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, the same methodology and structural cointegrated VAR model was used. This paper investigates whether the findings from Cologni & Manera hold after 2003 in the United States, as the economic impact of a rise in oil prices during the period 1990 to 2017 is analysed. The Cologni & Manera paper sought to find the impact of an increase in the world oil price on economic variables and whether the response of central banks to a sudden oil price shock reduced the impact thereof. However, the scope of this replication is limited to the impulse response functions for each variable.

This replication paper finds that... is the optimal model for this time period and ...

2. Background

Many economists regard increases in the oil price as a major cause of asymmetries in the business cycle. Many studies have found a negative impact on aggregate economic activity as a result of an increase in the oil price (Hamilton, 1983). This issue became especially important to economists following the world oil market highs in the early 2000s which could lead to economic slowdowns in developed countries. The hypothesised asymmetric relationship between oil prices and economic activity was first hypothesised after the oil price collapse of 1986 which did not lead to an economic boom, which is what theoretically should have been the case following the view that there existed an inverse relationship between oil prices and the economy.

However, the channels through which an increase in the oil price impacts economic variables remains unclear. There are many possible theoretical explanations; some of which link to the effect of decreasing

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firms' profits which may reduce capital spending and consumers' expectations which causes them to consume more today, others link to the income transfer between oil-importing countries and oil exporting countries that shifts, and others link an increase in oil prices to the increases in prices of related goods, thereby increasing inflation.

There is also, importantly, effects on economic variables that flow indirectly from an increase in oil prices. Namely, that the monetary authority responds to increase employment and ensure price stability once an increase in oil prices threatens these two objectives. For example, in the US, the Federal bank ... The role of monetary policy may cause delayed impacts of an increase in oil prices on economic variables.

Cologni & Manera motivate their inclusion of exchange rates based on it serving as a measurement of monetary policy because monetary authorities may offset the short-term effect of a shock to the economy with the exchange rate or they may target the exchange rate. The choice of time period from 1980 to 2003 was because it was a volatile period for oil prices and the authors sought to verify the role of exogenous shocks at this time. Cologni & Manera impose short-run and long-run restrictions on the model based on economic theory. Thereafter, cointegration analysis is conducted on the long-run model, in other words, the VAR system, and the lags are selected.

For our purposes, the imposition of both the long-run and short-run restrictions was contrained by the capabilities of the coding software used. Therefore, we imposed only the short-run restrictions. Moreover, the inclusion of the exchange rate in the model is challenged on the grounds that after the 2008 financial crisis which is included in our period of analysis, interest rates were close to the lower bound which undermined the Federal Bank's ability to target the exchange rate (Amador et al, 2017). Moreover, an exchange rate is generally affected indirectly from a change in interest rates, which therefore would be captured in interest rates, rendering exchange rates in the model specification redundant. As stated in Cologni & Manera (2006), in order to obtain a more parsimonious result, a visual representation of the cointegrating vectors if two were identified by the Johansen test and motivated by economic theory could be analysed. If the cointegrating vectors looked to be trending, then include. But could motivate on economic reasoning.

