ARDL HuYuDataInsight LLC

Zhaowei Cai 2024-05-03

ARDL creates complex autoregressive distributed lag (ARDL) models and constructs the underlying unrestricted and restricted error correction model (ECM) automatically, just by providing the order. It also performs the bounds-test for cointegration as described in Pesaran et al. (2001) and provides the multipliers and the cointegrating equation. The validity and the accuracy of this package have been verified by successfully replicating the results of Pesaran et al. (2001) in Natsiopoulos and Tzeremes (2022).

```
# install.packages("ARDL")
# install.packages("devtools")
# devtools::install_github("Natsiopoulos/ARDL")
library(ARDL)
```

```
## Warning: package 'ARDL' was built under R version 4.2.3
```

```
## To cite the ARDL package in publications:
##
## Use this reference to refer to the validity of the ARDL package.
##
##   Natsiopoulos, Kleanthis, and Tzeremes, Nickolaos G. (2022). ARDL
##   bounds test for cointegration: Replicating the Pesaran et al. (2001)
##   results for the UK earnings equation using R. Journal of Applied
##   Econometrics, 37(5), 1079-1090. https://doi.org/10.1002/jae.2919
##
## Use this reference to cite this specific version of the ARDL package.
##
##   Kleanthis Natsiopoulos and Nickolaos Tzeremes (2023). ARDL: ARDL, ECM
##   and Bounds-Test for Cointegration. R package version 0.2.4.
##   https://CRAN.R-project.org/package=ARDL
```

```
data(denmark)
head(denmark)
```

```
##              LRM      LRY        LPY       IBO    IDE
## 1974 Q1 11.63255 5.903658 -0.6187359 0.1547356 0.0940
## 1974 Q2 11.60415 5.873820 -0.5807479 0.1779912 0.0955
## 1974 Q3 11.58152 5.837818 -0.5428478 0.1705647 0.0955
## 1974 Q4 11.60185 5.812255 -0.5046041 0.1522273 0.0955
## 1975 Q1 11.58630 5.803945 -0.4864585 0.1342276 0.0885
## 1975 Q2 11.60450 5.786761 -0.4544386 0.1334805 0.0790
```

```
data(br_month)
```

```
## Warning in data(br_month): data set 'br_month' not found
```

First, we find the best ARDL specification. We search up to order 5.

```
models <- auto_ardl(LRM ~ LRY + IBO + IDE, data = denmark, max_order = 5, selection = 'AIC')
# It searches for the best ARDL order specification, according to the selected criterion, taking into a

# The top 20 models according to the AIC
models$top_orders
```

```
##    LRM LRY IBO IDE       AIC
## 1    3   1   3   2 -251.0259
## 2    3   1   3   3 -250.1144
## 3    2   2   0   0 -249.6266
## 4    3   2   3   2 -249.1087
## 5    3   2   3   3 -248.1858
## 6    2   2   0   1 -247.7786
## 7    2   1   0   0 -247.5643
## 8    2   2   1   1 -246.6885
## 9    3   3   3   3 -246.3061
## 10   2   2   1   2 -246.2709
## 11   2   1   1   1 -245.8736
## 12   2   2   2   2 -245.7722
## 13   1   1   0   0 -245.6620
## 14   2   1   2   2 -245.1712
## 15   3   1   2   2 -245.0996
## 16   1   0   0   0 -244.4317
## 17   1   1   0   1 -243.7702
## 18   5   5   5   5 -243.3120
## 19   4   1   3   2 -243.0728
## 20   4   1   3   3 -242.4378
```

```
models$best_order
```

```
## LRM LRY IBO IDE
##   3   1   3   2
```

```
# The best model was found to be the ARDL(3,1,3,2)
ardl_3132 <- models$best_model
ardl_3132$order
```

```
## LRM LRY IBO IDE
##   3   1   3   2
```

```
summary(ardl_3132)
```

```
##
## Time series regression with "zooreg" data:
## Start = 1974 Q4, End = 1987 Q3
##
## Call:
## dynlm::dynlm(formula = full_formula, data = data, start = start,
##     end = end)
```

```
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.029939 -0.008856 -0.002562  0.008190  0.072577
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.6202     0.5678   4.615 4.19e-05 ***
## L(LRM, 1)     0.3192     0.1367   2.336 0.024735 *
## L(LRM, 2)     0.5326     0.1324   4.024 0.000255 ***
## L(LRM, 3)    -0.2687     0.1021  -2.631 0.012143 *
## LRY           0.6728     0.1312   5.129 8.32e-06 ***
## L(LRY, 1)    -0.2574     0.1472  -1.749 0.088146 .
## IBO          -1.0785     0.3217  -3.353 0.001790 **
## L(IBO, 1)    -0.1062     0.5858  -0.181 0.857081
## L(IBO, 2)     0.2877     0.5691   0.505 0.616067
## L(IBO, 3)    -0.9947     0.3925  -2.534 0.015401 *
## IDE           0.1255     0.5545   0.226 0.822161
## L(IDE, 1)    -0.3280     0.7213  -0.455 0.651847
## L(IDE, 2)     1.4079     0.5520   2.550 0.014803 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.0191 on 39 degrees of freedom
## Multiple R-squared:  0.988,  Adjusted R-squared:  0.9843
## F-statistic: 266.8 on 12 and 39 DF,  p-value: < 2.2e-16
```

