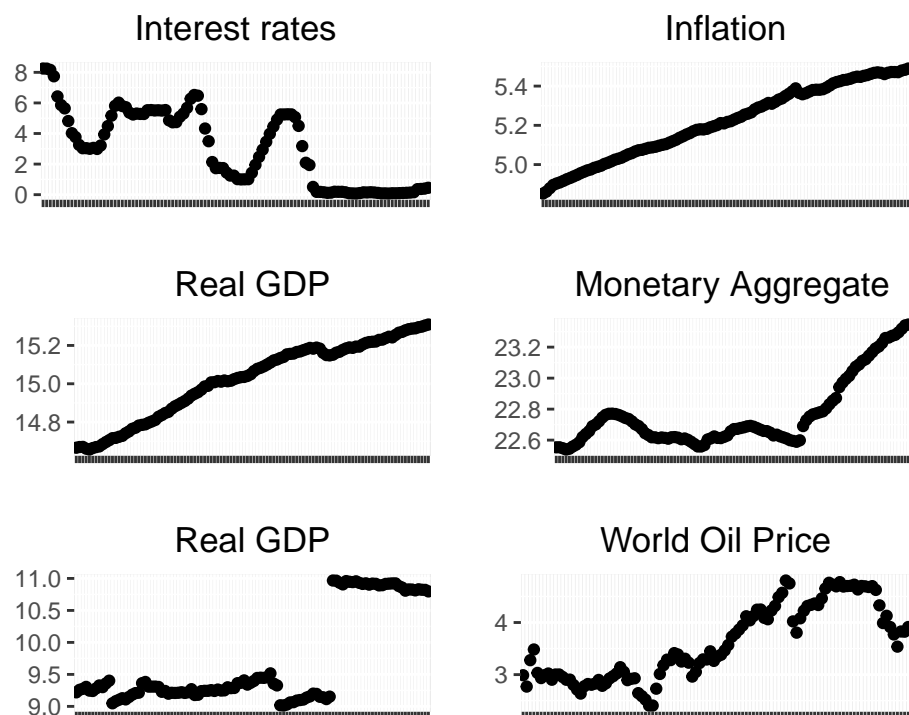
= Domestic Currency, Seasonally Adjusted, quarterly, source IMF Monetary Aggregate = Dollars, Seasonally Adjusted, monthly source: IMF World Oil Price = U.S. Dollars per Barrel, Not Seasonally Adjusted, monthly, IMF. Need to do until 2017 because of monetary aggregate data constraints

The methodology that I applied in order to replicate the study, was to first transform all of the quarterly series in logarithms except for the interest rate. As in the paper, we run Augmented Dickey Fuller tests on all the time series variables. Findings at the 1% confidence interval were that are all variables were non-stationary and were integrated of order 1, except for the monetary aggregate which was found to be integrated of order 2. The lags were selected according to the AIC criteria, as done in the paper. The results in this replication differed only from the paper regarding the integration order of inflation, which was found to be integrated of order 1 by Cologni & Manera. This difference from the paper dictated that only the monetary aggregate be transformed by subtracting inflation to become the real monetary aggregate (by taking the difference between the logarithm of monetary aggregate and the logarithm of inflation), and the transformation for inflation was not followed. This is because for finding cointegrating relationships, the time series variables must be integrated of order 1.

Resultant time series variables were as follows:

Interest rates

8 –
6 –
4 –
2 –
0 –

Inflation

5.4 –
5.2 –
5.0 –

Real GDP

15.2 –
15.0 –
14.8 –

Monetary Aggregate

23.2 –
23.0 –
22.8 –
22.6 –

Real GDP

11.0 –
10.5 –
10.0 –
9.5 –
9.0 –

World Oil Price

4 –
3 –

We then construct our VAR model by creating a matrix which includes the time series variables included in Figure 1. We set the lag max to 4. The VAR model was found to have 3 lags (4 - 1) when we used the AIC lag selection criteria and accounted for a time trend, as is done in the paper.

```
## AIC(n)  HQ(n)  SC(n) FPE(n)
##      4      2      1      4
```

Use AIC and find that lag should be 2 according to the paper, but we find AIC suggests 4, so we use 3. As can be seen in Figure 1, there is clearly a lot of persistence after the financial crisis. Exchange rates for the US had a stark level increase around this water-shed event and interest rates were set close to zero to try and stimulate the economy, where they have remained fairly constant since this monetary policy adjustment. Similarly, we can note real GDP has diminished since 2008.

Now we can see long-run trends in the time series variables, but wish to now see if there exists any cointegrating relationships. We test this using the Johansen test, namely the eigenvalue test and the trace test. For the eigenvalue test, we find that we can reject the null hypothesis of the number of cointegrating relationships equalling 3 or exceeding it at the 5% confidence interval where our critical value is smaller than the test statistic. For the trace test, we find that we can reject the null hypothesis

when the relationships equal or exceed 2. Therefore, because the rejection of the null hypothesis in the eigenvalue test is incredibly marginal (25.71 critical value marginally larger than 25.54 test statistic), we conclude from our estimates that there is likely one cointegrating relationship. This is the same result as is found for the US in Cologni & Manera.