3. Replication methodology & results

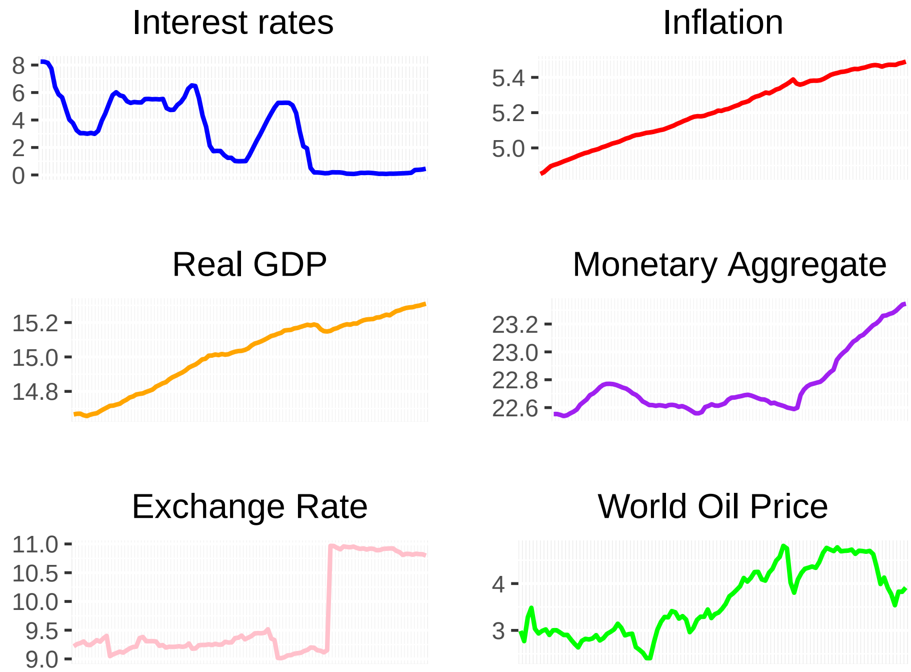
3.1. Finding the data

The data for this replication was sourced where possible from the IMF to be as similar to Cologni & Manera's method as possible. However, for the interest rate and exchange rate we sourced the data from Board of Governors of the Federal Reserve System and for inflation the data was obtained from the US Bureau of Labor Statistics. Firstly, all the data was converted into quarterly data. The time period available to reproduce the results of the paper was constrained by the availability of world oil price and monetary aggregate data. For the world oil price, data was only available from 1990, and for the monetary aggregate, data was only available up until 2017. Therefore, our time period was constrained due to data availability. In the Cologni & Manera (2006) paper, predominantly seasonally-adjusted data was used but due to constraints on availability of data, for this replication I used a combination of seasonally-adjusted and non-seasonally-adjusted data.

Economic variable	Cologni & Manera (all IMF)	Replication paper
Interest Rate	Federal Funds rate (% per annum)	Federal Funds Effective rate (% per month)
Inflation	Consumer price index (index number)	Consumer price index (1982-1984=100)
Real GDP	Real GDP (constant prices 1995) (billions)	Real GDP (constant prices 1995) (billions) (IMF)
Monetary Aggregate	Money M1 (billions)	Money M1 (billions) (IMF)
Exchange Rate	US dollars (per SDR)	US dollars (millions)
World Oil Price	International average price (Brent dated)	US dollars per barrel (IMF)

Thereafter, all of the quarterly time series variables were transformed in logarithms, except for the interest rate. As in the paper, Augmented Dickey Fuller tests were run 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 results in this replication for the Augmented Dickey Fuller tests 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.

Figure 1: Replicated time series variables from 1980−2017



We then construct our VAR model and estimate the number of lags to be included. According to the paper, the lag max is set to 4 and the AIC lag selection criteria is used. The VAR model in the replication was found to have 4 lags and accounted for a time trend, as is done in the paper. We order our VAR system in the same way as the short run restrictions matrix in the paper: monetary aggregate, interest rate, real GDP, inflation, exchange rate and world oil price. Cologni & Manera find that the number of lags should be 2. 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 its upward trajectory path slightly since 2008. Therefore, it is likely the difference in the optimal lags between this replication and the Cologni & Manera paper arises from the different time periods used, as Cologni & Manera's time period ends before the financial crisis.

For a VAR model, we use the lag of 4. For the VECM model, we use the lag of 3 because a VECM model has a difference term.

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 we cannot reject the null hypothesis that the number of cointegrating relationships is between 0 and 1 at the 5% confidence interval where our critical value is smaller than the test statistic, however, only marginally (37.26 estimated value < 37.52 critical value). For the trace test, we find that we cannot reject the null hypothesis that the number of cointegrating relationships is between 1 and 2. Therefore, because the rejection of the null hypothesis in the eigenvalue test is incredibly marginal, we conclude from our estimates that there is likely two cointegrating relationships. This is a divergence from the result as is found for the US in Cologni & Manera.

