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 done by 1. They analyse the determinants of the Real Effective Exchange Rate (REER) based on a collection of variables as determinants. The purpose of their study was to find a set of variables with explanatory power in determining the long term behaviour of the REER in South Africa over the period starting from the first quarter of the year 1970 until the first quarter of the year 2002. Towards this end, they made use of the Maximum Likelihood method of estimating the Vector Error Correction Model (VECM) from the paper by Johansen (1995).

- What did I do? This paper is a replication and critical evaluation of the research paper by

1.

- 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

3. Replication

4. Importing and Cleaning the Data

4.1. Importing the full dataset:

```
full_df <- fetch_full()
full_df
```

```
## # A tibble: 129 x 20
##    obs    LREERS    RIRR LRGDPPCR OPENY  FBYA NFAOFPY LPR2COMM5 LPRCOMM5
##    <chr>   <dbl>   <dbl>    <dbl> <dbl> <dbl>   <dbl>     <dbl>    <dbl>
##  1 1970Q1   4.59 -0.541     0.670  44.8 -5.62    7.41    -0.734   -0.851
##  2 1970Q2   4.58 -0.0509    0.663  46.1 -1.94    6.92    -0.729   -0.849
##  3 1970Q3   4.59 -0.707     0.632  47.9 -1.55    6.29    -0.747   -0.875
##  4 1970Q4   4.59  0.906     0.637  46.8 -3.49    5.12    -0.703   -0.846
##  5 1971Q1   4.59  1.54      0.675  47.5 -6.51    4.40    -0.690   -0.825
##  6 1971Q2   4.60  0.628     0.651  47.3 -4.91    3.86    -0.659   -0.792
##  7 1971Q3   4.59  1.09      0.643  46.9 -5.09    3.11    -0.675   -0.795
##  8 1971Q4   4.56  0.301     0.624  47.4 -7.57    2.87    -0.653   -0.749
##  9 1972Q1   4.49  0.117     0.625  45.7 -4.69    3.33    -0.591   -0.665
## 10 1972Q2   4.50 -0.0238    0.617  47.4 -8.77    4.63    -0.407   -0.481
## # ... with 119 more rows, and 11 more variables: LPR2COMM3 <dbl>,
## #   LPRCOMM3 <dbl>, LPR2GOLD <dbl>, LPRGOLD <dbl>, SDUMC1 <dbl>, SDUMC2 <dbl>,
## #   SDUMC3 <dbl>, DUMRER1 <dbl>, DUMRER2 <dbl>, DUMFBYA <dbl>, DUMNFAOFPY <dbl>
```

4.2. Wrangling the dataset

```
full_df <- full_clean(full_df)
full_df
```

```
## # A tibble: 129 x 20
##    date       LREERS    RIRR LRGDPPCR OPENY  FBYA NFAOFPY LPR2COMM5 LPRCOMM5
##    <date>      <dbl>   <dbl>    <dbl> <dbl> <dbl>   <dbl>     <dbl>    <dbl>
##  1 1970-03-31   4.59 -0.541     0.670  44.8 -5.62    7.41    -0.734   -0.851
##  2 1970-06-30   4.58 -0.0509    0.663  46.1 -1.94    6.92    -0.729   -0.849
##  3 1970-09-30   4.59 -0.707     0.632  47.9 -1.55    6.29    -0.747   -0.875
##  4 1970-12-31   4.59  0.906     0.637  46.8 -3.49    5.12    -0.703   -0.846
##  5 1971-03-31   4.59  1.54      0.675  47.5 -6.51    4.40    -0.690   -0.825
##  6 1971-06-30   4.60  0.628     0.651  47.3 -4.91    3.86    -0.659   -0.792
##  7 1971-09-30   4.59  1.09      0.643  46.9 -5.09    3.11    -0.675   -0.795
```

```
##  8 1971-12-31   4.56  0.301     0.624  47.4 -7.57    2.87    -0.653   -0.749
##  9 1972-03-31   4.49  0.117     0.625  45.7 -4.69    3.33    -0.591   -0.665
## 10 1972-06-30   4.50 -0.0238    0.617  47.4 -8.77    4.63    -0.407   -0.481
## # ... with 119 more rows, and 11 more variables: LPR2COMM3 <dbl>,
## #   LPRCOMM3 <dbl>, LPR2GOLD <dbl>, LPRGOLD <dbl>, SDUMC1 <dbl>, SDUMC2 <dbl>,
## #   SDUMC3 <dbl>, DUMRER1 <dbl>, DUMRER2 <dbl>, DUMFBYA <dbl>, DUMNFAOFPY <dbl>
```