We obtain the cointegrating vectors from the Johansen test and construct a matrix is which each column is a cointegrating vector. Then we multiply the VAR system by the cointegrating vector matrix to obtain the error correction terms.

Let us set up the imposed restrictions in a matrix, known as B matrix in the paper.

```
##         [,1] [,2] [,3] [,4] [,5] [,6]
## Brow1     1    1    0    1    0    0
## Brow2     0    1    1    1    1    1
## Brow3     0    0    1    1    1    1
## Brow4     0    0    0    1    1    1
## Brow5     0    0    0    0    1    1
## Brow6     0    0    0    0    0    1
```

Let us see if we can impose the restrictions contained in the B matrix onto the cointegrating vectors contained in the Et matrix.

```
##                 [,1]        [,2]         [,3]         [,4]         [,5]
## [1,] -0.03485871  0.01603781  0.000000000  0.001526585  0.000000000
## [2,]  0.00000000 -0.03217102 -0.011618819 -0.000240614 -0.022636950
## [3,]  0.00000000  0.00000000  0.004480429 -0.032083484  0.016714331
## [4,]  0.00000000  0.00000000  0.000000000 -0.139231280 -0.012532633
## [5,]  0.00000000  0.00000000  0.000000000  0.000000000 -0.008558293
## [6,]  0.00000000  0.00000000  0.000000000  0.000000000  0.000000000
##                 [,6]
## [1,]  0.000000e+00
## [2,] -5.406431e-03
## [3,] -5.789421e-03
## [4,] -8.313818e-03
## [5,] -8.248844e-05
## [6,]  9.414487e-03
```

5. Set up VECM

```
## #############
## ###Model VECM
## #############
## Full sample size: 108    End sample size: 104
## Number of variables: 6   Number of estimated slope parameters 120
## AIC -3198.134    BIC -2867.585    SSR 75.25772
## Cointegrating vector (estimated by ML):
##    MonetaryAggregate InterestRate  RealGDP  Inflation ExchangeRate
## r1                1   -0.134276 4.787817 -0.0522194     0.615354
##    WorldOilPrice
## r1    0.4247612
##
##
##                              ECT                Intercept
## Equation MonetaryAggregate 0.0126(0.0045)**    -1.1623(0.4105)**
## Equation InterestRate       -0.0200(0.1043)     1.9540(9.5628)
## Equation RealGDP            0.0005(0.0020)      -0.0411(0.1876)
## Equation Inflation          -0.0750(0.3299)     8.4465(30.2481)
## Equation ExchangeRate       -0.1963(0.0391)*** 18.3351(3.5838)***
## Equation WorldOilPrice      -0.0645(0.0542)     6.0297(4.9693)
##                              MonetaryAggregate -1 InterestRate -1
## Equation MonetaryAggregate 0.4105(0.1324)**     0.0031(0.0046)
## Equation InterestRate       -0.3107(3.0852)      0.5676(0.1068)***
## Equation RealGDP            -0.0478(0.0605)      -0.0022(0.0021)
## Equation Inflation          -0.1479(9.7587)      -0.8517(0.3377)*
## Equation ExchangeRate       -0.0068(1.1562)      0.0353(0.0400)
## Equation WorldOilPrice      -0.0068(1.6032)      -0.0309(0.0555)
##                              RealGDP -1           Inflation -1
## Equation MonetaryAggregate -0.3634(0.2590)      0.0094(0.0022)***
## Equation InterestRate       8.9686(6.0343)       -0.1328(0.0503)**
## Equation RealGDP            0.3067(0.1184)*      -0.0007(0.0010)
## Equation Inflation          25.2237(19.0871)     -0.3050(0.1591).
## Equation ExchangeRate       -0.2586(2.2614)      -0.0372(0.0189).
## Equation WorldOilPrice      5.6317(3.1357).      -0.0643(0.0261)*
##                              ExchangeRate -1      WorldOilPrice -1
## Equation MonetaryAggregate -0.0031(0.0073)      -0.0391(0.0131)**
## Equation InterestRate       -0.0114(0.1698)      0.4794(0.3046)
```

```
## Equation RealGDP             0.0026(0.0033)         -0.0013(0.0060)
## Equation Inflation           0.1635(0.5372)          4.0925(0.9635)***
## Equation ExchangeRate        -0.2607(0.0636)***   0.3036(0.1142)**
## Equation WorldOilPrice        0.0616(0.0882)          0.4672(0.1583)**
##                              MonetaryAggregate -2 InterestRate -2
## Equation MonetaryAggregate -0.0357(0.1367)         -0.0010(0.0054)
## Equation InterestRate          4.6836(3.1852)          0.0479(0.1247)
## Equation RealGDP             0.0919(0.0625)          0.0021(0.0024)
## Equation Inflation           4.6173(10.0751)         0.1513(0.3946)
## Equation ExchangeRate        0.7482(1.1937)          0.0708(0.0468)
## Equation WorldOilPrice        2.2347(1.6552)         -0.0113(0.0648)
##                              RealGDP -2             Inflation -2
## Equation MonetaryAggregate -0.5758(0.2612)*        0.0015(0.0022)
## Equation InterestRate         -0.5452(6.0847)          0.0186(0.0511)
## Equation RealGDP             0.2504(0.1194)*        -0.0009(0.0010)
## Equation Inflation           -8.8860(19.2466)        -0.1707(0.1615)
## Equation ExchangeRate        -5.6094(2.2803)*        -0.0100(0.0191)
## Equation WorldOilPrice        0.4852(3.1619)         -0.0251(0.0265)
##                              ExchangeRate -2       WorldOilPrice -2
## Equation MonetaryAggregate -0.0013(0.0068)        -0.0075(0.0133)
## Equation InterestRate         -0.1535(0.1591)         -0.3310(0.3089)
## Equation RealGDP             -0.0028(0.0031)          0.0035(0.0061)
## Equation Inflation           -0.7990(0.5032)          0.9032(0.9770)
## Equation ExchangeRate        -0.0974(0.0596)         -0.0140(0.1157)
## Equation WorldOilPrice        -0.0530(0.0827)          0.0298(0.1605)
##                              MonetaryAggregate -3 InterestRate -3
## Equation MonetaryAggregate 0.0399(0.1264)         -0.0120(0.0045)**
## Equation InterestRate          1.5625(2.9449)          0.0465(0.1056)
## Equation RealGDP             -0.0549(0.0578)          0.0009(0.0021)
## Equation Inflation           -0.9284(9.3150)          0.9919(0.3339)**
## Equation ExchangeRate        2.9212(1.1036)**        -0.0599(0.0396)
## Equation WorldOilPrice        -0.6155(1.5303)          0.0691(0.0549)
##                              RealGDP -3             Inflation -3
## Equation MonetaryAggregate 0.3512(0.2735)          0.0037(0.0021).
## Equation InterestRate          5.8409(6.3702)         -0.1417(0.0488)**
## Equation RealGDP             -0.0610(0.1250)         -0.0016(0.0010)
## Equation Inflation           -9.7967(20.1495)        -0.0537(0.1543)
## Equation ExchangeRate        -10.5904(2.3873)***  -0.1229(0.0183)***
## Equation WorldOilPrice        -1.3140(3.3102)         -0.0394(0.0253)
```

```
##                                  ExchangeRate -3      WorldOilPrice -3
## Equation MonetaryAggregate 0.0004(0.0068)       -0.0189(0.0127)
## Equation InterestRate       -0.0609(0.1588)       1.2460(0.2968)***
## Equation RealGDP            0.0013(0.0031)        0.0060(0.0058)
## Equation Inflation          -0.6361(0.5022)       0.3802(0.9388)
## Equation ExchangeRate       0.0260(0.0595)        0.3845(0.1112)***
## Equation WorldOilPrice      0.0156(0.0825)        0.2993(0.1542).
```