Cointegration analysis of the restricted system

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.

4. Restricted VAR system

The covariance matrix of residuals from the VAR system provides us with an estimate of the contemporaneous effects of each variable.

Let us check which variables might be cointegrated, by regressing them on each other and checking if the residuals are stationary or not

monetaryaggregate, interestrate, realGDP, inflation, exchangerate, worldoilprice

```
##
## Call:
## lm(formula = worldoilprice ~ interestrate, data = cointanalysisVAR)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.94266 -0.47859 -0.09981  0.50308  1.15148
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   4.18258    0.08474  49.359  < 2e-16 ***
## interestrate -0.18810    0.02172  -8.661 5.72e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.5513 on 106 degrees of freedom
```

```
## Multiple R-squared:  0.4144, Adjusted R-squared:  0.4089
## F-statistic: 75.01 on 1 and 106 DF,  p-value: 5.718e-14

##
## ###############################################
## # 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
## -0.84167 -0.08570  0.01493  0.10515  0.33617
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## z.lag.1     -0.09937    0.03340  -2.975  0.00369 **
## z.diff.lag1  0.40830    0.09193   4.441 2.35e-05 ***
## z.diff.lag2 -0.08156    0.09961  -0.819  0.41486
## z.diff.lag3  0.19250    0.09558   2.014  0.04674 *
## z.diff.lag4  0.06950    0.09326   0.745  0.45791
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1663 on 98 degrees of freedom
## Multiple R-squared:  0.2295, Adjusted R-squared:  0.1902
## F-statistic: 5.839 on 5 and 98 DF,  p-value: 9.195e-05
##
##
## Value of test-statistic is: -2.9751
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

At 1%… M & IR not stationary, M& G not, & inf not, &exch not, &oil not int rate and oil YES (yes) IR & GDP yes (yes) IR & inflation yes (yes) IR & exch rate yes (no) GDP & exch no, & infla no, %oil no infla & exch no infla & oil price yes (no) exh & oil no

We want to set up our own VECM model

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

We want to find whether our restrictions are exogenous or not.

According to the paper, $u_t = E_t B$ which means that we can recover the short run error vector u_t from the long-run error we obtain from our VAR system. We obtain the covariance matrix of residuals from our VAR system and then mutiply that by our B matrix of short-run restrictions and the transpose of the B matrix, because the paper states that these are equivalent.