4.3. Variable Names (SECTION TO BE DELETED)

```
as_tibble(names(full_df))
```

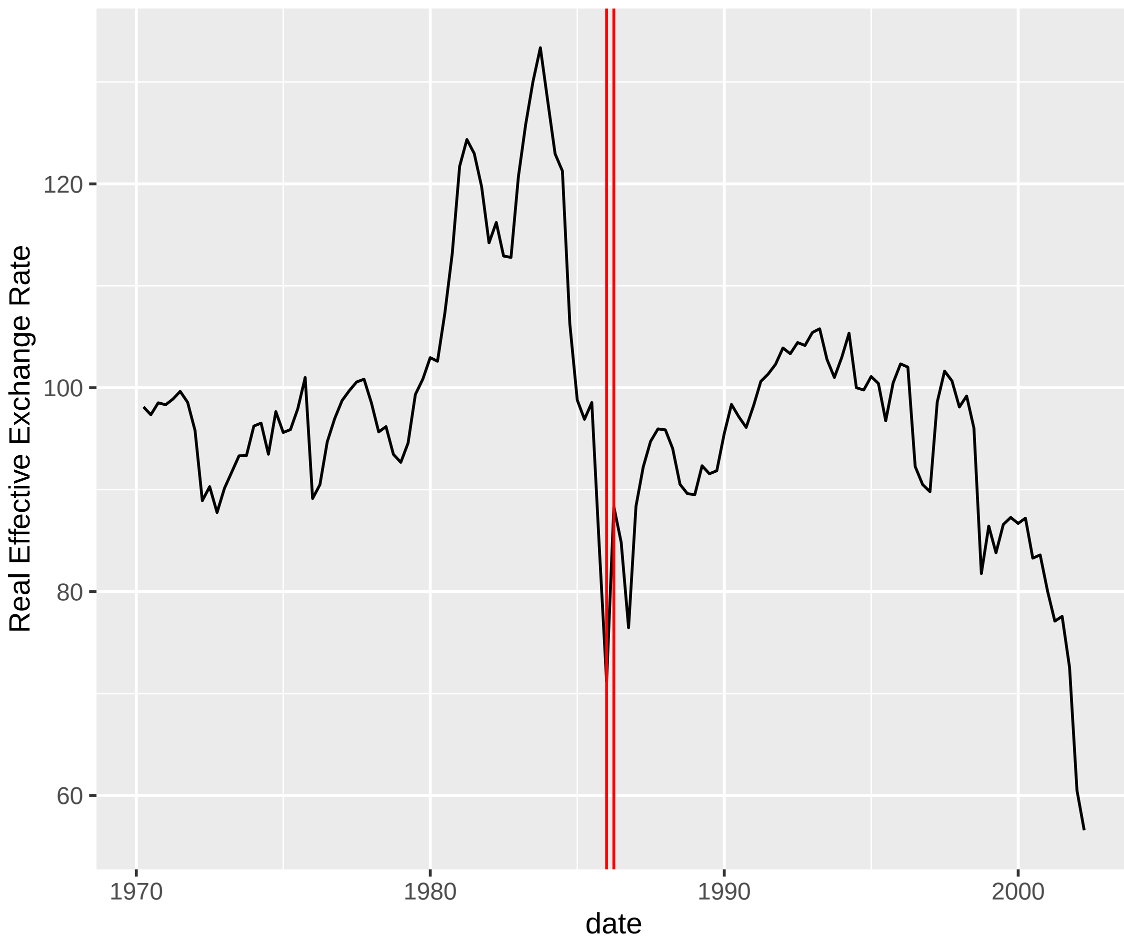
```
## # A tibble: 20 x 1
##    value
##    <chr>
##  1 date
##  2 LREERS
##  3 RIRR
##  4 LRGDPPCR
##  5 OPENY
##  6 FBYA
##  7 NFAOFPY
##  8 LPR2COMM5
##  9 LPRCOMM5
## 10 LPR2COMM3
## 11 LPRCOMM3
## 12 LPR2GOLD
## 13 LPRGOLD
## 14 SDUMC1
## 15 SDUMC2
## 16 SDUMC3
## 17 DUMRER1
## 18 DUMRER2
## 19 DUMFBYA
## 20 DUMNFAOFPY
```

4.4. Plotting the Variables of Interest

All variables appear as they were before their natural logarithm was determined.