Then test for white noise residuals.

6. Step 3: Augemented Dickey-Fuller tests

The null-hypothesis of an Augmented Dickey-Fuller test is that the series has a unit-root. We ask, is the estimated critical value small enough to reject the null-hypothesis? If yes, we cannot reject the null hypothesis, therefore, the series may be non-stationary.

In this section, we find that the interest rate is stationary, change in inflation is stationary, detrended real GDP is still not stationary, detrended monetary aggregate is still non-stationary and world oil price is non stationary.

7. Augmented Dickey Fuller tests

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.30124 -0.04024  0.03284  0.19765  0.64002
##
```

```
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -0.017754   0.007925  -2.240   0.0272 *
## z.diff.lag  0.665828   0.070243   9.479 9.82e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3117 on 104 degrees of freedom
## Multiple R-squared:  0.4962, Adjusted R-squared:  0.4865
## F-statistic: 51.22 on 2 and 104 DF,  p-value: 3.283e-16
##
##
## Value of test-statistic is: -2.2403
##
## Critical values for test statistics:
##      1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62


##
## #################################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## #################################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##     Min      1Q   Median       3Q      Max
## -1.26565 -0.04976  0.00946  0.14002  0.64079
##
## Coefficients:
##            Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -0.29184    0.07777  -3.753  0.00029 ***
## z.diff.lag -0.06765    0.09829  -0.688  0.49278
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3199 on 103 degrees of freedom
## Multiple R-squared:  0.1604, Adjusted R-squared:  0.1441
## F-statistic:  9.84 on 2 and 103 DF,  p-value: 0.0001228
##
##
## Value of test-statistic is: -3.7526
##
## Critical values for test statistics:
##      1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62


##
## #################################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## #################################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.031918 -0.001413  0.000394  0.002783  0.010390
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## z.lag.1    0.0007928  0.0001390   5.703 1.11e-07 ***
## z.diff.lag 0.2926254  0.0935172   3.129  0.00228 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.004852 on 104 degrees of freedom
## Multiple R-squared:  0.6129, Adjusted R-squared:  0.6054
## F-statistic: 82.32 on 2 and 104 DF,  p-value: < 2.2e-16
```

```
##
##
## Value of test-statistic is: 5.7029
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62


##
## ##################################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ##################################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.033954 -0.000482  0.002075  0.004001  0.012994
##
## Coefficients:
##            Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -0.26980    0.07387  -3.652  0.00041 ***
## z.diff.lag -0.16294    0.09511  -1.713  0.08968 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.005415 on 103 degrees of freedom
## Multiple R-squared:  0.1927, Adjusted R-squared:  0.177
## F-statistic: 12.29 on 2 and 103 DF,  p-value: 1.628e-05
##
##
## Value of test-statistic is: -3.6524
##
## Critical values for test statistics:
```