```
##                    MonetaryAggregate InterestRate      RealGDP Inflation
## MonetaryAggregate       0.0001328802   0.00000000 0.000000e+00  0.000000
## InterestRate            0.0000000000   0.07138726 0.000000e+00  0.000000
## RealGDP                 0.0000000000   0.00000000 2.804883e-05  0.000000
## Inflation               0.0000000000   0.00000000 0.000000e+00  0.753182
## ExchangeRate            0.0000000000   0.00000000 0.000000e+00  0.000000
## WorldOilPrice           0.0000000000   0.00000000 0.000000e+00  0.000000
##                    ExchangeRate WorldOilPrice
## MonetaryAggregate    0.00000000    0.00000000
## InterestRate         0.00000000    0.00000000
## RealGDP              0.00000000    0.00000000
## Inflation            0.00000000    0.00000000
## ExchangeRate         0.01135468    0.00000000
## WorldOilPrice        0.00000000    0.02108534
```

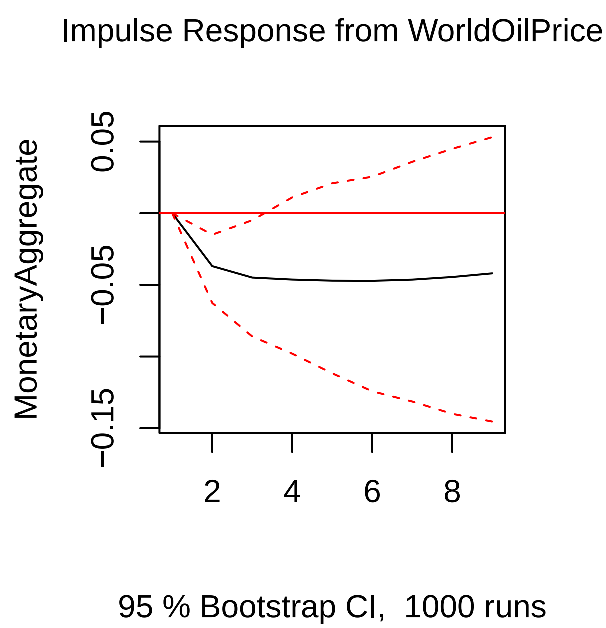
We then obtain a single entry for each row, which we can create our short-run error vector from.

Comparison of cointegrating vectors

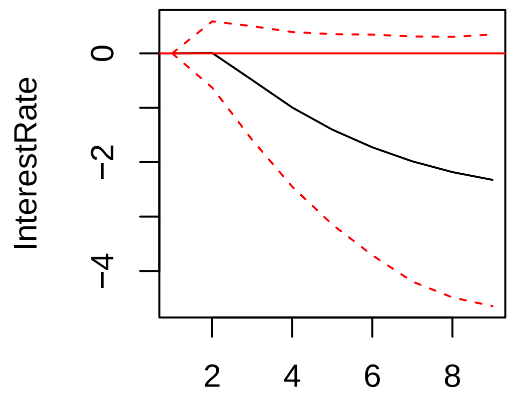
	Real GDP	World Oil Price	Interest Rate	Inflation	Exchange Rate	Monetary Aggregate