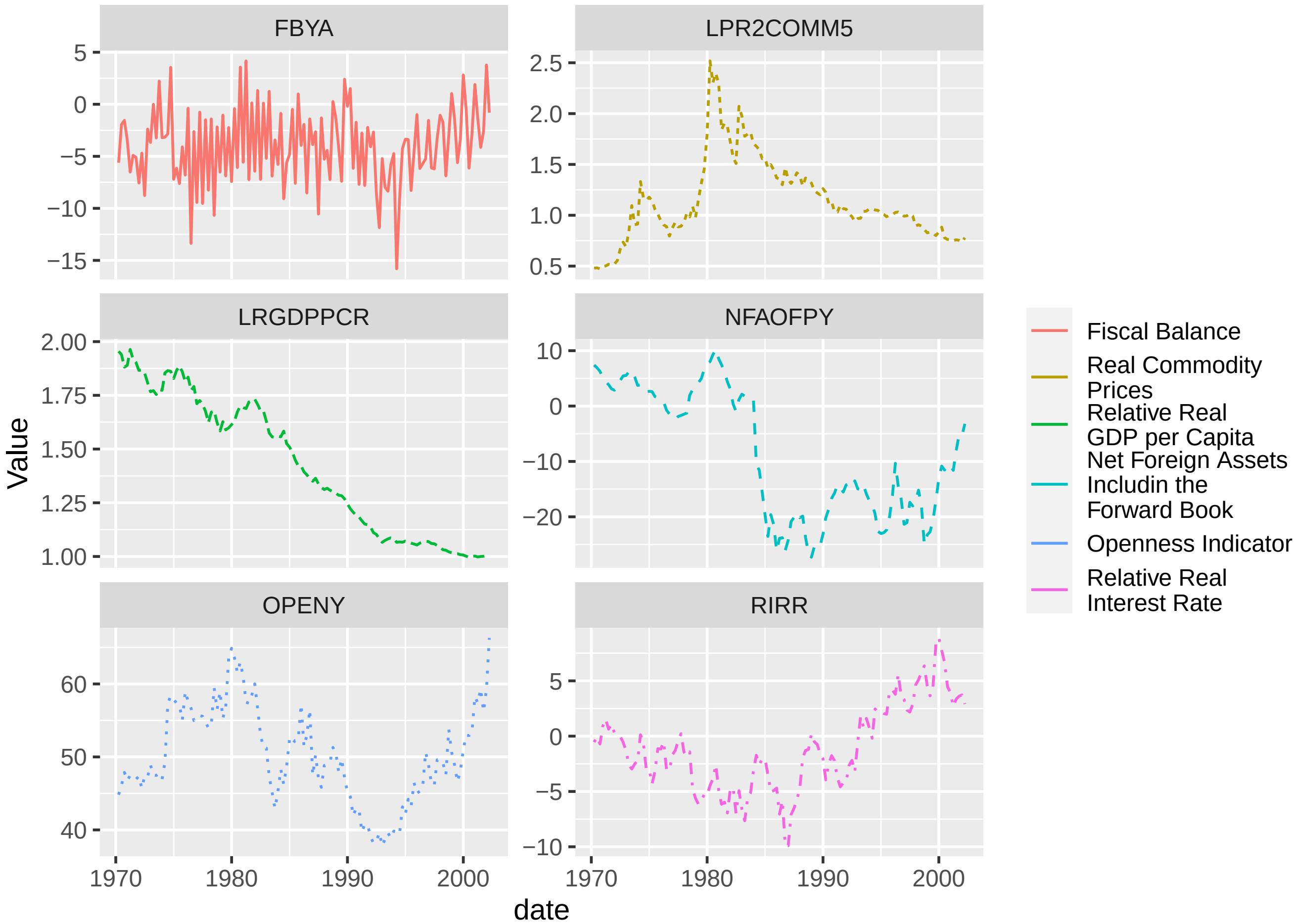
4.4.1. Plotting the Real Effective Exchange Rate:

```
plot_endog1(full_df)
```



4.4.2. Plotting the Determinants of the Real Effective Exchange Rate:

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



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.