```
##        1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

Real GDP

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##         Min         1Q     Median         3Q        Max
## -0.0234977 -0.0030666  0.0004404  0.0032845  0.0130056
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## z.lag.1    2.365e-04  5.087e-05   4.649 9.84e-06 ***
## z.diff.lag 4.100e-01  8.943e-02   4.585 1.27e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.005598 on 104 degrees of freedom
## Multiple R-squared:  0.5797, Adjusted R-squared:  0.5716
## F-statistic: 71.72 on 2 and 104 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic is: 4.6489
##
## Critical values for test statistics:
##        1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

```
##
## #################################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## #################################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.021479 -0.002183  0.001511  0.004429  0.013011
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## z.lag.1     -0.19720    0.07196  -2.740  0.00724 **
## z.diff.lag  -0.33194    0.09306  -3.567  0.00055 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.00583 on 103 degrees of freedom
## Multiple R-squared:  0.2414, Adjusted R-squared:  0.2267
## F-statistic: 16.39 on 2 and 103 DF,  p-value: 6.62e-07
##
##
## Value of test-statistic is: -2.7403
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

Monetary Aggregates

```
##
## #################################################
## # Augmented Dickey-Fuller Test Unit Root Test #
```

```
## #################################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.024123 -0.007572 -0.000144  0.005791  0.052443
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## z.lag.1    0.0001535  0.0000529    2.902  0.00453 **
## z.diff.lag 0.6811085  0.0718457    9.480 9.76e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.01155 on 104 degrees of freedom
## Multiple R-squared:  0.6921, Adjusted R-squared:  0.6862
## F-statistic: 116.9 on 2 and 104 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic is: 2.902
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62


##
## #################################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## #################################################
##
## Test regression none
##
##
```

```
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.021316 -0.005213  0.000844  0.007164  0.051563
##
## Coefficients:
##            Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -0.13784    0.05814  -2.371   0.0196 *
## z.diff.lag -0.24266    0.09651  -2.514   0.0135 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.0117 on 103 degrees of freedom
## Multiple R-squared:  0.1441, Adjusted R-squared:  0.1275
## F-statistic: 8.672 on 2 and 103 DF,  p-value: 0.0003305
##
##
## Value of test-statistic is: -2.3707
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

Exchange Rate

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
```

```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.36660 -0.02652 -0.00900  0.01104  1.80232
##
## Coefficients:
##            Estimate Std. Error t value Pr(>|t|)
## z.lag.1    0.001348   0.001877   0.718    0.474
## z.diff.lag 0.005283   0.098225   0.054    0.957
##
## Residual standard error: 0.187 on 104 degrees of freedom
## Multiple R-squared:  0.005078,   Adjusted R-squared:  -0.01406
## F-statistic: 0.2654 on 2 and 104 DF,  p-value: 0.7674
##
##
## Value of test-statistic is: 0.7184
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62


##
## #################################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## #################################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.35260 -0.01246  0.00443  0.02440  1.81361
##
## Coefficients:
##            Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -1.01592    0.13846  -7.338 5.18e-11 ***
```

```
## z.diff.lag  0.02795    0.09848   0.284    0.777
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1883 on 103 degrees of freedom
## Multiple R-squared:  0.4945, Adjusted R-squared:  0.4847
## F-statistic: 50.38 on 2 and 103 DF,  p-value: 5.501e-16
##
##
## Value of test-statistic is: -7.3375
##
## Critical values for test statistics:
##      1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

World Oil Price

```
##
## #################################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## #################################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.72572 -0.06453  0.01614  0.08600  0.53844
##
## Coefficients:
##            Estimate Std. Error t value Pr(>|t|)
## z.lag.1    0.001240   0.004215   0.294    0.769
## z.diff.lag 0.160192   0.096223   1.665    0.099 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 0.1595 on 104 degrees of freedom
## Multiple R-squared:  0.02747,    Adjusted R-squared:  0.008763
## F-statistic: 1.469 on 2 and 104 DF,  p-value: 0.235
##
##
## Value of test-statistic is: 0.2942
##
## Critical values for test statistics:
##      1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

8. Set up the VAR model

9. Build VAR model

```
##
## VAR Estimation Results:
## =========================
## Endogenous variables: MonetaryAggregate, InterestRate, RealGDP, Inflation, ExchangeRate, Worl
## Deterministic variables: trend
## Sample size: 105
## Log Likelihood: 800.372
## Roots of the characteristic polynomial:
## 1.001 0.9865 0.9865 0.9096 0.9096 0.8717 0.8717 0.6162 0.5794 0.5794 0.4751 0.4751 0.4373 0.4
## Call:
## VAR(y = groupedVAR, p = 3, type = "trend", exogen = NULL)
##
##
## Estimation results for equation MonetaryAggregate:
## ====================================================
## MonetaryAggregate = MonetaryAggregate.l1 + InterestRate.l1 + RealGDP.l1 + Inflation.l1 + Exch
##
##                     Estimate Std. Error t value Pr(>|t|)
## MonetaryAggregate.l1  1.3047772  0.1271001  10.266  < 2e-16 ***
## InterestRate.l1      -0.0010960  0.0047783  -0.229 0.819120
## RealGDP.l1           -0.3187494  0.2467876  -1.292 0.199958
## Inflation.l1          0.0087185  0.0021686   4.020 0.000124 ***
```

