Time Series Research Assignment

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Abstract

Abstract to be written here.

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1. Introduction

The aim of this paper is to replicate the work by MacDonald & Ricci (2004). They analyse the determinants of the Real Effective Exchange Rate (REER) based on a collection of variables as determinants, using a Vector Error Correction Model. The purpose of their study was to use the most current research to investigate a set of variables with explanatory power in determining the long term behaviour of the REER in South Africa. They used the period starting from the first quarter of 1970 until the first quarter of the year 2002. Towards this end, they made use of the Maximum Likelihood method of estimating the VECM, developed in Johansen (1995). Their choice of variables is based on the most recent research at the time, of the determinants of the real exchange rate in developing economies such as South Africa. This paper serves to replicate the steps taken by MacDonald & Ricci (2004) and reach a conclusion independently, and thus will critically evaluate the logical flow towards estimating the final model. Therefore, additional tests and evaluations are made to reassess the robustness of the final mode.

The choice of the model vector introduced later, is based on several developments prior to 2004. Briefly, the variables have been found to serve as feasible explanatory variables for the REER includes: productivity, real interest rates relative to mostly traded with, the relative openness of the selected economy to trade, and the magnitude of the fiscal balance and net foreign assets (MacDonald & Ricci, 2004).

The Purchasing Power Parity (PPP) points to the equality between the price levels between two countries if they were quoted in the same currencies. When the PPP holds, the real exchange rate must not vary (Sarno & Taylor, 2002). The VECM for the REER is thus an attempt to elucidate the nature of deviations from the PPP. A comprehensive and accurate model for the deviations from the PPP that is explainable by real factors would provide an appropriate framework for policy-makers to respond with ideal policy (Sarno & Taylor, 2002). In light of this, MacDonald & Ricci (2004) attempt to bring various explanatory variables together in a broad model that can appropriately explain these deviations.

- What did I do?
- why did I do this?

2. Literature Review

2.1. What did the Authors do?

2.2. Motivation

- Importance
- Methods
- Novel Contribution(s)

2.3. Critical Evaluation

- Robustness checks/extensions

Replication

3. Importing and Cleaning the Data

3.1. Variable Names (SECTION TO BE DELETED)

4. Plotting the Model Variables (STEP 0.)

Figures 4.1 & 4.2 showcases each variable as they as they were before their natural logarithm transformation.

```
# p1 <- plot_endog1(full_df)
# p2 <- plot_endog2(df = full_df)
plot_endog1(full_df)
```

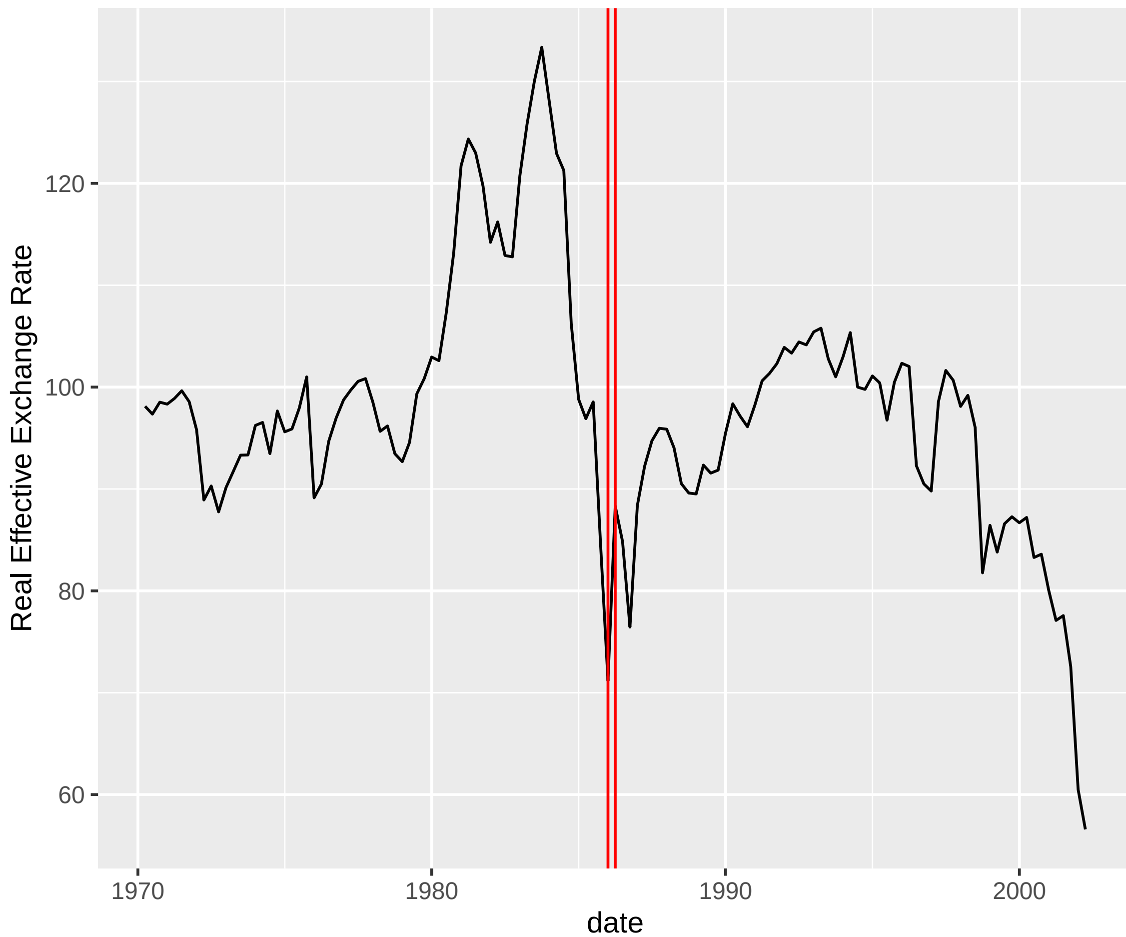

Figure 4.1: The South Africa Real Exchange Rate

```
# grid.arrange(p1, p2, nrow=2)
```

The red lines indicate the dates at which dummy variables for possible outliers will be included as an alternative specification.

```
plot_endog2(df = full_df)
```