4.4.3. Plotting the Diffirenced Variables

```
test_df <- full_df %>% mutate(across(names(.)[2:13], function(x) x-lag(x))) %>% filter(date > fi
plot_endog1(test_df)
```

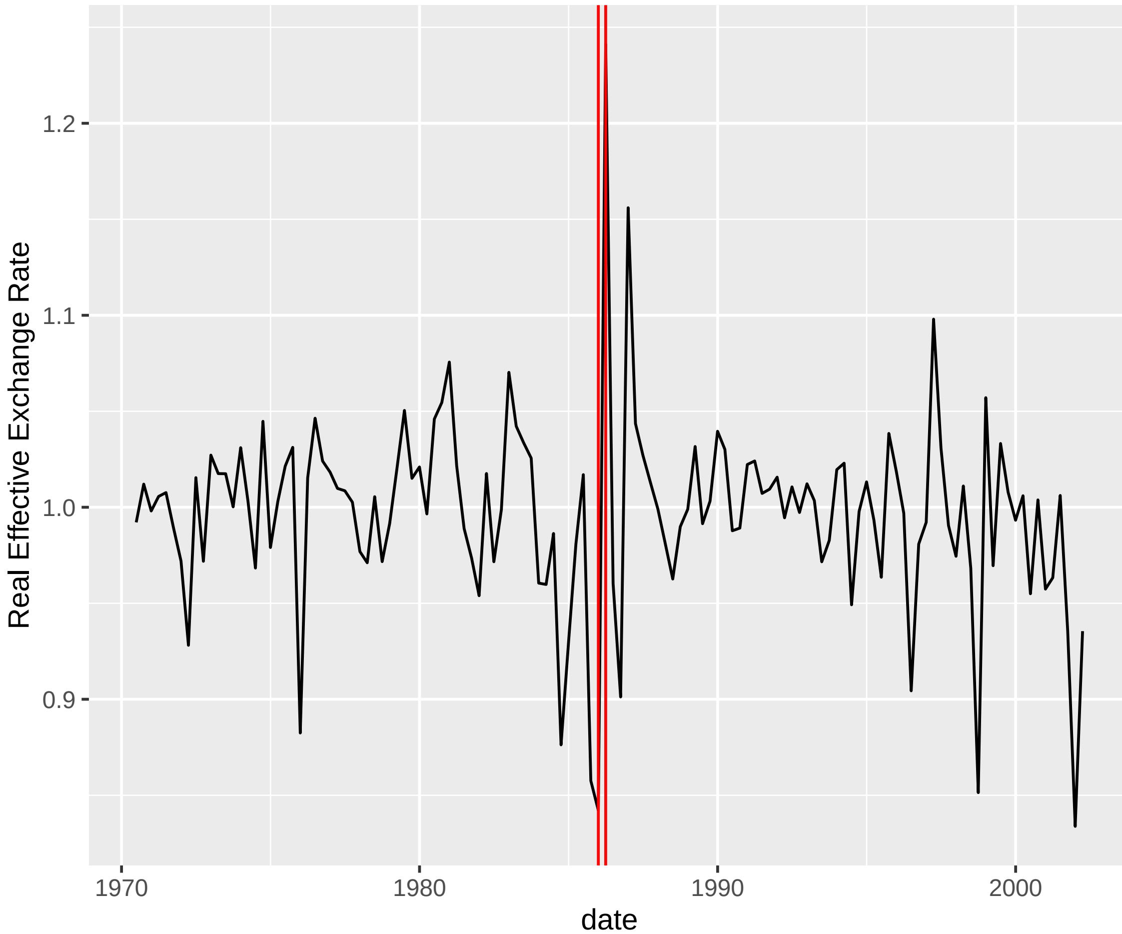
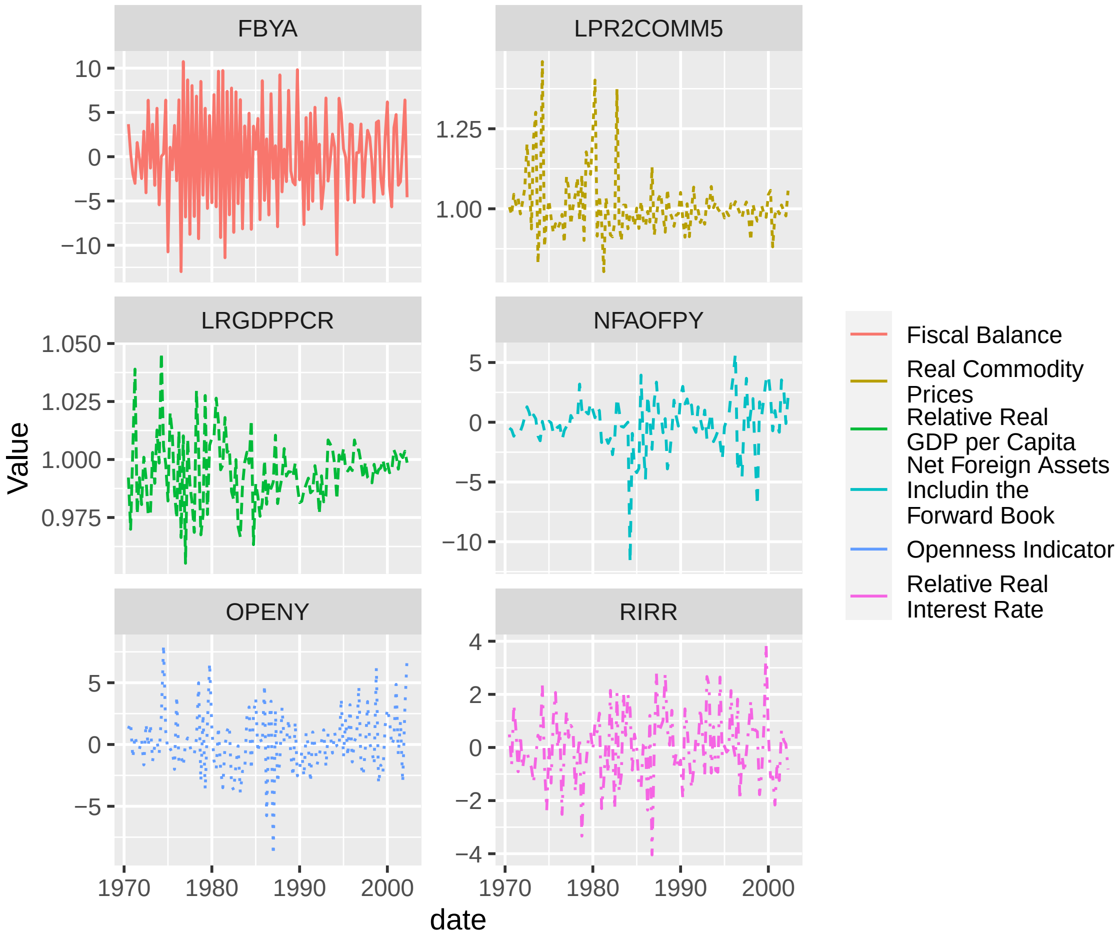