```
## ExchangeRate.l1       -0.0021688  0.0069313  -0.313 0.755113
## WorldOilPrice.l1       -0.0343555  0.0122044  -2.815 0.006046 **
## MonetaryAggregate.l2   -0.3088679  0.2076664  -1.487 0.140586
## InterestRate.l2        -0.0057323  0.0080447  -0.713 0.478048
## RealGDP.l2             -0.0476563  0.3758990  -0.127 0.899411
## Inflation.l2           -0.0051665  0.0030158  -1.713 0.090295 .
## ExchangeRate.l2         0.0003534  0.0089754   0.039 0.968680
## WorldOilPrice.l2        0.0237594  0.0164007   1.449 0.151062
## MonetaryAggregate.l3   -0.0215402  0.1251202  -0.172 0.863719
## InterestRate.l3         0.0037798  0.0045677   0.827 0.410245
## RealGDP.l3              0.3787652  0.2520508   1.503 0.136571
## Inflation.l3           -0.0008038  0.0021201  -0.379 0.705528
## ExchangeRate.l3         0.0134310  0.0069299   1.938 0.055890 .
## WorldOilPrice.l3       -0.0044031  0.0123397  -0.357 0.722095
## trend                  -0.0029500  0.0011267  -2.618 0.010439 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.01181 on 86 degrees of freedom
## Multiple R-Squared:     1,   Adjusted R-squared:     1
## F-statistic: 2.055e+07 on 19 and 86 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation InterestRate:
## ================================================
## InterestRate = MonetaryAggregate.l1 + InterestRate.l1 + RealGDP.l1 + Inflation.l1 + ExchangeR
##
##                         Estimate Std. Error t value Pr(>|t|)
## MonetaryAggregate.l1   -1.952221   3.084476  -0.633   0.5285
## InterestRate.l1         1.375258   0.115959  11.860   <2e-16 ***
## RealGDP.l1             14.290127   5.989063   2.386   0.0192 *
## Inflation.l1           -0.083859   0.052628  -1.593   0.1147
## ExchangeRate.l1        -0.163684   0.168210  -0.973   0.3332
## WorldOilPrice.l1        0.140811   0.296178   0.475   0.6357
## MonetaryAggregate.l2    3.003978   5.039666   0.596   0.5527
## InterestRate.l2        -0.210108   0.195229  -1.076   0.2848
## RealGDP.l2            -19.042812   9.122352  -2.087   0.0398 *
## Inflation.l2            0.117266   0.073189   1.602   0.1128
```

```
## ExchangeRate.l2          0.008949   0.217816    0.041    0.9673
## WorldOilPrice.l2        -0.516657   0.398013   -1.298    0.1977
## MonetaryAggregate.l3    -0.875961   3.036428   -0.288    0.7737
## InterestRate.l3         -0.267204   0.110850   -2.410    0.0181 *
## RealGDP.l3               4.714602   6.116792    0.771    0.4430
## Inflation.l3            -0.045978   0.051451   -0.894    0.3740
## ExchangeRate.l3         -0.001112   0.168175   -0.007    0.9947
## WorldOilPrice.l3         0.415155   0.299460    1.386    0.1692
## trend                    0.010115   0.027342    0.370    0.7123
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.2866 on 86 degrees of freedom
## Multiple R-Squared: 0.9951,  Adjusted R-squared: 0.994
## F-statistic: 919.1 on 19 and 86 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation RealGDP:
## =======================================
## RealGDP = MonetaryAggregate.l1 + InterestRate.l1 + RealGDP.l1 + Inflation.l1 + ExchangeRate.l
##
##                        Estimate Std. Error t value Pr(>|t|)
## MonetaryAggregate.l1 -0.0383785  0.0575594   -0.667    0.507
## InterestRate.l1      -0.0018227  0.0021639   -0.842    0.402
## RealGDP.l1            1.2456502  0.1117619   11.146   <2e-16 ***
## Inflation.l1          0.0002404  0.0009821    0.245    0.807
## ExchangeRate.l1       0.0039487  0.0031390    1.258    0.212
## WorldOilPrice.l1     -0.0087332  0.0055270   -1.580    0.118
## MonetaryAggregate.l2  0.1079090  0.0940452    1.147    0.254
## InterestRate.l2       0.0047055  0.0036432    1.292    0.200
## RealGDP.l2           -0.0945479  0.1702322   -0.555    0.580
## Inflation.l2         -0.0012468  0.0013658   -0.913    0.364
## ExchangeRate.l2      -0.0048538  0.0040647   -1.194    0.236
## WorldOilPrice.l2      0.0108246  0.0074273    1.457    0.149
## MonetaryAggregate.l3 -0.0707778  0.0566628   -1.249    0.215
## InterestRate.l3      -0.0032253  0.0020686   -1.559    0.123
## RealGDP.l3           -0.1463459  0.1141455   -1.282    0.203
## Inflation.l3          0.0006937  0.0009601    0.723    0.472
```