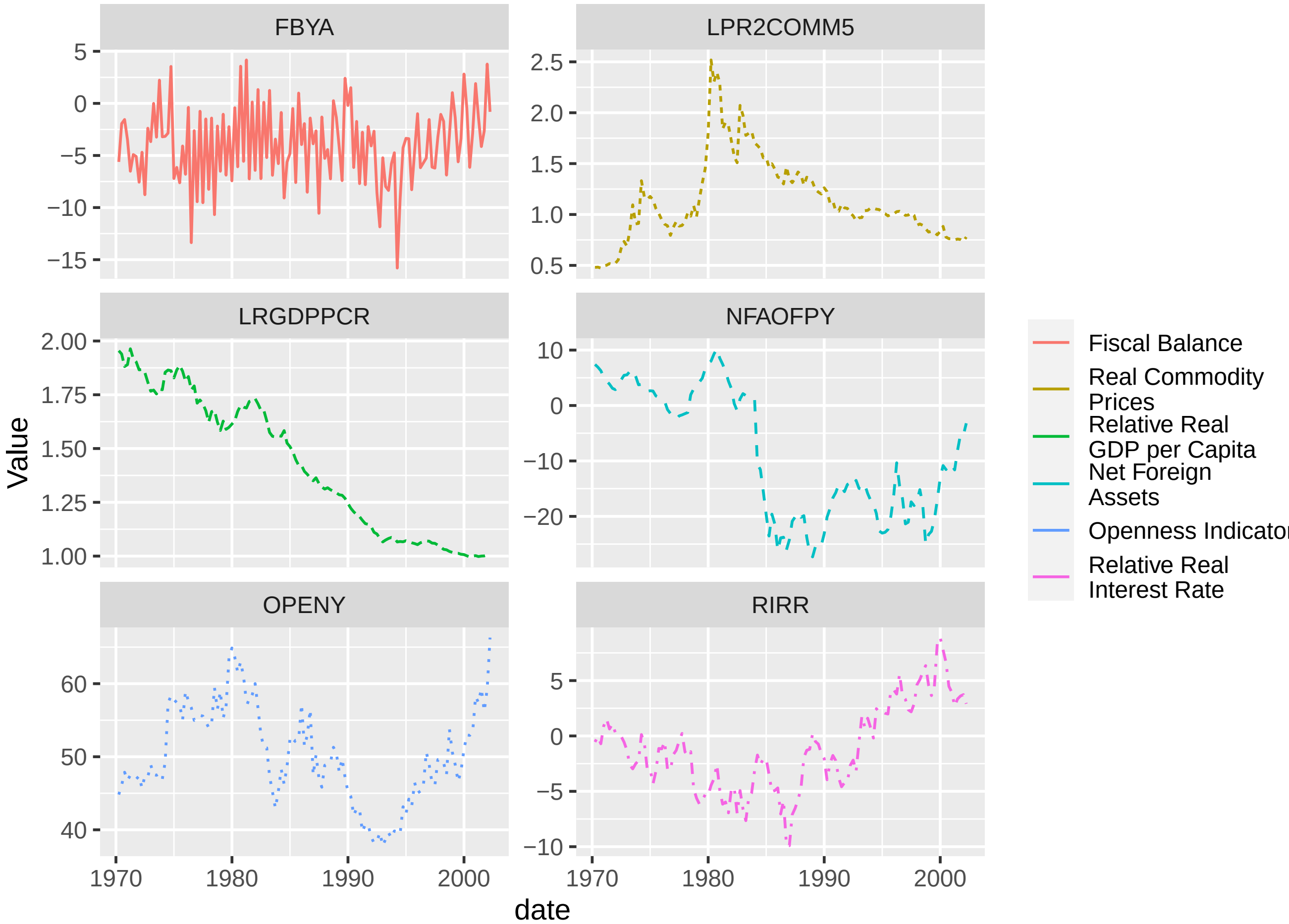

Figure 4.2: Determinants of the Real Exchange Rate for South Africa

Figure 4.2 above suggests that there is a possible structural break in the time series around the year 1985. This is mostly evident in the behaviour of the variable `NFAOFPY`, the Net Foreign Assets proxy. The openness indicator, Relative Real Interest Rate, Relative Real GDP, and Real Commodity prices slightly correspond to this theory as well. A test for this is therefore necessary.

To illustrate the co-movement of the system, figure **??** below plots them jointly. Note that the Openness Indicator has also been logged to make the visual comparison easier.

```
plot_endog_joint(df = full_df)
```

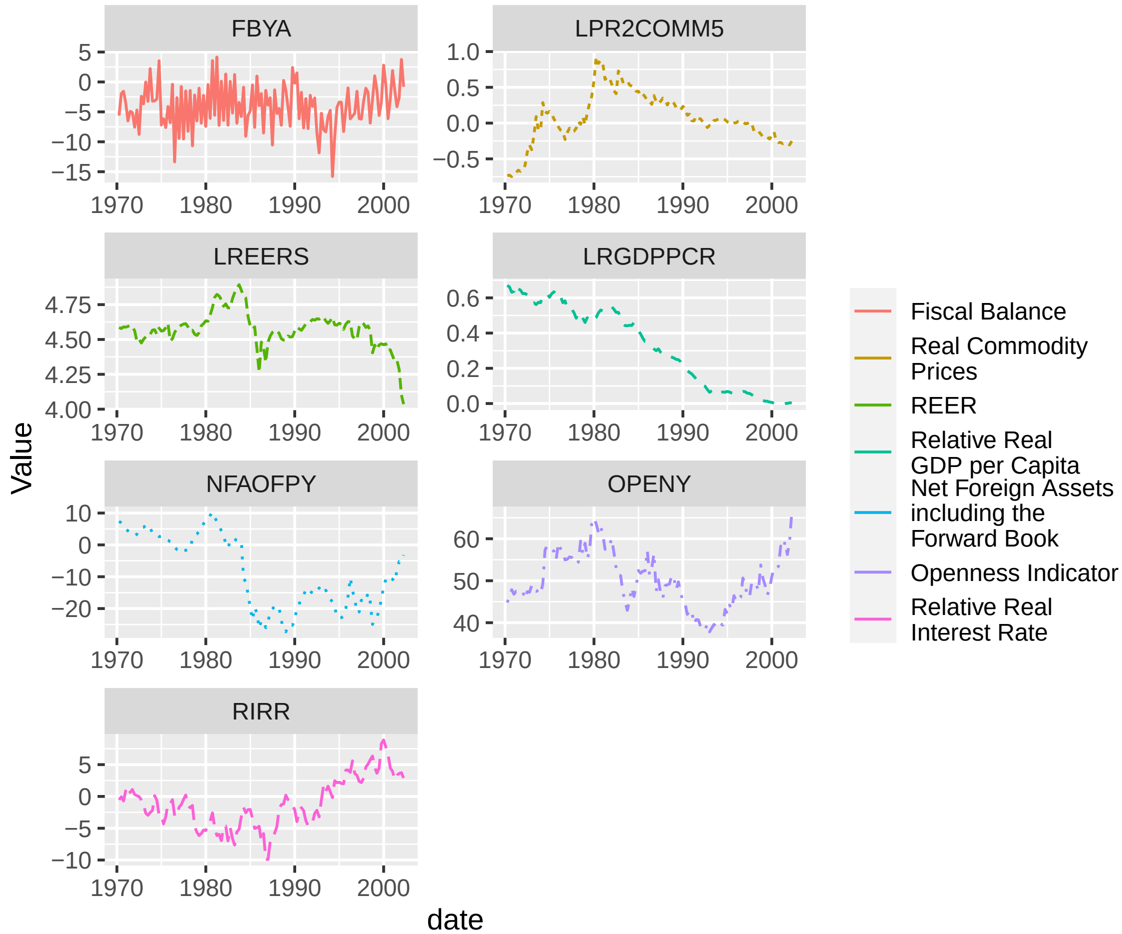

Figure 4.3: The Joint plot of the Model Varibales (Logged where necessary)

A relative degree of co-movement is noticeable in each of these time series altogether. The Log of Real GDP, however, requires one to take into account the declining trend, after which the co-movement seems more evident.

5. The Johansen Method in Theory

explain johansen method

The Johansen (1995) method requires six steps in the estimation process, which follows as:

1. Choosing a specification for the deterministic parts of the model
2. Pre-testing the variables in the system to ensure that they are likely integrated of order one (i.e. $x_t \sim I(1)$\$)

3. Estimating the unrestricted Vector Autoregressive model in levels and checking this models adequacy
4. Estimating the VECM form and determining the cointegration rank (i.e. ‘r’)
5. etc.

6. 0. Plotting the Diffirenced Variables (STEP 1.)