Figure 4.1: The First Difference of the Real Exchange Rate Time Series

```
plot_endog2(df = test_df)
```



The figure above suggest that the REER time series is most likely integrated of order 1 (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 opf 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

```r
# Better format this later
joint_adf_test <- joint_adf(full_df)
knitr::kable(joint_adf_test)
```

	RIRR	OPENY	FBYA	NFAOFPY	LREER	LRGDPPCR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
statistic	-5.10084[illegible]	-[illegible]	-[illegible]	-[illegible]	-[illegible]	-[illegible]	-[illegible]	-[illegible]	-[illegible]	-[illegible]	-[illegible]	-[illegible]47692998

	RIRR	OPENY	FBYA	NFAOFPY	LREERS	LRGDPPCR	LPR2COMM5	LPRCOMM5	LPR2COMM3	LPRCOMM3	LPR2GOLD	LPRGOLD
Lag order	5	5	5	5	5	5	5	5	5	5	5	5
Alternative Hypothesis	stationary	stationary	stationary	stationary	stationary	stationary	stationary	stationary	stationary	stationary	stationary	stationary
p.value	0.01	0.0228622[illegible]	0.078361[illegible]	0.8946075[illegible]	0.4285309[illegible]	0.01	0.01	0.01	0.01	0.01	0.01	0.01