Cologni & Manera	1	0.16	0	-26.019	0.218	0

	Real GDP	World Oil Price	Interest Rate	Inflation	Exchange Rate	Monetary Aggregate
Cointegrating vector 1	1	0	-0.170	-0.017	0.616	-0.375
Cointegrating vector 2	0	1	1.606	0.0699	-5.496	6.579

We need to find the SR error, which is equal to the LR error (ECT in the VECM) multiplied by the SR restrictions (B matrix)

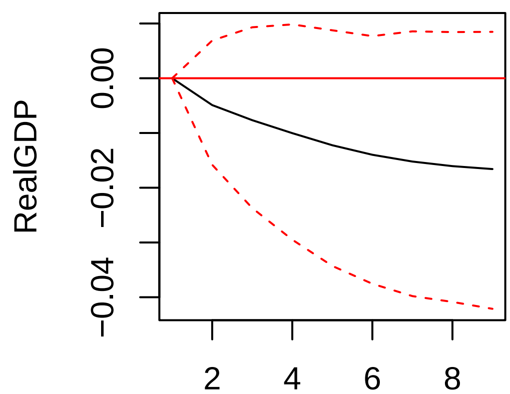


Impulse Response from WorldOilPrice



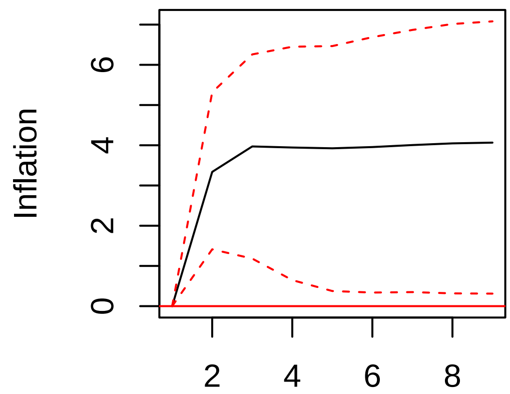
95 % Bootstrap CI, 1000 runs

Impulse Response from WorldOilPrice



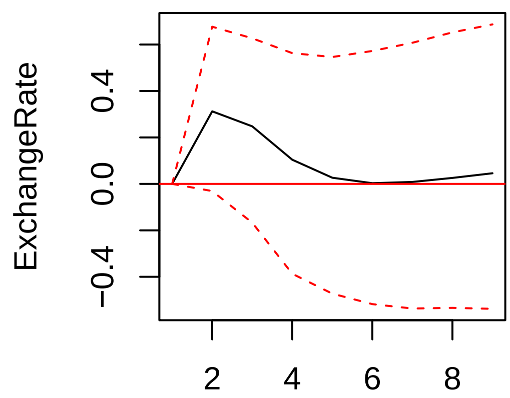
95 % Bootstrap CI, 1000 runs

Impulse Response from WorldOilPrice

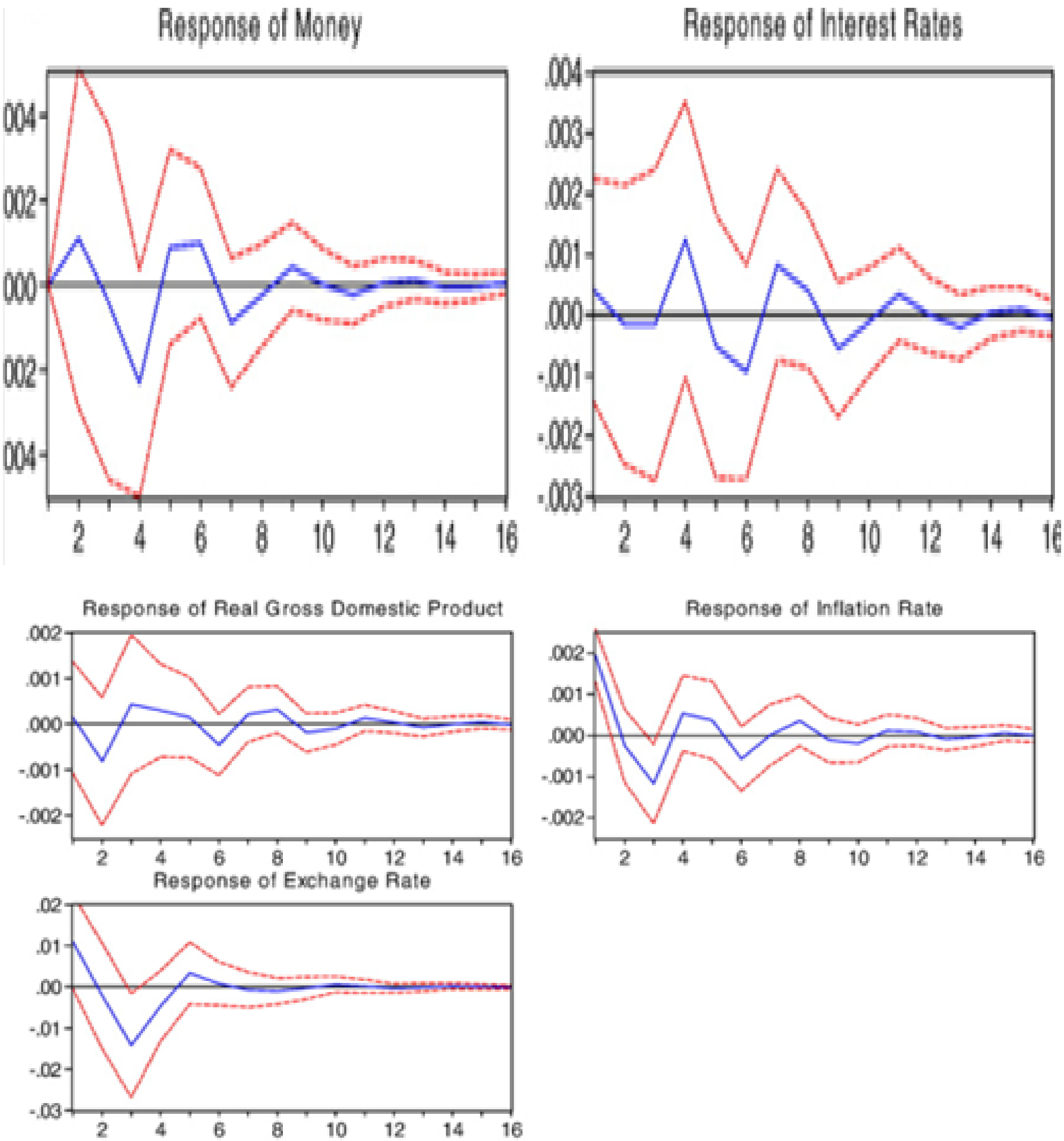


95 % Bootstrap CI, 1000 runs

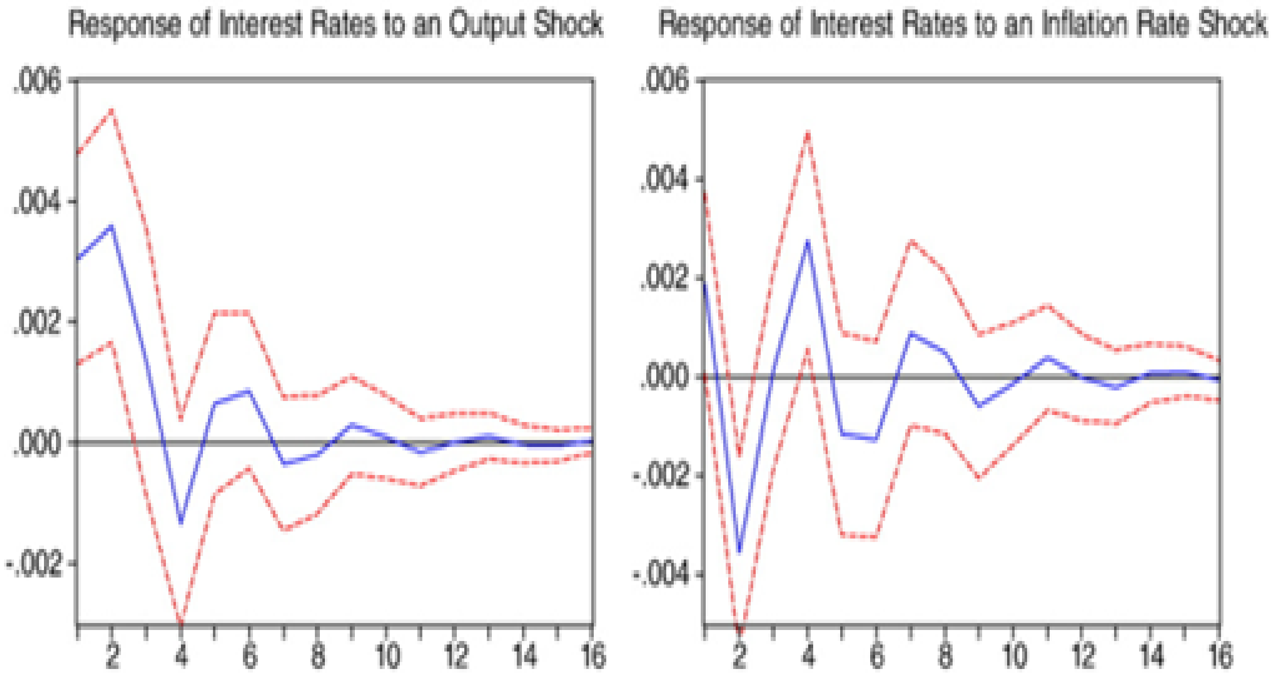
Impulse Response from WorldOilPrice



95 % Bootstrap CI, 1000 runs



Response of Money
Response of Interest Rates
Response of Real Gross Domestic Product
Response of Inflation Rate
Response of Exchange Rate
.004
.003
.002
.001
.000
-.001
-.002
-.003
.02
.01
.00
-.01
-.02
-.03
2
4
6
8
10
12
14
16



Cologni & Manera found that the cointegrating vector for the US showed a non-significant coefficient on the money demand variable and in the long-run, this country shows an excess-output relationship and a long-run negative effected of oil prices on excess output. Find no instantaneous effect of oil prices on real GDP growth. Interest rates do not rise due to inflation rate shock. United States IRFs are showing that output significantly influenced by the oil shock. Monetary policy impulse response is output shock and inflation shock. Found exchange rates generally significantly impacted by oil price.

an increase in short-term interest rates results in a temporary decrease in output, which peaks about four/five quarters after the initial monetary policy shock and reverts back to the baseline level thereafter. At the same time, inflation rate adjusts gradually downward. In Canada and the U.S. the monetary contraction begins to affect output and real money balances only after three or four quarters. In short, our results suggest a temporary impact of monetary policy shocks on output and inflation rate

Cointegrating vectors visually??

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