```
## ExchangeRate.l3         0.0021952  0.0031383   0.699     0.486
## WorldOilPrice.l3        -0.0042240  0.0055882  -0.756     0.452
## trend                    0.0002802  0.0005102   0.549     0.584
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.005348 on 86 degrees of freedom
## Multiple R-Squared:     1,    Adjusted R-squared:     1
## F-statistic: 4.367e+07 on 19 and 86 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation Inflation:
## =========================================
## Inflation = MonetaryAggregate.l1 + InterestRate.l1 + RealGDP.l1 + Inflation.l1 + ExchangeRate
##
##                     Estimate Std. Error t value Pr(>|t|)
## MonetaryAggregate.l1   3.60914    9.42515   0.383 0.702719
## InterestRate.l1       -0.63442    0.35433  -1.790 0.076898 .
## RealGDP.l1            35.59225   18.30062   1.945 0.055059 .
## Inflation.l1           0.68199    0.16081   4.241 5.59e-05 ***
## ExchangeRate.l1        0.35204    0.51400   0.685 0.495245
## WorldOilPrice.l1       3.61241    0.90502   3.992 0.000138 ***
## MonetaryAggregate.l2  -0.42293   15.39958  -0.027 0.978153
## InterestRate.l2        1.25515    0.59656   2.104 0.038299 *
## RealGDP.l2           -47.18496   27.87493  -1.693 0.094125 .
## Inflation.l2          -0.11986    0.22364  -0.536 0.593388
## ExchangeRate.l2       -0.85553    0.66557  -1.285 0.202101
## WorldOilPrice.l2      -2.02065    1.21620  -1.661 0.100264
## MonetaryAggregate.l3  -2.34086    9.27833  -0.252 0.801417
## InterestRate.l3       -0.51864    0.33872  -1.531 0.129399
## RealGDP.l3            12.32548   18.69092   0.659 0.511377
## Inflation.l3           0.18876    0.15722   1.201 0.233200
## ExchangeRate.l3        0.26353    0.51389   0.513 0.609395
## WorldOilPrice.l3       0.12679    0.91505   0.139 0.890124
## trend                  0.24008    0.08355   2.874 0.005113 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
##
## Residual standard error: 0.8757 on 86 degrees of freedom
## Multiple R-Squared:     1,   Adjusted R-squared:     1
## F-statistic: 2.65e+05 on 19 and 86 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation ExchangeRate:
## ============================================
## ExchangeRate = MonetaryAggregate.l1 + InterestRate.l1 + RealGDP.l1 + Inflation.l1 + ExchangeR
##
##                         Estimate Std. Error t value Pr(>|t|)
## MonetaryAggregate.l1    1.996060   1.864598   1.071  0.28739
## InterestRate.l1         0.031558   0.070099   0.450  0.65370
## RealGDP.l1             -0.540009   3.620451  -0.149  0.88178
## Inflation.l1           -0.001199   0.031814  -0.038  0.97004
## ExchangeRate.l1         0.847479   0.101685   8.334 1.11e-12 ***
## WorldOilPrice.l1        0.372465   0.179043   2.080  0.04047 *
## MonetaryAggregate.l2   -2.958531   3.046531  -0.971  0.33421
## InterestRate.l2        -0.003892   0.118018  -0.033  0.97377
## RealGDP.l2            -10.067770   5.514557  -1.826  0.07137 .
## Inflation.l2           -0.014022   0.044243  -0.317  0.75206
## ExchangeRate.l2         0.024395   0.131672   0.185  0.85345
## WorldOilPrice.l2       -0.440474   0.240603  -1.831  0.07061 .
## MonetaryAggregate.l3    0.948965   1.835553   0.517  0.60649
## InterestRate.l3        -0.040467   0.067010  -0.604  0.54750
## RealGDP.l3             10.486913   3.697665   2.836  0.00569 **
## Inflation.l3            0.043474   0.031102   1.398  0.16578
## ExchangeRate.l3         0.036406   0.101664   0.358  0.72114
## WorldOilPrice.l3       -0.108599   0.181027  -0.600  0.55015
## trend                  -0.026148   0.016528  -1.582  0.11731
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.1732 on 86 degrees of freedom
## Multiple R-Squared: 0.9997,  Adjusted R-squared: 0.9997
## F-statistic: 1.747e+04 on 19 and 86 DF,  p-value: < 2.2e-16
##
##
```