4.5. VECM Model Estimation:

paper table 1 col's:

1. Var's + Seasonal(4) + lags(4) 2. ^{Above} + outlier_dummies -> Trace test $\Longrightarrow$ 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

4.5.1. Determine the Lag Order

First we split the data into the additional dummies and the main variables:

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

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

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

summary(vec)
```

```
##
## ######################
## # Johansen-Procedure #
## ######################
##
## Test type: trace statistic , without linear trend and constant in cointegration
##
## Eigenvalues (lambda):
## [1]  2.741384e-01  2.056177e-01  1.997777e-01  1.202430e-01  1.111450e-01
## [6]  6.313826e-02  4.743264e-02 -1.670334e-16
##
## Values of teststatistic and critical values of test:
##
##             test  10pct   5pct   1pct
## r <= 6 |    6.07   7.52   9.24  12.97
## r <= 5 |   14.23  17.85  19.96  24.60
## r <= 4 |   28.95  32.00  34.91  41.07
## r <= 3 |   44.97  49.65  53.12  60.16
## r <= 2 |   72.83  71.86  76.07  84.45
## r <= 1 |  101.60  97.18 102.14 111.01
## r = 0  |  141.65 126.58 131.70 143.09
##
## 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  1.00000000  1.0000000000
## RIRR.l1        -0.034477285 -0.063811357 -0.009346723  0.13402907  0.0005436228
## LRGDPPCR.l1    -0.230930452 -1.979972815  0.220425455  1.21783849  0.1933115316
## OPENY.l1        0.008764965  0.058750655  0.034174450 -0.01896788  0.0092309447
## FBYA.l1         0.018668473  0.038031301 -0.063011996  0.50306497  0.0190210726
## NFAOFPY.l1     -0.005434018 -0.004171023 -0.036568269 -0.03361502 -0.0127952636
```

```
## LPR2COMM5.l1 -0.479741162 -1.216902985 -0.584758148 -0.99438252 -0.0630707443
## constant     -4.888234747 -6.999166718 -6.698582220 -1.81614163 -5.1579047707
##                NFAOFPY.l1 LPR2COMM5.l1     constant
## LREERS.l1      1.00000000  1.000000000  1.000000000
## RIRR.l1        0.02712490  0.006444232  0.023024728
## LRGDPPCR.l1    0.93836513 -0.448950307  0.576574119
## OPENY.l1       0.03025468  0.012413433 -0.007913675
## FBYA.l1       -0.01188010 -0.007032678 -0.013589504
## NFAOFPY.l1    -0.01613723  0.002262130 -0.011528765
## LPR2COMM5.l1  -0.30291162 -0.127398851 -0.183636782
## constant      -6.53786889 -5.026297709 -4.525355672
##
## Weights W:
## (This is the loading matrix)
##
##                 LREERS.l1      RIRR.l1 LRGDPPCR.l1      OPENY.l1      FBYA.l1
## LREERS.d      -0.03905540  0.009542747  0.02039254 -3.016394e-03  0.056264052
## RIRR.d         2.85186904  0.672316964  0.55505618 -9.518194e-02 -0.620548723
## LRGDPPCR.d    -0.03738182  0.012467654 -0.01100385  4.345389e-05 -0.008292489
## OPENY.d       -4.11197066 -0.971890116 -0.27421153  2.471038e-01 -6.750016203
## FBYA.d       -14.32992479  0.677115272  1.52182656 -3.805992e-01 -1.127317608
## NFAOFPY.d      0.50573233  1.705655623  1.46584329  3.250713e-01 -0.405973425
## LPR2COMM5.d    0.16445725  0.039012790 -0.02156001 -8.125198e-03 -0.241502261
##                NFAOFPY.l1 LPR2COMM5.l1      constant
## LREERS.d      0.001401803 -0.087318974 -2.163361e-14
## RIRR.d       -1.192751656  0.720502337  3.674215e-13
## LRGDPPCR.d   -0.006841840  0.001697689 -6.005828e-15
## OPENY.d      -1.236150400  0.836600047 -3.701988e-13
## FBYA.d        0.690078812  1.881228636 -3.039855e-12
## NFAOFPY.d     0.560346240 -1.969193524 -1.063830e-12
## LPR2COMM5.d   0.036485387 -0.033810781 -5.100729e-15
```