```
## #############
## ###Model VECM
## #############
```

```
## Full sample size: 108    End sample size: 104
## Number of variables: 6   Number of estimated slope parameters 126
## AIC -3210.216    BIC -2855.868   SSR 74.89496
## Cointegrating vector (estimated by ML):
##    realGDP worldoilprice interestrate   inflation exchangerate
## r1       1             0   -0.1704922 -0.01710960    0.6161332
## r2       0             1    1.6056301  0.06991751   -5.4962156
##    monetaryaggregate
## r1        -0.3747751
## r2         6.5786487
##
##
##                              ECT1                ECT2
## Equation realGDP             0.0114(0.0262)      0.0012(0.0029)
## Equation worldoilprice       -1.1213(0.6892)     -0.1191(0.0757)
## Equation interestrate        -0.8253(1.3364)     -0.0909(0.1468)
## Equation inflation           1.9807(4.2269)      0.2323(0.4642)
## Equation exchangerate        -1.5280(0.4970)**   -0.1498(0.0546)**
## Equation monetaryaggregate -0.0999(0.0543).    -0.0127(0.0060)*
##                              Intercept             realGDP -1
## Equation realGDP             -0.2387(0.5689)       0.3017(0.1198)*
## Equation worldoilprice       23.9522(14.9378)      6.0850(3.1445).
## Equation interestrate        18.0500(28.9642)      9.3757(6.0972)
## Equation inflation           -43.1723(91.6115)     23.9182(19.2849)
## Equation exchangerate        31.3052(10.7722)**    0.0695(2.2676)
## Equation monetaryaggregate 2.3668(1.1764)*       -0.2741(0.2476)
##                              worldoilprice -1    interestrate -1
## Equation realGDP             -0.0015(0.0061)     -0.0022(0.0021)
## Equation worldoilprice       0.4921(0.1589)**    -0.0330(0.0553)
## Equation interestrate        0.5017(0.3081)      0.5658(0.1072)***
## Equation inflation           4.0209(0.9746)***   -0.8458(0.3391)*
## Equation exchangerate        0.3216(0.1146)**    0.0338(0.0399)
## Equation monetaryaggregate -0.0342(0.0125)**   0.0027(0.0044)
##                              inflation -1        exchangerate -1
## Equation realGDP             -0.0007(0.0010)     0.0030(0.0035)
## Equation worldoilprice       -0.0649(0.0261)*    0.0232(0.0930)
## Equation interestrate        -0.1333(0.0505)**   -0.0459(0.1802)
## Equation inflation           -0.3031(0.1598).    0.2740(0.5701)
## Equation exchangerate        -0.0376(0.0188)*    -0.2884(0.0670)***
```