```
## Estimation results for equation WorldOilPrice:
## ===============================================
## WorldOilPrice = MonetaryAggregate.l1 + InterestRate.l1 + RealGDP.l1 + Inflation.l1 + Exchange
##
##                      Estimate Std. Error t value Pr(>|t|)
## MonetaryAggregate.l1 -0.336350   1.542221  -0.218   0.8279
## InterestRate.l1      -0.018076   0.057979  -0.312   0.7560
## RealGDP.l1            5.092957   2.994499   1.701   0.0926 .
## Inflation.l1         -0.046980   0.026314  -1.785   0.0777 .
## ExchangeRate.l1       0.073540   0.084104   0.874   0.3843
## WorldOilPrice.l1      1.304504   0.148087   8.809  1.2e-13 ***
## MonetaryAggregate.l2  1.714025   2.519806   0.680   0.4982
## InterestRate.l2       0.067057   0.097613   0.687   0.4940
## RealGDP.l2           -6.823966   4.561127  -1.496   0.1383
## Inflation.l2          0.028944   0.036594   0.791   0.4312
## ExchangeRate.l2      -0.070110   0.108907  -0.644   0.5214
## WorldOilPrice.l2     -0.441991   0.199004  -2.221   0.0290 *
## MonetaryAggregate.l3 -1.577365   1.518198  -1.039   0.3017
## InterestRate.l3      -0.045944   0.055424  -0.829   0.4094
## RealGDP.l3            2.140717   3.058363   0.700   0.4858
## Inflation.l3          0.004053   0.025725   0.158   0.8752
## ExchangeRate.l3       0.022652   0.084087   0.269   0.7883
## WorldOilPrice.l3      0.149508   0.149728   0.999   0.3208
## trend                 0.013013   0.013671   0.952   0.3438
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.1433 on 86 degrees of freedom
## Multiple R-Squared: 0.9988,  Adjusted R-squared: 0.9985
## F-statistic:  3675 on 19 and 86 DF,  p-value: < 2.2e-16
##
##
##
## Covariance matrix of residuals:
##                   MonetaryAggregate InterestRate    RealGDP  Inflation
## MonetaryAggregate         1.395e-04   -0.0012598 -2.245e-05 -0.0053184
## InterestRate             -1.260e-03    0.0821286  4.932e-04  0.0632735
## RealGDP                  -2.245e-05    0.0004932  2.860e-05  0.0008689
```

```
## Inflation                  -5.318e-03     0.0632735  8.689e-04  0.7668462
## ExchangeRate               -9.553e-05    -0.0046854  8.183e-05 -0.0005647
## WorldOilPrice              -8.396e-04     0.0128679  1.740e-04  0.0945846
##                    ExchangeRate WorldOilPrice
## MonetaryAggregate   -9.553e-05    -0.0008396
## InterestRate        -4.685e-03     0.0128679
## RealGDP              8.183e-05     0.0001740
## Inflation           -5.647e-04     0.0945846
## ExchangeRate         3.001e-02     0.0003972
## WorldOilPrice        3.972e-04     0.0205317
##
## Correlation matrix of residuals:
##                    MonetaryAggregate InterestRate   RealGDP Inflation
## MonetaryAggregate            1.00000     -0.37227 -0.35555 -0.514295
## InterestRate                -0.37227      1.00000  0.32180  0.252128
## RealGDP                     -0.35555      0.32180  1.00000  0.185535
## Inflation                   -0.51430      0.25213  0.18554  1.000000
## ExchangeRate                -0.04669     -0.09437  0.08833 -0.003723
## WorldOilPrice               -0.49619      0.31336  0.22707  0.753796
##                    ExchangeRate WorldOilPrice
## MonetaryAggregate     -0.046694        -0.4962
## InterestRate          -0.094374         0.3134
## RealGDP                0.088329         0.2271
## Inflation             -0.003723         0.7538
## ExchangeRate           1.000000         0.0160
## WorldOilPrice          0.016000         1.0000
```

10. **Step 5: ACF & PACF? or AIC criteria to choose lags**

11. **Step 6: Is it stationary?**

12. **Step 7: Are the residuals white noise?**

13. **Step 8: Find VECM model by imposing SR contemporaneous effects**

14. **Step 9: Test model specification using congruency, parsimony, lag inclusion...**

Appendix

Johansen Tests

```
##
## ######################
## # Johansen-Procedure #
## ######################
##
## Test type: maximal eigenvalue statistic (lambda max) , with linear trend in cointegration
##
## Eigenvalues (lambda):
## [1]  3.625609e-01  2.963807e-01  2.076486e-01  1.541662e-01  9.800368e-02
## [6]  3.747924e-02 -8.856705e-18
##
## Values of teststatistic and critical values of test:
##
##           test 10pct  5pct  1pct
## r <= 5 |   4.05 10.49 12.25 16.26
## r <= 4 |  10.93 16.85 18.96 23.65
## r <= 3 |  17.75 23.11 25.54 30.34
## r <= 2 |  24.67 29.12 31.46 36.65
## r <= 1 |  37.26 34.75 37.52 42.36
## r = 0  |  47.73 40.91 43.97 49.51
##
## Eigenvectors, normalised to first column:
## (These are the cointegration relations)
```