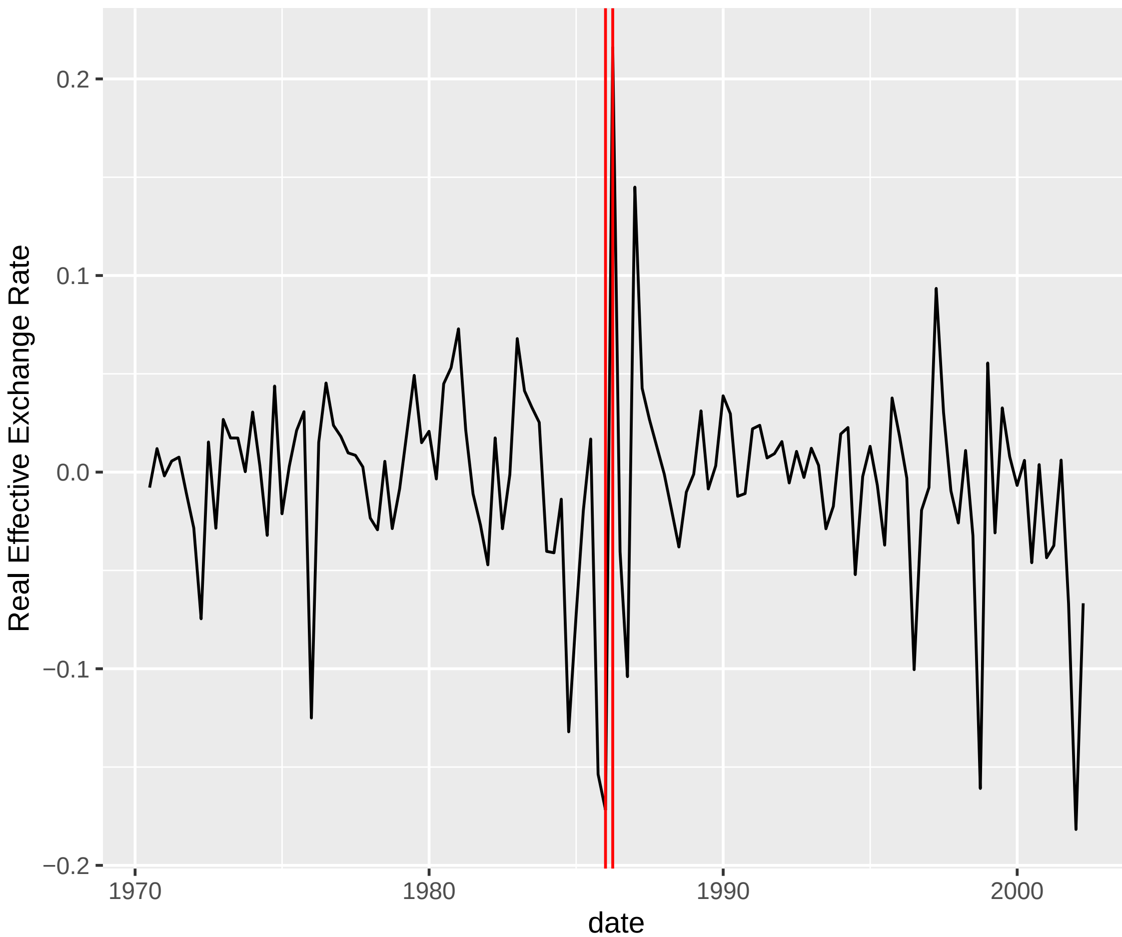

Figure 6.1: The First Difference of the LREERS

```
plot_endog2_log(df = diff_df)
```

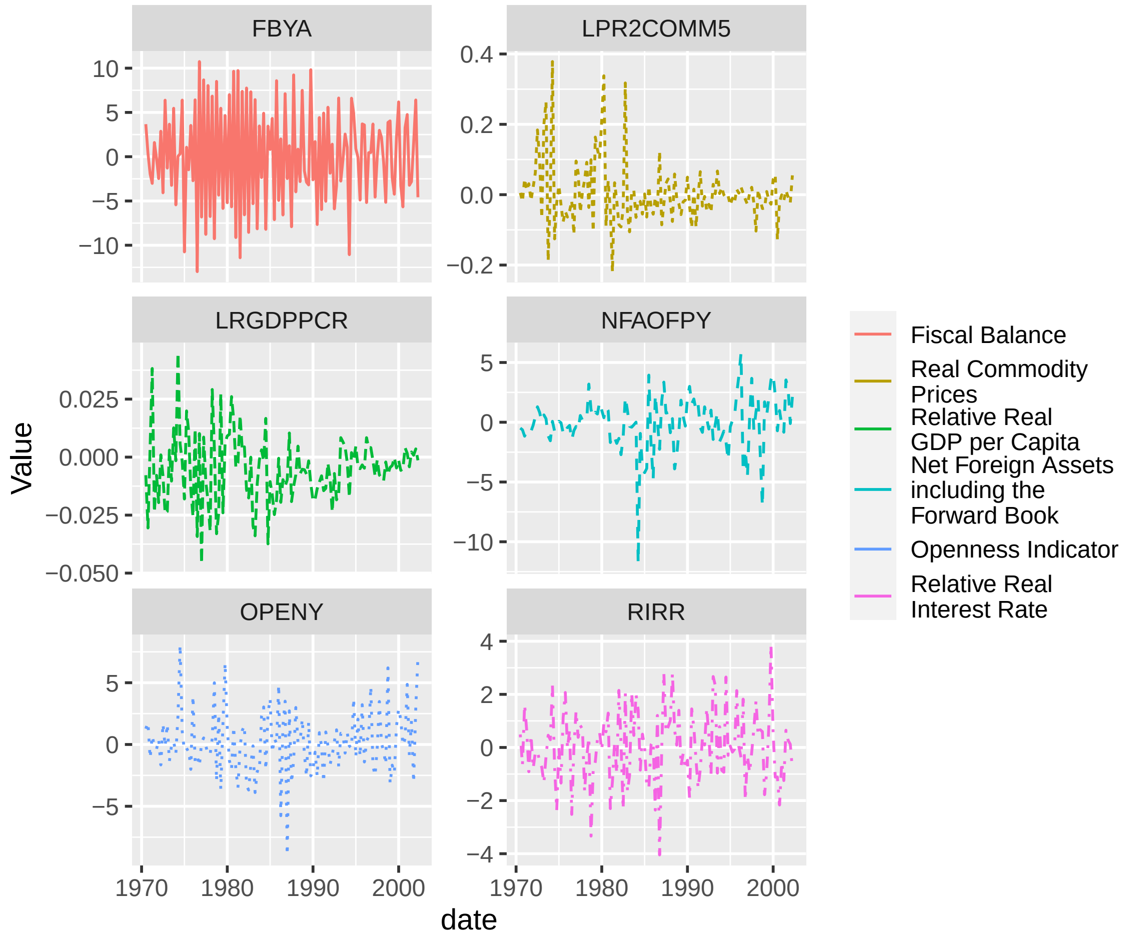

Figure 6.2: The First Difference of the Determinants of the Real Exchange Rate

figures 6.2 and 6.1 above suggest that the REER time series and its candidate explanatory variables are possibly integrated of the first order (i.e. $REER \sim I(1)$), and includes a constant term.

To test this hypothesis, the Augmented Dickey Fuller test is employed. The p-value for each of the differenced time series is less than 0.05 and thus the null hypothesis is rejected, and we can conclude that these series are all stationary after one difference

The Augmented Dicky-Fuller tests for the differenced time series values of all the variables in the system, as well as the first difference of each of these series are displayed in figures **??** and **??** below.

```
##                                     RIRR             OPENY              FBYA
## statistic                -2.38462381354433 -1.41520930294888 -2.78464219204947
## Lag order                                5                 5                 5
## Alternative Hypothesis          stationary        stationary        stationary
```

```
## p.value                  0.416625588494009 0.819624761470709  0.25033235278204
##                                    NFAOFPY            LREERS           LRGDPPCR
## statistic                -0.726702534543652 -1.60754795387395 -2.35890115070675
## Lag order                                 5                 5                 5
## Alternative Hypothesis           stationary        stationary        stationary
## p.value                   0.965806321320507 0.739666893698904 0.427318859264153
##                                  LPR2COMM5          LPRCOMM5         LPR2COMM3
## statistic                -2.41968238737432 -2.70975599360111 -2.50126679665837
## Lag order                                5                 5                 5
## Alternative Hypothesis          stationary        stationary        stationary
## p.value                  0.402051248926356 0.281463593043258 0.368135468720973
##                                   LPRCOMM3          LPR2GOLD           LPRGOLD
## statistic                -2.83555524551097 -2.47972355133744 -2.78418176316389
## Lag order                                5                 5                 5
## Alternative Hypothesis          stationary        stationary        stationary
## p.value                  0.229167084246809 0.377091297164509 0.250523759510613
```

The Augmented Dicky-Fuller tests for the differenced time series values of all the variables in the system are displayed in figure **??** below.

```
##                                       RIRR              OPENY              FBYA
## statistic                -5.10084175770901  -3.76672305393889 -6.18347214444395
## Lag order                                5                  5                 5
## Alternative Hypothesis          stationary         stationary        stationary
## p.value                               0.01 0.0228622783611834              0.01
##                                    NFAOFPY            LREERS           LRGDPPCR
## statistic                -0.723559520045346 -5.21343979738062 -4.07675332825604
## Lag order                                 5                 5                 5
## Alternative Hypothesis           stationary        stationary        stationary
## p.value                   0.966075042853094              0.01              0.01
##                                  LPR2COMM5          LPRCOMM5         LPR2COMM3
## statistic                -5.26358049519449 -5.69103704497667 -5.21681313467281
## Lag order                                5                 5                 5
## Alternative Hypothesis          stationary        stationary        stationary
## p.value                               0.01              0.01              0.01
##                                   LPRCOMM3          LPR2GOLD           LPRGOLD
## statistic                -5.73704796302016 -5.35199824805661 -5.81245247692998
## Lag order                                5                 5                 5
```

```
## Alternative Hypothesis          stationary        stationary        stationary
## p.value                               0.01              0.01              0.01
```

Figures **??** and **??** therefore confirm that none of the variables are stationary, and that all but `NFAOFPY` i.e. the net foreign assets are stationary after the first difference. For those that are stationary, the null hypothesis was rejected at the 1% significance level, barring the openness indicator. This might be due to the irregular behaviour created by the apartheid era sanctions (MacDonald & Ricci, 2004).