```
## Equation monetaryaggregate 0.0093(0.0021)***   -0.0107(0.0073)
##                             monetaryaggregate -1 realGDP -2
## Equation realGDP            -0.0421(0.0628)      0.2444(0.1211)*
## Equation worldoilprice      -0.5255(1.6486)      1.0297(3.1793)
## Equation interestrate       -0.7766(3.1966)      -0.0562(6.1646)
## Equation inflation          1.3461(10.1107)      -10.4541(19.4983)
## Equation exchangerate       -0.3822(1.1889)      -5.2154(2.2927)*
## Equation monetaryaggregate 0.3084(0.1298)*       -0.4686(0.2504).
##                             worldoilprice -2    interestrate -2
## Equation realGDP            0.0033(0.0061)      0.0020(0.0025)
## Equation worldoilprice      0.0529(0.1609)      0.0008(0.0653)
## Equation interestrate       -0.3103(0.3121)     0.0588(0.1266)
## Equation inflation          0.8367(0.9870)      0.1164(0.4004)
## Equation exchangerate       0.0028(0.1161)      0.0796(0.0471).
## Equation monetaryaggregate -0.0030(0.0127)      0.0014(0.0051)
##                             inflation -2        exchangerate -2
## Equation realGDP            -0.0010(0.0010)     -0.0023(0.0034)
## Equation worldoilprice      -0.0211(0.0266)     -0.0957(0.0890)
## Equation interestrate       0.0222(0.0516)      -0.1919(0.1725)
## Equation inflation          -0.1823(0.1633)     -0.6758(0.5456)
## Equation exchangerate       -0.0071(0.0192)     -0.1283(0.0642)*
## Equation monetaryaggregate 0.0023(0.0021)       -0.0097(0.0070)
##                             monetaryaggregate -2 realGDP -3
## Equation realGDP            0.0925(0.0628)       -0.0572(0.1260)
## Equation worldoilprice      2.1871(1.6496)       -1.6558(3.3091)
## Equation interestrate       4.6408(3.1985)       5.5340(6.4163)
## Equation inflation          4.7544(10.1165)      -8.8125(20.2941)
## Equation exchangerate       0.7138(1.1896)       -10.8377(2.3863)***
## Equation monetaryaggregate -0.0451(0.1299)       0.2839(0.2606)
##                             worldoilprice -3   interestrate -3
## Equation realGDP            0.0061(0.0059)     0.0007(0.0022)
## Equation worldoilprice      0.2848(0.1541).    0.0895(0.0570)
## Equation interestrate       1.2330(0.2988)***  0.0649(0.1105)
## Equation inflation          0.4219(0.9450)     0.9330(0.3494)**
## Equation exchangerate       0.3740(0.1111)**   -0.0451(0.0411)
## Equation monetaryaggregate -0.0218(0.0121).   -0.0080(0.0045).
##                             inflation -3        exchangerate -3
## Equation realGDP            -0.0016(0.0010)     0.0017(0.0034)
## Equation worldoilprice      -0.0329(0.0258)     -0.0271(0.0888)
```

```
## Equation interestrate      -0.1358(0.0500)**   -0.0992(0.1721)
## Equation inflation         -0.0726(0.1580)     -0.5133(0.5445)
## Equation exchangerate      -0.1181(0.0186)***  -0.0048(0.0640)
## Equation monetaryaggregate 0.0050(0.0020)*     -0.0079(0.0070)
##                            monetaryaggregate -3
## Equation realGDP           -0.0568(0.0583)
## Equation worldoilprice     -0.4480(1.5304)
## Equation interestrate      1.7129(2.9674)
## Equation inflation         -1.4109(9.3857)
## Equation exchangerate      3.0424(1.1036)**
## Equation monetaryaggregate 0.0729(0.1205)
```

#Find VECM residuals

We want to compare our estimates to the one in Table 3.

Maybe instead it is the VAR system … missing constant and trend

Then test for white noise residuals.

5. Step 6: Is it stationary?

6. Step 7: Are the residuals white noise?

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

8. Step 9: Test model specification using congruency, parsimony, lag inclusion…

Alternatively, exclude exchange rates as the paper unusually included these. However, in our models we could not find exchange rates to be significant.

Appendix