```
##
##                      MonetaryAggregate.l2 InterestRate.l2   RealGDP.l2
## MonetaryAggregate.l2           1.00000000       1.0000000  1.00000000
## InterestRate.l2                0.02090796      -0.1815780 -0.05463788
## RealGDP.l2                     5.79168509      11.4507610 -1.41461126
## Inflation.l2                   0.01263811       0.1391621 -0.08991552
## ExchangeRate.l2                0.20637462       0.6731770 -0.29247756
## WorldOilPrice.l2               0.08300303      -0.6733798  0.98679887
## trend.l2                      -0.06055900      -0.2378757  0.08962033
##                      Inflation.l2 ExchangeRate.l2 WorldOilPrice.l2      trend.l2
## MonetaryAggregate.l2    1.0000000      1.00000000      1.000000000  1.000000000
## InterestRate.l2        -0.0107365     -0.03832031      0.096334240  0.081610505
## RealGDP.l2              3.9793206      1.65375391     -9.343016135  0.346116761
## Inflation.l2            0.1079603     -0.03067633      0.060520904 -0.009945965
## ExchangeRate.l2        -0.1427203     -0.18869668     -0.011991905 -0.041187182
## WorldOilPrice.l2       -0.3129209      0.13160811     -0.210068744 -0.374636824
## trend.l2               -0.1405501      0.01532017     -0.006572137  0.023968868
##
## Weights W:
## (This is the loading matrix)
##
##                      MonetaryAggregate.l2 InterestRate.l2    RealGDP.l2
## MonetaryAggregate.d          -0.034858708      0.016037808  0.007271973
## InterestRate.d               -0.338396750      0.177174677  0.212651360
## RealGDP.d                    -0.004020157      0.001844628 -0.003167251
## Inflation.d                   0.833537291     -1.144421528  0.771708313
## ExchangeRate.d               -1.036106898     -0.197592759 -0.042723775
## WorldOilPrice.d              -0.108557713     -0.101243881 -0.055028948
##                      Inflation.l2 ExchangeRate.l2 WorldOilPrice.l2      trend.l2
## MonetaryAggregate.d   0.001526585     -0.02120366      0.0012239580  1.979170e-14
## InterestRate.d        0.022410843      0.59072985     -0.0561215932 -1.634378e-12
## RealGDP.d            -0.008062553      0.01010690      0.0006196523  8.444640e-14
## Inflation.d          -1.289652532      0.40854415     -0.1373710103  5.817831e-11
## ExchangeRate.d        0.081145460      0.04535476      0.0068786772  2.184548e-11
## WorldOilPrice.d      -0.201465643      0.03207400     -0.0448162206  7.370779e-12


##
## ######################
```

```
## # Johansen-Procedure #
## ######################
##
## Test type: trace statistic , with linear trend in cointegration
##
## Eigenvalues (lambda):
## [1]  3.625609e-01  2.963807e-01  2.076486e-01  1.541662e-01  9.800368e-02
## [6]  3.747924e-02 -8.856705e-18
##
## Values of teststatistic and critical values of test:
##
##            test  10pct   5pct   1pct
## r <= 5 |   4.05  10.49  12.25  16.26
## r <= 4 |  14.98  22.76  25.32  30.45
## r <= 3 |  32.73  39.06  42.44  48.45
## r <= 2 |  57.40  59.14  62.99  70.05
## r <= 1 |  94.66  83.20  87.31  96.58
## r = 0  | 142.39 110.42 114.90 124.75
##
## Eigenvectors, normalised to first column:
## (These are the cointegration relations)
##
##                     MonetaryAggregate.l2 InterestRate.l2  RealGDP.l2
## MonetaryAggregate.l2          1.00000000       1.0000000  1.00000000
## InterestRate.l2               0.02090796      -0.1815780 -0.05463788
## RealGDP.l2                    5.79168509      11.4507610 -1.41461126
## Inflation.l2                  0.01263811       0.1391621 -0.08991552
## ExchangeRate.l2               0.20637462       0.6731770 -0.29247756
## WorldOilPrice.l2              0.08300303      -0.6733798  0.98679887
## trend.l2                     -0.06055900      -0.2378757  0.08962033
##                     Inflation.l2 ExchangeRate.l2 WorldOilPrice.l2     trend.l2
## MonetaryAggregate.l2    1.0000000      1.00000000      1.000000000  1.000000000
## InterestRate.l2        -0.0107365     -0.03832031      0.096334240  0.081610505
## RealGDP.l2              3.9793206      1.65375391     -9.343016135  0.346116761
## Inflation.l2            0.1079603     -0.03067633      0.060520904 -0.009945965
## ExchangeRate.l2        -0.1427203     -0.18869668     -0.011991905 -0.041187182
## WorldOilPrice.l2       -0.3129209      0.13160811     -0.210068744 -0.374636824
## trend.l2               -0.1405501      0.01532017     -0.006572137  0.023968868
##
```

```
## Weights W:
## (This is the loading matrix)
##
##                      MonetaryAggregate.l2 InterestRate.l2   RealGDP.l2
## MonetaryAggregate.d         -0.034858708      0.016037808  0.007271973
## InterestRate.d              -0.338396750      0.177174677  0.212651360
## RealGDP.d                   -0.004020157      0.001844628 -0.003167251
## Inflation.d                  0.833537291     -1.144421528  0.771708313
## ExchangeRate.d              -1.036106898     -0.197592759 -0.042723775
## WorldOilPrice.d             -0.108557713     -0.101243881 -0.055028948
##                      Inflation.l2 ExchangeRate.l2 WorldOilPrice.l2      trend.l2
## MonetaryAggregate.d   0.001526585     -0.02120366     0.0012239580  1.979170e-14
## InterestRate.d        0.022410843      0.59072985    -0.0561215932 -1.634378e-12
## RealGDP.d            -0.008062553      0.01010690     0.0006196523  8.444640e-14
## Inflation.d          -1.289652532      0.40854415    -0.1373710103  5.817831e-11
## ExchangeRate.d        0.081145460      0.04535476     0.0068786772  2.184548e-11
## WorldOilPrice.d      -0.201465643      0.03207400    -0.0448162206  7.370779e-12
```