The UECM (Unrestricted Error Correction Model) of the underlying ARDL(3,1,3,2):

```
uecm_3132 <- uecm(ardl_3132)
summary(uecm_3132)
```

```
##
## Time series regression with "zooreg" data:
## Start = 1974 Q4, End = 1987 Q3
##
## Call:
## dynlm::dynlm(formula = full_formula, data = data, start = start,
##     end = end)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.029939 -0.008856 -0.002562  0.008190  0.072577
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.62019    0.56777   4.615 4.19e-05 ***
## L(LRM, 1)    -0.41685    0.09166  -4.548 5.15e-05 ***
## L(LRY, 1)     0.41538    0.11761   3.532  0.00108 **
## L(IBO, 1)    -1.89172    0.39111  -4.837 2.09e-05 ***
## L(IDE, 1)     1.20534    0.44690   2.697  0.01028 *
## d(L(LRM, 1)) -0.26394    0.10192  -2.590  0.01343 *
## d(L(LRM, 2))  0.26867    0.10213   2.631  0.01214 *
```

```
## d(LRY)        0.67280    0.13116   5.129 8.32e-06 ***
## d(IBO)       -1.07852    0.32170  -3.353  0.00179 **
## d(L(IBO, 1))  0.70701    0.46874   1.508  0.13953
## d(L(IBO, 2))  0.99468    0.39251   2.534  0.01540 *
## d(IDE)        0.12546    0.55445   0.226  0.82216
## d(L(IDE, 1)) -1.40786    0.55204  -2.550  0.01480 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.0191 on 39 degrees of freedom
## Multiple R-squared:  0.7458, Adjusted R-squared:  0.6676
## F-statistic: 9.537 on 12 and 39 DF,  p-value: 3.001e-08
```

The RECM (Restricted Error Correction Model) of the underlying ARDL(3,1,3,2): allowing the constant to join the long-run relationship, instead of the short-run

```
recm_3132 <- recm(uecm_3132, case = 2)
summary(recm_3132)
```

```
##
## Time series regression with "zooreg" data:
## Start = 1974 Q4, End = 1987 Q3
##
## Call:
## dynlm::dynlm(formula = full_formula, data = data, start = start,
##     end = end)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.029939 -0.008856 -0.002562  0.008190  0.072577
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## d(L(LRM, 1)) -0.26394    0.09008  -2.930 0.005405 **
## d(L(LRM, 2))  0.26867    0.09127   2.944 0.005214 **
## d(LRY)        0.67280    0.11591   5.805 7.03e-07 ***
## d(IBO)       -1.07852    0.30025  -3.592 0.000837 ***
## d(L(IBO, 1))  0.70701    0.44359   1.594 0.118300
## d(L(IBO, 2))  0.99468    0.36491   2.726 0.009242 **
## d(IDE)        0.12546    0.48290   0.260 0.796248
## d(L(IDE, 1)) -1.40786    0.48867  -2.881 0.006160 **
## ect          -0.41685    0.07849  -5.311 3.63e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.01819 on 43 degrees of freedom
##   (0 observations deleted due to missingness)
## Multiple R-squared:  0.7613, Adjusted R-squared:  0.7113
## F-statistic: 15.24 on 9 and 43 DF,  p-value: 9.545e-11
```