6.1. VECM Model Estimation in Theory:

paper table 1 col's:

1. Var's + Seasonal(4) + lags(4) 2. ^{Above} *+ outlier_dummies -> Trace test* $\implies$ *two CI vectors*

Multiple ways to estimate VEC models:

First approach: ordinary least squares (yields accurate result) but does not allow to estimate the cointegrating relations among the variables. The estimated generalised least squares (EGLS) approach would be an alternative.

Most popular estimator: MLE of Johansen (1995) [In R: ca.jo function of the urca package of Pfaff (2008a)] Alternatively, ***`VECM`*** *of tsDyn package of Di Narzo et al. (2020)*

Before VECM: 1. Determine lag order p -> Det. rank of CI matrix r 2. deterministic terms have to be specified. 3. Choose lag order: est. the VAR in levels 4. Choose lag specification that minimises an Information criterion

7. 1. Estimating the Unrestricted VAR in Levels and Checking Adequacy

```
options(scipen=999)
var_aic <- VAR(endog_df[,c(2:8)], type = "const", lag.max = 8,
               ic = "AIC", season = 4)

VARselect(endog_df[,c(2:8)], type = "const", lag.max =8, season = 4)$selection
```

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

```
var_aic2 <- endog_df %>% dplyr::select(2:8) %>% VAR(., type = "const", season = 4,
                                                    exogen = exog_df[,5:8],
                                                    lag.max = 8, ic = "AIC")
summary(var_aic2)
```

```
##
## VAR Estimation Results:
## =========================
## Endogenous variables: LREERS, RIRR, LRGDPPCR, OPENY, FBYA, NFAOFPY, LPR2COMM5
## Deterministic variables: const
## Sample size: 128
## Log Likelihood: -261.745
## Roots of the characteristic polynomial:
## 1.015 1.015 0.9506 0.8945 0.8702 0.6983 0.05248
## Call:
## VAR(y = ., type = "const", season = 4L, exogen = exog_df[, 5:8],
##     lag.max = 8, ic = "AIC")
##
##
## Estimation results for equation LREERS:
## =======================================
## LREERS = LREERS.l1 + RIRR.l1 + LRGDPPCR.l1 + OPENY.l1 + FBYA.l1 + NFAOFPY.l1 + LPR2COMM5.l1 +
##
##                Estimate Std. Error t value             Pr(>|t|)
## LREERS.l1     0.9484189  0.0649237  14.608 < 0.0000000000000002 ***
## RIRR.l1      -0.0022000  0.0018169  -1.211             0.228477
## LRGDPPCR.l1   0.0227875  0.0362830   0.628             0.531239
## OPENY.l1     -0.0010698  0.0011189  -0.956             0.341054
## FBYA.l1       0.0022785  0.0014013   1.626             0.106752
## NFAOFPY.l1    0.0001043  0.0006809   0.153             0.878504
## LPR2COMM5.l1  0.0159898  0.0247188   0.647             0.519029
## const         0.2843994  0.3361829   0.846             0.399359
## sd1           0.0095745  0.0119143   0.804             0.423308
## sd2          -0.0017904  0.0114332  -0.157             0.875842
## sd3          -0.0035095  0.0132389  -0.265             0.791420
## DUMRER1       0.1950306  0.0474181   4.113            0.0000744 ***
## DUMRER2       0.1927261  0.0493740   3.903             0.000162 ***
```

```
## DUMFBYA       0.0228688  0.0467183   0.490            0.625433
## DUMNFAOFPY   -0.0477218  0.0475782  -1.003            0.317996
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.04524 on 113 degrees of freedom
## Multiple R-Squared: 0.8916,  Adjusted R-squared: 0.8782
## F-statistic: 66.41 on 14 and 113 DF,  p-value: < 0.00000000000000022
##
##
## Estimation results for equation RIRR:
## =====================================
## RIRR = LREERS.l1 + RIRR.l1 + LRGDPPCR.l1 + OPENY.l1 + FBYA.l1 + NFAOFPY.l1 + LPR2COMM5.l1 + c
##
##               Estimate Std. Error t value            Pr(>|t|)
## LREERS.l1      2.54606    1.81922   1.400             0.16439
## RIRR.l1        0.83107    0.05091  16.324 < 0.0000000000000002 ***
## LRGDPPCR.l1   -2.67773    1.01668  -2.634             0.00963 **
## OPENY.l1      -0.00292    0.03135  -0.093             0.92597
## FBYA.l1       -0.03981    0.03927  -1.014             0.31281
## NFAOFPY.l1     0.01017    0.01908   0.533             0.59495
## LPR2COMM5.l1  -1.26608    0.69264  -1.828             0.07020 .
## const        -10.76928    9.42013  -1.143             0.25536
## sd1           -0.21865    0.33385  -0.655             0.51385
## sd2           -0.01460    0.32037  -0.046             0.96373
## sd3           -0.28062    0.37096  -0.756             0.45095
## DUMRER1       -0.56604    1.32870  -0.426             0.67091
## DUMRER2       -1.53639    1.38350  -1.111             0.26914
## DUMFBYA       -1.35366    1.30909  -1.034             0.30332
## DUMNFAOFPY     1.14853    1.33318   0.861             0.39079
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 1.268 on 113 degrees of freedom
## Multiple R-Squared: 0.9065,  Adjusted R-squared: 0.8949
## F-statistic: 78.27 on 14 and 113 DF,  p-value: < 0.00000000000000022
##
```

```
##
## Estimation results for equation LRGDPPCR:
## =========================================
## LRGDPPCR = LREERS.l1 + RIRR.l1 + LRGDPPCR.l1 + OPENY.l1 + FBYA.l1 + NFAOFPY.l1 + LPR2COMM5.l1
##
##                 Estimate Std. Error t value             Pr(>|t|)
## LREERS.l1    -0.0297295  0.0197222  -1.507              0.13450
## RIRR.l1       0.0004955  0.0005519   0.898              0.37126
## LRGDPPCR.l1   0.9811873  0.0110219  89.022 < 0.0000000000000002 ***
## OPENY.l1     -0.0002590  0.0003399  -0.762              0.44765
## FBYA.l1      -0.0007541  0.0004257  -1.771              0.07918 .
## NFAOFPY.l1    0.0006911  0.0002069   3.341              0.00113 **
## LPR2COMM5.l1  0.0138935  0.0075090   1.850              0.06689 .
## const         0.1527630  0.1021242   1.496              0.13748
## sd1           0.0106497  0.0036193   2.943              0.00395 **
## sd2           0.0050327  0.0034731   1.449              0.15009
## sd3          -0.0006643  0.0040217  -0.165              0.86910
## DUMRER1      -0.0154608  0.0144045  -1.073              0.28541
## DUMRER2      -0.0178312  0.0149986  -1.189              0.23699
## DUMFBYA      -0.0202227  0.0141919  -1.425              0.15693
## DUMNFAOFPY   -0.0079670  0.0144531  -0.551              0.58256
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.01374 on 113 degrees of freedom
## Multiple R-Squared: 0.9968,  Adjusted R-squared: 0.9964
## F-statistic:  2536 on 14 and 113 DF,  p-value: < 0.00000000000000022
##
##
## Estimation results for equation OPENY:
## ======================================
## OPENY = LREERS.l1 + RIRR.l1 + LRGDPPCR.l1 + OPENY.l1 + FBYA.l1 + NFAOFPY.l1 + LPR2COMM5.l1 +
##
##                 Estimate Std. Error t value             Pr(>|t|)
## LREERS.l1    -10.910445   3.311638  -3.295              0.00132 **
## RIRR.l1        0.257073   0.092676   2.774              0.00648 **
## LRGDPPCR.l1    1.484532   1.850730   0.802              0.42416
## OPENY.l1       0.799565   0.057071  14.010 < 0.0000000000000002 ***
```

```
## FBYA.l1       -0.015862   0.071479  -0.222             0.82478
## NFAOFPY.l1     0.098528   0.034733   2.837             0.00540 **
## LPR2COMM5.l1   3.544205   1.260862   2.811             0.00582 **
## const         60.471695  17.148081   3.526             0.00061 ***
## sd1           -0.596224   0.607725  -0.981             0.32865
## sd2            0.006386   0.583186   0.011             0.99128
## sd3            0.579582   0.675291   0.858             0.39256
## DUMRER1       -4.823274   2.418713  -1.994             0.04854 *
## DUMRER2       -5.551398   2.518476  -2.204             0.02953 *
## DUMFBYA       -0.366206   2.383016  -0.154             0.87814
## DUMNFAOFPY     3.229422   2.426879   1.331             0.18597
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 2.308 on 113 degrees of freedom