```r
vec2 <- ca.jo(full_df[,2:8], type = "trace", ecdet = "const", #spec = "transitory",
             K = 4, season = 4)

summary(vec2)
```

```
##
```

```
## ######################
## # Johansen-Procedure #
## ######################
##
## Test type: trace statistic , without linear trend and constant in cointegration
##
## Eigenvalues (lambda):
## [1] 2.741384e-01 2.056177e-01 1.997777e-01 1.202430e-01 1.111450e-01
## [6] 6.313826e-02 4.743264e-02 8.789624e-17
##
## Values of teststatistic and critical values of test:
##
##            test  10pct   5pct   1pct
## r <= 6 |   6.07   7.52   9.24  12.97
## r <= 5 |  14.23  17.85  19.96  24.60
## r <= 4 |  28.95  32.00  34.91  41.07
## r <= 3 |  44.97  49.65  53.12  60.16
## r <= 2 |  72.83  71.86  76.07  84.45
## r <= 1 | 101.60  97.18 102.14 111.01
## r = 0  | 141.65 126.58 131.70 143.09
##
## Eigenvectors, normalised to first column:
## (These are the cointegration relations)
##
##                  LREERS.l4      RIRR.l4  LRGDPPCR.l4    OPENY.l4       FBYA.l4
## LREERS.l4      1.000000000  1.000000000  1.000000000  1.00000000  1.0000000000
## RIRR.l4       -0.034477285 -0.063811357 -0.009346723  0.13402907  0.0005436228
## LRGDPPCR.l4   -0.230930452 -1.979972815  0.220425455  1.21783849  0.1933115316
## OPENY.l4       0.008764965  0.058750655  0.034174450 -0.01896788  0.0092309447
## FBYA.l4        0.018668473  0.038031301 -0.063011996  0.50306497  0.0190210726
## NFAOFPY.l4    -0.005434018 -0.004171023 -0.036568269 -0.03361502 -0.0127952636
## LPR2COMM5.l4 -0.479741162 -1.216902985 -0.584758148 -0.99438252 -0.0630707443
## constant      -4.888234747 -6.999166718 -6.698582220 -1.81614163 -5.1579047707
##                 NFAOFPY.l4 LPR2COMM5.l4     constant
## LREERS.l4       1.00000000  1.000000000  1.000000000
## RIRR.l4         0.02712490  0.006444232  0.023024728
## LRGDPPCR.l4     0.93836513 -0.448950307  0.576574119
## OPENY.l4        0.03025468  0.012413433 -0.007913675
## FBYA.l4        -0.01188010 -0.007032678 -0.013589504
```

```
## NFAOFPY.l4   -0.01613723  0.002262130 -0.011528765
## LPR2COMM5.l4 -0.30291162 -0.127398851 -0.183636782
## constant     -6.53786889 -5.026297709 -4.525355672
##
## Weights W:
## (This is the loading matrix)
##
##                LREERS.l4      RIRR.l4 LRGDPPCR.l4      OPENY.l4      FBYA.l4
## LREERS.d     -0.03905540  0.009542747  0.02039254 -3.016394e-03  0.056264052
## RIRR.d        2.85186904  0.672316964  0.55505618 -9.518194e-02 -0.620548723
## LRGDPPCR.d   -0.03738182  0.012467654 -0.01100385  4.345389e-05 -0.008292489
## OPENY.d      -4.11197066 -0.971890116 -0.27421153  2.471038e-01 -6.750016203
## FBYA.d      -14.32992479  0.677115272  1.52182656 -3.805992e-01 -1.127317608
## NFAOFPY.d     0.50573233  1.705655623  1.46584329  3.250713e-01 -0.405973425
## LPR2COMM5.d   0.16445725  0.039012790 -0.02156001 -8.125198e-03 -0.241502261
##               NFAOFPY.l4 LPR2COMM5.l4      constant
## LREERS.d     0.001401803 -0.087318974 -8.897356e-15
## RIRR.d      -1.192751656  0.720502337  9.019749e-14
## LRGDPPCR.d  -0.006841840  0.001697689 -6.117938e-15
## OPENY.d     -1.236150400  0.836600047 -6.321306e-13
## FBYA.d       0.690078812  1.881228636 -5.040780e-13
## NFAOFPY.d    0.560346240 -1.969193524  8.207158e-13
## LPR2COMM5.d  0.036485387 -0.033810781  7.318486e-14
```