Test if there is a long-run levels relationship (cointegration) using the bounds test from Pesaran et al. (2001).

```r
# The bounds F-test (under the case 2) rejects the NULL hypothesis (let's say, assuming alpha = 0.01) w
bounds_f_test(ardl_3132, case = 2)
```

```
##
##  Bounds F-test (Wald) for no cointegration
##
## data:  d(LRM) ~ L(LRM, 1) + L(LRY, 1) + L(IBO, 1) + L(IDE, 1) + d(L(LRM,     1)) + d(L(LRM, 2)) + d(
## F = 5.1168, p-value = 0.004418
## alternative hypothesis: Possible cointegration
## null values:
##    k    T
##    3 1000
```

```r
# The bounds t-test (under the case 3) rejects the NULL hypothesis (let's say, assuming alpha = 0.01) w
# We also provide the critical value bounds for alpha = 0.01.
tbounds <- bounds_t_test(uecm_3132, case = 3, alpha = 0.01)
tbounds
```

```
##
##  Bounds t-test for no cointegration
##
## data:  d(LRM) ~ L(LRM, 1) + L(LRY, 1) + L(IBO, 1) + L(IDE, 1) + d(L(LRM,     1)) + d(L(LRM, 2)) + d(
## t = -4.5479, Lower-bound I(0) = -3.4430, Upper-bound I(1) = -4.3799,
## p-value = 0.005538
## alternative hypothesis: Possible cointegration
## null values:
##    k    T
##    3 1000
```

```r
# Here is a more clear view of the main results.
tbounds$tab
```

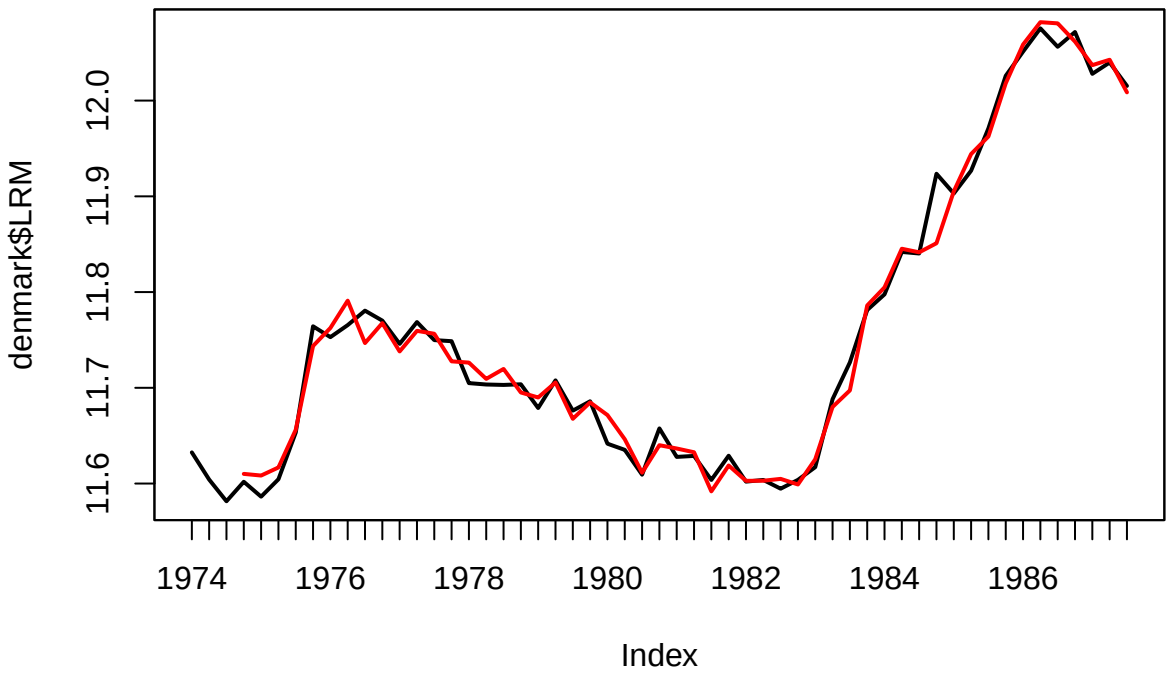
```
##   statistic Lower-bound I(0) Upper-bound I(1) alpha     p.value
## t -4.547939        -3.442978        -4.379886  0.01 0.005538316
```

Forecasting and using an ardl, uecm, or recm model in other functions are easy as they can be converted in regular lm models.

```r
ardl_3132_lm <- to_lm(ardl_3132) # convert ardl into an lm model

# Forecast using the in-sample data
insample_data <- ardl_3132$model
predicted_values <- predict(ardl_3132_lm, newdata = insample_data)

# Convert to ts class for the plot
predicted_values <- ts(predicted_values, start = c(1974,4), frequency=4)
plot(denmark$LRM, lwd=2) #The input dependent variable
lines(predicted_values, col="red", lwd=2) #The predicted values
```


denmark$LRM
11.6
11.7
11.8
11.9
12.0
1974
1976
1978
1980
1982
1984
1986
Index