## Multiple R-Squared: 0.8907,  Adjusted R-squared: 0.8771
## F-statistic: 65.75 on 14 and 113 DF,  p-value: < 0.00000000000000022
##
##
## Estimation results for equation FBYA:
## =====================================
## FBYA = LREERS.l1 + RIRR.l1 + LRGDPPCR.l1 + OPENY.l1 + FBYA.l1 + NFAOFPY.l1 + LPR2COMM5.l1 + c
##
##              Estimate Std. Error t value  Pr(>|t|)
## LREERS.l1    -10.68363    3.98485  -2.681   0.00844 **
## RIRR.l1        0.21582    0.11152   1.935   0.05545 .
## LRGDPPCR.l1    0.43289    2.22696   0.194   0.84622
## OPENY.l1      -0.00700    0.06867  -0.102   0.91899
## FBYA.l1       -0.09192    0.08601  -1.069   0.28747
## NFAOFPY.l1     0.06118    0.04179   1.464   0.14601
## LPR2COMM5.l1   3.96501    1.51718   2.613   0.01018 *
## const         45.36388   20.63404   2.198   0.02995 *
## sd1            1.55759    0.73127   2.130   0.03534 *
## sd2           -3.12724    0.70174  -4.456 0.0000197 ***
## sd3            1.37012    0.81257   1.686   0.09453 .
## DUMRER1        0.74877    2.91040   0.257   0.79744
## DUMRER2       -2.08677    3.03044  -0.689   0.49248
## DUMFBYA      -12.80970    2.86745  -4.467 0.0000189 ***
```

```
## DUMNFAOFPY     2.08643    2.92023   0.714   0.47641
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 2.777 on 113 degrees of freedom
## Multiple R-Squared: 0.4892,  Adjusted R-squared: 0.4259
## F-statistic: 7.729 on 14 and 113 DF,  p-value: 0.0000000000327
##
##
## Estimation results for equation NFAOFPY:
## ========================================
## NFAOFPY = LREERS.l1 + RIRR.l1 + LRGDPPCR.l1 + OPENY.l1 + FBYA.l1 + NFAOFPY.l1 + LPR2COMM5.l1
##
##               Estimate Std. Error t value             Pr(>|t|)
## LREERS.l1     -1.52914    2.67110  -0.572              0.56814
## RIRR.l1       -0.15610    0.07475  -2.088              0.03903 *
## LRGDPPCR.l1   -2.67541    1.49276  -1.792              0.07577 .
## OPENY.l1       0.03423    0.04603   0.744              0.45865
## FBYA.l1        0.12322    0.05765   2.137              0.03473 *
## NFAOFPY.l1     0.99764    0.02802  35.611 < 0.0000000000000002 ***
## LPR2COMM5.l1  -1.53415    1.01699  -1.509              0.13421
## const          6.60967   13.83132   0.478              0.63366
## sd1            0.66261    0.49018   1.352              0.17915
## sd2            0.21151    0.47039   0.450              0.65382
## sd3            0.30364    0.54468   0.557              0.57831
## DUMRER1        5.54128    1.95089   2.840              0.00535 **
## DUMRER2        1.01238    2.03135   0.498              0.61919
## DUMFBYA       -1.02393    1.92210  -0.533              0.59528
## DUMNFAOFPY   -10.67633    1.95747  -5.454          0.000000293 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 1.861 on 113 degrees of freedom
## Multiple R-Squared: 0.9764,  Adjusted R-squared: 0.9735
## F-statistic: 334.6 on 14 and 113 DF,  p-value: < 0.00000000000000022
##
##
```

```
## Estimation results for equation LPR2COMM5:
## ==========================================
## LPR2COMM5 = LREERS.l1 + RIRR.l1 + LRGDPPCR.l1 + OPENY.l1 + FBYA.l1 + NFAOFPY.l1 + LPR2COMM5.l
##
##               Estimate Std. Error t value           Pr(>|t|)
## LREERS.l1    -0.042310   0.125047  -0.338             0.7357
## RIRR.l1      -0.006767   0.003499  -1.934             0.0556 .
## LRGDPPCR.l1  -0.071225   0.069883  -1.019             0.3103
## OPENY.l1      0.000570   0.002155   0.265             0.7919
## FBYA.l1      -0.001721   0.002699  -0.638             0.5250
## NFAOFPY.l1    0.001798   0.001311   1.371             0.1732
## LPR2COMM5.l1  0.921402   0.047610  19.353 <0.0000000000000002 ***
## const         0.199396   0.647507   0.308             0.7587
## sd1           0.027803   0.022947   1.212             0.2282
## sd2           0.014052   0.022021   0.638             0.5247
## sd3           0.007050   0.025499   0.276             0.7827
## DUMRER1       0.023945   0.091330   0.262             0.7937
## DUMRER2      -0.017073   0.095097  -0.180             0.8578
## DUMFBYA      -0.003942   0.089982  -0.044             0.9651
## DUMNFAOFPY   -0.010657   0.091638  -0.116             0.9076
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.08713 on 113 degrees of freedom
## Multiple R-Squared: 0.9435,  Adjusted R-squared: 0.9365
## F-statistic: 134.7 on 14 and 113 DF,  p-value: < 0.00000000000000022
##
##
##
## Covariance matrix of residuals:
##                 LREERS       RIRR  LRGDPPCR     OPENY       FBYA   NFAOFPY
## LREERS      0.00204661 -0.0026399 0.0000279 -0.047045 -0.0026079  0.035012
## RIRR       -0.00263995  1.6069320 0.0059040  0.487310  0.0725680  0.140912
## LRGDPPCR    0.00002790  0.0059040 0.0001889  0.003148  0.0015816  0.001025
## OPENY      -0.04704532  0.4873097 0.0031477  5.324941 -0.8497372 -0.398411
## FBYA       -0.00260787  0.0725680 0.0015816 -0.849737  7.7099590  0.104695
## NFAOFPY     0.03501220  0.1409122 0.0010247 -0.398411  0.1046952  3.464262
## LPR2COMM5   0.00006883  0.0009869 0.0001745  0.018152  0.0005024  0.024408
```

```
##            LPR2COMM5
## LREERS    0.00006883
## RIRR      0.00098693
## LRGDPPCR  0.00017449
## OPENY     0.01815200
## FBYA      0.00050236
## NFAOFPY   0.02440835
## LPR2COMM5 0.00759228
##
## Correlation matrix of residuals:
##             LREERS      RIRR LRGDPPCR    OPENY      FBYA  NFAOFPY LPR2COMM5
## LREERS     1.00000 -0.046034  0.04488 -0.45065 -0.020761  0.41581  0.017461
## RIRR      -0.04603  1.000000  0.33890  0.16659  0.020617  0.05972  0.008935
## LRGDPPCR   0.04488  0.338904  1.00000  0.09926  0.041448  0.04006  0.145722
## OPENY     -0.45065  0.166590  0.09926  1.00000 -0.132618 -0.09276  0.090278
## FBYA      -0.02076  0.020617  0.04145 -0.13262  1.000000  0.02026  0.002076
## NFAOFPY    0.41581  0.059723  0.04006 -0.09276  0.020258  1.00000  0.150504
## LPR2COMM5  0.01746  0.008935  0.14572  0.09028  0.002076  0.15050  1.000000
```

```
# var_aic3 <- endog_df %>% dplyr::select(2:7 | 9) %>% VAR(., type = "const", season = 4,
#                                                exogen = exog_df[,5:8],
#                                                lag.max = 8, ic = "AIC")
#
# var_aic4 <- endog_df %>% dplyr::select(2:7 | 10) %>% VAR(., type = "const", season = 4,
#                                                exogen = exog_df[,5:8],
#                                                lag.max = 8, ic = "AIC")
#
# var_aic5 <- endog_df %>% dplyr::select(2:7 | 11) %>% VAR(., type = "const", season = 4,
#                                                exogen = exog_df[,5:8],
#                                                lag.max = 8, ic = "AIC")
#
# var_aic6 <- endog_df %>% dplyr::select(2:7 | 12) %>% VAR(., type = "const", season = 4,
#                                                exogen = exog_df[,5:8],
#                                                lag.max = 8, ic = "AIC")
#
# var_aic7 <- endog_df %>% dplyr::select(2:7 | 13) %>% VAR(., type = "const", season = 4,
#                                                exogen = exog_df[,5:8],
#                                                lag.max = 8, ic = "AIC")
```

```
# var_aic$p; var_aic2$p; var_aic3$p; var_aic4$p; var_aic5$p; var_aic6$p; var_aic7$p
 var_aic$p; var_aic2$p
```

```
## AIC(n)
##      2
```

```
## AIC(n)
##      1
```

```
# normality.test(var_aic)

options(scipen=0)
```

```
stargazer(var_aic$varresult, font.size = "tiny")
```