```r
mod1 <- tsDyn::VECM(full_df[,2:8], lag = 4, estim = "ML", include = "const",
                    r=1, exogen = exog_df$season_dum)

summ <- mod1$model
```

```r
#
#
#
# mod <- VECM(data = endog_df[,2:8], lag = 4, r = 1,
#             include = "const", estim = "ML", exogen = exog_df[,2:4])
#
# mod_summ <- summary(mod)
```

```
# mod <- dynlm(full_df$LREERS ~ full_df$RIRR + full_df$LRGDPPCR + full_df$OPENY
#             + full_df$FBYA + full_df$NFAOFPY + full_df$LPR2COMM5
#             + full_df$DUMNFAOFPY + full_df$DUMRER1
#             + full_df$DUMRER2 + full_df$DUMFBYA + full_df$SDUMC1
#             + full_df$SDUMC2 + full_df$SDUMC3,
#             lag = 4,
#             include = "const", estim = "ML", exog
#             exogen = exog_df[,2:8])
```

```
stargazer(summ, header = FALSE)
```

Table 4.2

Statistic	N	Mean	St. Dev.	Min	Max
LREERS	129	4.573	0.129	4.036	4.893
RIRR	129	−1.137	3.896	−9.909	8.880
LRGDPPCR	129	0.324	0.231	−0.004	0.675
OPENY	129	50.200	6.575	37.826	66.305
FBYA	129	−3.984	3.653	−15.805	4.168
NFAOFPY	129	−8.683	11.484	−27.309	10.234
LPR2COMM5	129	0.073	0.352	−0.747	0.924
ECT	124	4.968	0.100	4.725	5.231
Intercept	124	1.000	0.000	1	1
LREERS -1	124	−0.004	0.052	−0.182	0.216
RIRR -1	124	0.023	1.345	−4.047	3.865
LRGDPPCR -1	124	−0.005	0.015	−0.046	0.045
OPENY -1	124	0.101	2.489	−8.939	8.067
FBYA -1	124	0.059	5.603	−12.986	10.748
NFAOFPY -1	124	−0.084	2.258	−11.802	5.779
LPR2COMM5 -1	124	0.003	0.089	−0.219	0.378
LREERS -2	124	−0.002	0.050	−0.172	0.216
RIRR -2	124	0.035	1.353	−4.047	3.865
LRGDPPCR -2	124	−0.005	0.015	−0.046	0.045
OPENY -2	124	0.067	2.477	−8.939	8.067
FBYA -2	124	−0.009	5.576	−12.986	10.748
NFAOFPY -2	124	−0.093	2.260	−11.802	5.779
LPR2COMM5 -2	124	0.004	0.089	−0.219	0.378
LREERS -3	124	−0.002	0.049	−0.172	0.216
RIRR -3	124	0.027	1.354	−4.047	3.865
LRGDPPCR -3	124	−0.005	0.015	−0.046	0.045
OPENY -3	124	0.107	2.465	−8.939	8.067
FBYA -3	124	−0.018	5.575	−12.986	10.748
NFAOFPY -3	124	−0.121	2.244	−11.802	5.779
LPR2COMM5 -3	124	0.004	0.089	−0.219	0.378
LREERS -4	124	−0.002	0.049	−0.172	0.216
RIRR -4	124	0.026	1.353	−4.047	3.865
LRGDPPCR -4	124	−0.005	0.015	−0.046	0.045
OPENY -4	124	0.101	2.462	−8.939	8.067
FBYA -4	124	0.035	5.578	−12.986	10.748
NFAOFPY -4	124	−0.153	2.220	−11.802	5.779
LPR2COMM5 -4	124	0.004	0.089	−0.219	0.378

5. Directly from (MacDonald & Ricci, 2004)

5.1. 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.

6. Old Stuff

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.