% Table created by stargazer v.5.2.3 by Marek Hlavac, Social Policy Institute. E-mail: marek.hlavac at gmail.com % Date and time: Mon, Jun 27, 2022 - 20:51:56

Table 7.1

	Dependent variable:						
	y						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LREERS.l1	1.159***	3.255	−0.003	−13.827**	−10.886	7.550	−0.034
	(0.118)	(2.996)	(0.032)	(5.467)	(6.599)	(4.877)	(0.207)
RIRR.l1	−0.004	0.917***	0.001	0.533***	0.178	−0.043	−0.003
	(0.004)	(0.101)	(0.001)	(0.184)	(0.222)	(0.164)	(0.007)
LRGDPPCR.l1	0.291	3.652	0.892***	10.079	−17.329	−6.684	0.277
	(0.368)	(9.319)	(0.101)	(17.009)	(20.531)	(15.172)	(0.645)
OPENY.l1	0.003	−0.098	−0.0002	0.569***	0.062	0.027	0.001
	(0.002)	(0.060)	(0.001)	(0.110)	(0.133)	(0.098)	(0.004)
FBYA.l1	0.002	−0.050	−0.001	−0.020	−0.066	0.115*	−0.002
	(0.002)	(0.040)	(0.0004)	(0.073)	(0.089)	(0.065)	(0.003)
NFAOFPY.l1	−0.006**	0.039	−0.001	0.162	0.160	1.014***	0.003
	(0.002)	(0.063)	(0.001)	(0.114)	(0.138)	(0.102)	(0.004)
LPR2COMM5.l1	0.035	−1.098	0.022	4.044	3.349	1.451	0.882***
	(0.056)	(1.406)	(0.015)	(2.566)	(3.097)	(2.288)	(0.097)
LREERS.l2	−0.298**	−0.091	−0.030	5.796	0.424	−9.308*	0.023
	(0.124)	(3.140)	(0.034)	(5.732)	(6.919)	(5.113)	(0.217)
RIRR.l2	0.001	−0.077	−0.001	−0.299*	0.105	−0.104	−0.006
	(0.004)	(0.097)	(0.001)	(0.177)	(0.214)	(0.158)	(0.007)
LRGDPPCR.l2	−0.294	−6.154	0.078	−9.080	19.048	4.244	−0.360
	(0.367)	(9.279)	(0.100)	(16.935)	(20.442)	(15.106)	(0.642)
OPENY.l2	−0.004*	0.115**	−0.00001	0.298***	−0.094	0.063	−0.0002
	(0.002)	(0.057)	(0.001)	(0.104)	(0.126)	(0.093)	(0.004)
FBYA.l2	−0.001	0.008	0.001	−0.088	0.298***	0.061	−0.0004
	(0.002)	(0.041)	(0.0004)	(0.074)	(0.090)	(0.066)	(0.003)
NFAOFPY.l2	0.006**	−0.037	0.002***	−0.081	−0.104	−0.048	−0.001
	(0.003)	(0.065)	(0.001)	(0.118)	(0.143)	(0.105)	(0.004)
LPR2COMM5.l2	−0.014	−0.383	−0.012	−1.349	1.429	−3.885	0.015
	(0.059)	(1.498)	(0.016)	(2.734)	(3.300)	(2.439)	(0.104)
const	0.708	−14.683	0.168	43.635**	46.235*	4.672	0.029
	(0.433)	(10.962)	(0.119)	(20.008)	(24.151)	(17.847)	(0.758)
sd1	0.026*	−0.404	0.006	−0.512	−0.272	0.072	0.030
	(0.015)	(0.380)	(0.004)	(0.694)	(0.838)	(0.619)	(0.026)
sd2	0.007	−0.304	0.003	−0.305	−3.987***	−0.128	0.017
	(0.014)	(0.365)	(0.004)	(0.667)	(0.805)	(0.595)	(0.025)
sd3	0.007	−0.496	−0.003	0.596	0.219	0.032	0.008
	(0.016)	(0.416)	(0.005)	(0.760)	(0.918)	(0.678)	(0.029)
Observations	127	127	127	127	127	127	127
R^2	0.872	0.910	0.997	0.893	0.499	0.972	0.942
Adjusted R^2	0.852	0.895	0.996	0.877	0.421	0.967	0.933
Residual Std. Error (df = 109)	0.050	1.269	0.014	2.316	2.796	2.066	0.088
F Statistic (df = 17; 109)	43.511***	64.498***	2,058.637***	53.747***	6.391***	219.211***	104.377***
Note:							*p<0.1; **p<0.05; ***p<0.01

Tests to perform: 1. Structural break 2. White noise residuals 3. autocorr resid's 4. time-varying *params 5. heteroskedasticity*

8. Tests on VAR

8.1. Check for the presence of Structural Break

9. Determining the order of CI

```
vec <- ca.jo(full_df[,2:8], type = "trace", ecdet = "const", spec = "transitory",
             K = 2, season = 4)

vec2 <- full_df %>% dplyr::select(2:8) %>% ca.jo(., type = "trace",
                                                  ecdet = "const",
                                                  spec = "transitory", K = 2,
                                                  season = 4,
                                                  dumvar = exog_df[,5:8])

summary(vec2)
```

```
##
## ######################
## # Johansen-Procedure #
## ######################
##
## Test type: trace statistic , without linear trend and constant in cointegration
##
## Eigenvalues (lambda):
## [1]  3.564321e-01  3.052982e-01  1.815610e-01  1.277273e-01  1.083097e-01
## [6]  5.552225e-02  3.709582e-02 -1.362205e-16
##
## Values of teststatistic and critical values of test:
##
##             test  10pct   5pct   1pct
## r <= 6 |   4.80   7.52   9.24  12.97
## r <= 5 |  12.06  17.85  19.96  24.60
## r <= 4 |  26.61  32.00  34.91  41.07
```

```
## r <= 3 |  43.97  49.65  53.12  60.16
## r <= 2 |  69.41  71.86  76.07  84.45
## r <= 1 | 115.68  97.18 102.14 111.01
## r = 0  | 171.65 126.58 131.70 143.09
##
## Eigenvectors, normalised to first column:
## (These are the cointegration relations)
##
##                  LREERS.l1      RIRR.l1  LRGDPPCR.l1      OPENY.l1      FBYA.l1
## LREERS.l1      1.000000000  1.000000000  1.000000000  1.0000000000  1.000000000
## RIRR.l1       -0.024462301 -0.034319774 -0.313281290  0.0006589837 -0.119120165
## LRGDPPCR.l1   -0.142320882  0.273340146 -2.823149029 -0.0349733817 -3.002873006
## OPENY.l1       0.010839154  0.006998118 -0.093404865  0.0110347209  0.052775926
## FBYA.l1        0.040178157 -0.043276239 -0.003339443 -0.0038286833 -0.043435824
## NFAOFPY.l1    -0.007865785 -0.015345892  0.112090362 -0.0081463446  0.007673102
## LPR2COMM5.l1 -0.449798639 -0.457936024 -0.412047651 -0.0464772610 -1.371157006
## constant      -4.960697982 -5.174736246  1.168700249 -5.2288764902 -6.466851756
##                 NFAOFPY.l1 LPR2COMM5.l1    constant
## LREERS.l1      1.000000000  1.000000000  1.00000000
## RIRR.l1        0.010613483  0.021881375  0.03997785
## LRGDPPCR.l1    0.039903264 -0.615418565  2.25873668
## OPENY.l1       0.023763088 -0.018030605 -0.02412186
## FBYA.l1       -0.015241964  0.004833048 -0.01599012
## NFAOFPY.l1    -0.001835104  0.013116413 -0.04277166
## LPR2COMM5.l1 -0.334514874 -0.059778483 -0.86472419
## constant      -5.829376061 -3.261568041 -4.78139188
##
## Weights W:
## (This is the loading matrix)
##
##                 LREERS.l1      RIRR.l1  LRGDPPCR.l1     OPENY.l1      FBYA.l1
## LREERS.d      -0.00595641 -0.002948234  0.005356847 -0.017740305  0.001287587
## RIRR.d         0.50214090  1.066109369  0.114310150  0.661416963  0.687345144
## LRGDPPCR.d    -0.02098181 -0.025278557  0.001551319 -0.002905722  0.006651661
## OPENY.d       -4.04860588 -0.472419377 -0.193286701 -5.553275826 -0.179290650
## FBYA.d       -16.19868799  2.202329827 -0.166639246  1.577557644  0.687092400
## NFAOFPY.d      3.84379082 -0.668396338 -0.210642657 -2.324011586  0.790074726
## LPR2COMM5.d    0.04710617  0.053291631  0.010033262 -0.217283252  0.025766621
##                 NFAOFPY.l1 LPR2COMM5.l1      constant
```

```
## LREERS.d    -4.517370e-02 -0.026576514  1.431654e-15
## RIRR.d      -8.023743e-01  0.557902489 -1.976579e-14
## LRGDPPCR.d   8.234296e-05  0.002797179 -2.451721e-16
## OPENY.d     -1.959156e-01  1.291115382  5.644410e-14
## FBYA.d       5.113042e-01 -0.502381190 -3.581472e-13
## NFAOFPY.d   -1.065704e+00 -0.825705048  1.475157e-13
## LPR2COMM5.d  7.946503e-02 -0.014549072  4.065727e-15
```

10. Estimating VECM

```
mod1 <- full_df %>% dplyr::select(2:8) %>%
    tsDyn::VECM(., lag = 4, estim = "ML",
                include = "const", r=1,
                exogen = exog_df[,2:4])
summary(mod1)
```

```
## #############
## ###Model VECM
## #############
## Full sample size: 129    End sample size: 124
## Number of variables: 7   Number of estimated slope parameters 231
## AIC -1679.413    BIC -1011.006    SSR 1728.962
## Cointegrating vector (estimated by ML):
##    LREERS        RIRR   LRGDPPCR      OPENY       FBYA      NFAOFPY  LPR2COMM5
## r1      1 -0.02909863 -0.1647196 0.00982896 0.01958737 -0.005613747 -0.4615393
##
##
##                     ECT                  Intercept
## Equation LREERS     -0.0802(0.0946)      0.3950(0.4702)
## Equation RIRR       -0.4993(2.2393)      2.3687(11.1322)
## Equation LRGDPPCR   -0.0599(0.0224)**    0.2926(0.1114)*
## Equation OPENY      -9.6546(4.4953)*     48.3341(22.3480)*
## Equation FBYA       -17.8825(4.7971)*** 88.7352(23.8483)***
## Equation NFAOFPY    2.3354(4.1195)       -11.5338(20.4795)
## Equation LPR2COMM5 0.4014(0.1556)*      -2.0009(0.7737)*
##                     LREERS -1            RIRR -1
```

```
## Equation LREERS    0.2629(0.1522).      -0.0050(0.0047)
## Equation RIRR      4.8267(3.6039)       0.0831(0.1103)
## Equation LRGDPPCR  0.0607(0.0361).      -0.0010(0.0011)
## Equation OPENY     -5.3448(7.2349)      0.1597(0.2215)
## Equation FBYA      3.3136(7.7207)       -0.2945(0.2364)
## Equation NFAOFPY   3.7585(6.6300)       0.1155(0.2030)
## Equation LPR2COMM5 -0.3938(0.2505)      0.0108(0.0077)
##                    LRGDPPCR -1           OPENY -1
## Equation LREERS    0.0436(0.4370)        0.0010(0.0026)
## Equation RIRR      -11.5589(10.3463)     -0.1142(0.0614).
## Equation LRGDPPCR  -0.1824(0.1035).      0.0004(0.0006)
## Equation OPENY     13.6694(20.7703)      -0.2359(0.1233).
## Equation FBYA      -37.9912(22.1647).    0.0509(0.1315)
## Equation NFAOFPY   -5.0011(19.0337)      -0.0904(0.1129)
## Equation LPR2COMM5 0.6139(0.7191)        -0.0011(0.0043)
##                    FBYA -1              NFAOFPY -1           LPR2COMM5 -1
## Equation LREERS    0.0024(0.0022)       -0.0074(0.0029)*     0.0549(0.0682)
## Equation RIRR      -0.0844(0.0516)      -0.0251(0.0683)      0.3157(1.6146)
## Equation LRGDPPCR  0.0004(0.0005)       -0.0018(0.0007)*     -0.0014(0.0162)
## Equation OPENY     0.1216(0.1037)       0.0829(0.1372)       1.0239(3.2413)
## Equation FBYA      -0.5516(0.1106)***   0.0240(0.1464)       -0.9276(3.4589)
## Equation NFAOFPY   0.0967(0.0950)       0.1345(0.1257)       2.7607(2.9703)
## Equation LPR2COMM5 -0.0052(0.0036)      0.0031(0.0047)       0.1498(0.1122)
##                    LREERS -2            RIRR -2              LRGDPPCR -2
## Equation LREERS    -0.0492(0.1502)      -0.0062(0.0043)      -0.0017(0.4070)
## Equation RIRR      4.0023(3.5547)       -0.0963(0.1018)      0.5266(9.6344)
## Equation LRGDPPCR  0.0655(0.0356).      -0.0010(0.0010)      0.0060(0.0964)
## Equation OPENY     5.5440(7.1361)       -0.1134(0.2044)      0.1357(19.3411)
## Equation FBYA      15.8630(7.6152)*     -0.0777(0.2182)      -8.8396(20.6396)
## Equation NFAOFPY   -5.1275(6.5395)      -0.0439(0.1874)      -0.3689(17.7241)
## Equation LPR2COMM5 -0.0530(0.2470)      0.0039(0.0071)       -0.7982(0.6696)
##                    OPENY -2             FBYA -2              NFAOFPY -2
## Equation LREERS    -0.0040(0.0027)      0.0013(0.0023)       -0.0008(0.0030)
## Equation RIRR      -0.0310(0.0629)      -0.0408(0.0545)      -0.0887(0.0719)
## Equation LRGDPPCR  -0.0003(0.0006)      0.0003(0.0005)       0.0003(0.0007)
## Equation OPENY     0.0141(0.1263)       0.0114(0.1093)       0.0352(0.1444)
## Equation FBYA      0.0566(0.1348)       -0.3320(0.1167)**    -0.2854(0.1541).
## Equation NFAOFPY   0.0675(0.1157)       0.1597(0.1002)       0.0937(0.1324)
## Equation LPR2COMM5 0.0016(0.0044)       -0.0050(0.0038)      -0.0019(0.0050)
```

```
##                      LPR2COMM5 -2        LREERS -3           RIRR -3
## Equation LREERS      0.0576(0.0632)      0.1650(0.1459)      -0.0033(0.0043)
## Equation RIRR        -0.4218(1.4969)     10.2646(3.4531)**   0.1879(0.1006).
## Equation LRGDPPCR    -0.0055(0.0150)     0.1111(0.0346)**     4.3e-05(0.0010)
## Equation OPENY       -1.4465(3.0050)     -3.5360(6.9322)     -0.0400(0.2020)
## Equation FBYA        3.5934(3.2067)      7.6061(7.3976)      -0.0196(0.2156)
## Equation NFAOFPY     1.8807(2.7538)      -5.3952(6.3526)     -0.3847(0.1851)*
## Equation LPR2COMM5   0.0471(0.1040)      -0.3435(0.2400)     0.0098(0.0070)
##                      LRGDPPCR -3           OPENY -3
## Equation LREERS      -0.3709(0.3963)       -0.0022(0.0029)
## Equation RIRR        -13.5906(9.3815)      0.0798(0.0687)
## Equation LRGDPPCR    -0.0307(0.0939)       0.0022(0.0007)**
## Equation OPENY       19.0614(18.8334)      0.0107(0.1379)
## Equation FBYA        -29.3909(20.0977)     0.0020(0.1471)
## Equation NFAOFPY     -6.3871(17.2588)      0.0689(0.1264)
## Equation LPR2COMM5   -1.0129(0.6520)       0.0017(0.0048)
##                      FBYA -3             NFAOFPY -3           LPR2COMM5 -3
## Equation LREERS      0.0008(0.0023)      0.0031(0.0031)       0.1139(0.0605).
## Equation RIRR        -0.0026(0.0537)     -0.0086(0.0730)      0.9512(1.4317)
## Equation LRGDPPCR    0.0003(0.0005)      -2.4e-06(0.0007)     -0.0022(0.0143)
## Equation OPENY       0.0318(0.1079)      -0.0942(0.1465)      -4.5931(2.8741)
## Equation FBYA        -0.4259(0.1151)***  -0.0935(0.1563)      -2.1004(3.0670)
## Equation NFAOFPY     0.0602(0.0989)      0.2205(0.1342)       -1.4182(2.6338)
## Equation LPR2COMM5   -0.0052(0.0037)     0.0033(0.0051)       0.4189(0.0995)***
##                      LREERS -4           RIRR -4
## Equation LREERS      0.0086(0.1427)      -0.0026(0.0041)
## Equation RIRR        6.4661(3.3788).     -0.3418(0.0963)***
## Equation LRGDPPCR    0.1016(0.0338)**    -0.0024(0.0010)*
## Equation OPENY       7.5871(6.7830)      -0.1562(0.1933)
## Equation FBYA        1.4305(7.2383)      -0.3995(0.2063).
## Equation NFAOFPY     -6.1204(6.2159)     -0.1901(0.1772)
## Equation LPR2COMM5   -0.5209(0.2348)*    -0.0097(0.0067)
##                      LRGDPPCR -4           OPENY -4
## Equation LREERS      0.1979(0.3882)        -0.0012(0.0028)
## Equation RIRR        -7.6350(9.1907)       0.1846(0.0661)**
## Equation LRGDPPCR    0.0583(0.0920)        0.0020(0.0007)**
## Equation OPENY       -20.1050(18.4503)     -0.0109(0.1327)
## Equation FBYA        -2.8011(19.6890)      0.0347(0.1416)
## Equation NFAOFPY     34.5293(16.9077)*     -0.0195(0.1216)
```

```
## Equation LPR2COMM5 1.0574(0.6387)        -0.0011(0.0046)
##                    FBYA -4               NFAOFPY -4           LPR2COMM5 -4
## Equation LREERS    0.0002(0.0019)        -0.0008(0.0027)      -0.0502(0.0696)
## Equation RIRR      -0.0108(0.0459)       -0.0700(0.0649)      -2.8567(1.6483).
## Equation LRGDPPCR  0.0003(0.0005)        0.0003(0.0006)       0.0005(0.0165)
## Equation OPENY     0.0324(0.0921)        0.0362(0.1303)       -0.6438(3.3090)
## Equation FBYA      0.0557(0.0983)        -0.0316(0.1390)      -2.0911(3.5311)
## Equation NFAOFPY   -0.0410(0.0844)       -0.0407(0.1194)      -2.2249(3.0323)
## Equation LPR2COMM5 -6.9e-05(0.0032)      0.0042(0.0045)       0.1661(0.1146)
##                    SDUMC1               SDUMC2               SDUMC3
## Equation LREERS    0.0272(0.0181)       0.0132(0.0187)       0.0028(0.0191)
## Equation RIRR      -0.2619(0.4275)      -0.2273(0.4432)      -0.9129(0.4512)*
## Equation LRGDPPCR  0.0079(0.0043).      0.0057(0.0044)       -0.0027(0.0045)
## Equation OPENY     -0.2668(0.8581)      -0.1234(0.8897)      0.4964(0.9058)
## Equation FBYA      -0.8964(0.9158)      -2.2598(0.9494)*     -0.5301(0.9666)
## Equation NFAOFPY   -0.5097(0.7864)      -0.7208(0.8153)      0.1048(0.8300)
## Equation LPR2COMM5 0.0081(0.0297)       0.0046(0.0308)       0.0095(0.0314)
```

```
# mod2 <- full_df %>% dplyr::select(2:8) %>%
#     tsDyn::VECM(., lag = 4, estim = "ML",
#                 include = "const", r=1,
#                 exogen = exog_df[,2:8])
# summary(mod2)

# mod3 <- full_df %>% dplyr::select(2:7 | 9) %>%
#     tsDyn::VECM(., lag = 4, estim = "ML",
#                 include = "const", r=1,
#                 exogen = exog_df[,2:8])
# summary(mod3)

# mod4 <- full_df %>% dplyr::select(2:7 | 10) %>%
#     tsDyn::VECM(., lag = 4, estim = "ML",
#                 include = "const", r=1,
#                 exogen = exog_df[,2:8])
# summary(mod4)

# mod5 <- full_df %>% dplyr::select(2:7 | 11) %>%
#     tsDyn::VECM(., lag = 4, estim = "ML",
```

```
#                   include = "const", r=1,
#                   exogen = exog_df[,2:8])
# summary(mod5)

# mod6 <- full_df %>% dplyr::select(2:7 | 12) %>%
#      tsDyn::VECM(., lag = 4, estim = "ML",
#                   include = "const", r=1,
#                   exogen = exog_df[,2:8])
# summary(mod6)

# mod7 <- full_df %>% dplyr::select(2:7 | 13) %>%
#      tsDyn::VECM(., lag = 4, estim = "ML",
#                   include = "const", r=1,
#                   exogen = exog_df[,2:8])
# summary(mod7)
```

11. Directly from (MacDonald & Ricci, 2004)

11.1. Section 3 Data and Methodology

- Plotting the exp(LREER) and the rest of the variables
- Showcase the vector of interest
- Investigate LR CI Rel's amongst var's in vector
  - Method: MLE of Johansen (1995)
  - Why? Corrects for Autocorr and ednog parametrically using VECM specif.
  - Key Advantage: the estimated coefficient - the β vector - can be used to provide a measure of the equilibrium real exchange rate and therefore a quantification of the gap between the prevailing real exchange rate and its equilibrium level. The methodology also derives estimates of the speed at which the real exchange rates converges to the equilibrium level.

12. Old Stuff

13. References

10 Johansen, S. 1995. *Likelihood-based inference in cointegrated vector autoregressive models*. OUP Oxford.

MacDonald, R. & Ricci, L.A. 2004. Estimation of the equilibrium real exchange rate for south africa 1. *South African Journal of Economics*. 72(2):282–304.

Sarno, L. & Taylor, M.P. 2002. Purchasing Power Parity and the Real Exchange Rate. *IMF Staff Papers*. 49(1):65–105. [Online], Available: https://www.jstor.org/stable/3872492 [2022, June 27].

Appendix