SOFTWARE SOLUTIONS FOR ARDL MODELS

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Abstract

VAR type models can be used only for stationary time series. Causality analyses through econometric models need that series to have the same integrated order. Usually, when constraining the series to comply these restrictions (e.g. by differentiating), economic interpretation of the outcomes may become difficult.

Recent solution for mitigating these problems is the use of ARDL (autoregressive distributed lag) models. We present implementation in E-Views of these models and we test the impact of exchange rate on consumer price index.

Keywords: *ARDL models, Autoregressive distributed lag model, Cointegration, E-Views, software econometrics, economic policies, CPI.*

1. Introduction

ARDL is the achronim for "Autoregressive-Distributed Lag". Econometric analysis of long-run relations has been the effort of much theoretical and empirical research in different economic subjects. In the case where the variables of interest are trend stationary, the general run-through has been to extract the trend of the series and to model the de-trended series as stationary distributed lag or autoregressive distributed lag (ARDL) models.

The use of ARDL models has a long history, starting with distributed lag models form early '60 (Koyck, 1954), being adapted and constantly improved by economists (Almon, 1965; van Oest, 2004).

In today analyses, the use of computer software ease the simulation of different scenarious and the best solution can be found. The increasing datasets are analysed extensively using econometric software like E-Views.

We explain the use of E-Views for analyzing the relation between exchange rate EUR/RON and the CPI, expecting to find that the exchange rate influence the CPI.

2. Content (Times New Roman, Bold, 10, justify)

A standard ARDL regression model is:

$y_t = \beta_0 + \beta_1 y_{t-1} + ... + \beta_p y + \alpha_0 x_t + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + ... + \alpha_q x_{t-q} + \varepsilon_t$

Autoregression derives from the fact that explanatory variable is explained, partly, by lagged values of itself. The "distributed lag" component is because of the successive "lags" of the explanatory X variable. The standard notation for the above-mentioned model is ARDL(p,q).

The regular approach of this equations exclude the use of OLS (ordinary least squares) because the presence of lagged values suggest that the results would include biased estimators. Also, usually the autocorrelation in the disturbance term (ε_t) would result in inconsistent estimators, thus difficult to use the results.

When this model should be used? Is we suppose that we have a set of time-series variables and we need to represent the relationship between them, not ignoring the unit root and the cointegration.

If the series are I(0) – stationary, we can use basig OLS for estimation. If we know the order of integration for the series, and it is the same for all, but they are not cointegrated, we estimate each series independently. If the series are integrated of the same order and are cointegrated, the theory suggest that we estimate, according to Dave Giles "(i) An OLS regression model using the levels of the data. This will provide the long-run equilibrating relationship between the variables. (ii) An error-correction model (ECM), estimated by OLS. This model will represent the short-run dynamics of the relationship between the variables."

The problem is when just some of the variables may be stationary, some may be I(1) and there is a possibility of cointegration among the I(1) variables.

The stepts to analyse a model like this is presented by Dave Giles in "ARDL Bound test" (http://davegiles.blogspot.ca/2013/03/ardl-models-part-i.html)

We want to observe if the exchange rate EUR/RON has an effect on CPI. From the theory, we expect that the CPI is influenced by the exchange rate. The analyzed data series present exactly the aspects we mentioned before, we do not know the exact cointegration between the 2.

We use the data from www.insse.ro and www.bnr.ro for CPI and average exghange rate. The series have 195 entries (from Jan.1999 to Jan. 2015).

First step is to test if the series are I(2). We use ADF and the results are that there are not I(2):

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Null Hypothesis: D(CURS,2) has a unit root
Exogenous: Constant
Lag Length: 5 (Automatic - based on SIC, maxlag=14)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.744308	0.0000
Test critical values:	1% level	-3.465780	
	5% level	-2.877012	
	10% level	-2.575097	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CURS,3)
Method: Least Squares
Date: 03/22/15 Time: 19:02
Sample (adjusted): 9 193
Included observations: 185 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CURS(-1),2)	-3.087796	0.316882	-9.744308	0.0000
D(CURS(-1),3)	1.571859	0.281034	5.593123	0.0000
D(CURS(-2),3)	1.173686	0.235507	4.983657	0.0000
D(CURS(-3),3)	0.776085	0.182806	4.245405	0.0000
D(CURS(-4),3)	0.507179	0.128429	3.949111	0.0001
D(CURS(-5),3)	0.228636	0.072163	3.168313	0.0018
C	-0.000551	0.004463	-0.123366	0.9020

R-squared	0.721042	Mean dependent var	-0.000260
Adjusted R-squared	0.711639	S.D. dependent var	0.113031
S.E. of regression	0.060697	Akaike info criterion	-2.728752
Sum squared resid	0.655768	Schwarz criterion	-2.606901
Log likelihood	259.4096	Hannan-Quinn criter.	-2.679369
F-statistic	76.68134	Durbin-Watson stat	2.049758
Prob(F-statistic)	0.000000		

Eviews output, author's calculations

Also, the KPSS test indicates that the series are not level 2 stationary:

Null Hypothesis: D(CURS,2) is stationary
Exogenous: Constant
Bandwidth: 37 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		0.109348
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)	
Residual variance (no correction)	0.004747
HAC corrected variance (Bartlett kernel)	0.000210

KPSS Test Equation
Dependent Variable: D(CURS,2)
Method: Least Squares
Date: 03/22/15 Time: 19:04
Sample (adjusted): 3 193
Included observations: 191 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000147	0.004998	-0.029472	0.9765

R-squared	0.000000	Mean dependent var	-0.000147
Adjusted R-squared	0.000000	S.D. dependent var	0.069076
S.E. of regression	0.069076	Akaike info criterion	-2.501997
Sum squared resid	0.906584	Schwarz criterion	-2.484969
Log likelihood	239.9407	Hannan-Quinn criter.	-2.495100
Durbin-Watson stat	2.647966		

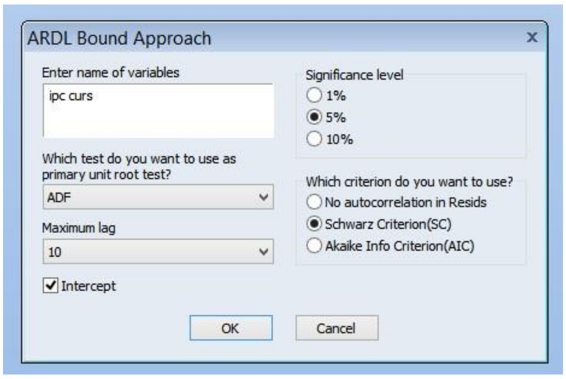
Eviews output, author's calculations

Both tests are passed, no I(2) integration rank for both series and both series are stationary.

Next step is to create a Error Correcting Model (ECM), like:

$$\Delta CPI_t = \beta_0 + \Sigma\beta_i \Delta CPI_{t-i} + \Sigma\gamma_j \Delta CURS_{t-j} + \theta_0 CPI_{t-1} + \theta_1 CURS_{t-1} + e_t$$

We use the ARDLbound add-in for EViews to estimate the ECM:



We select the dependant variable (IPC) and the explanatory variable (CURS), we select ADF for unit root test, we allow 10 maximum lags to be performed, at a 5% level of significance and Schwartz Criterion.

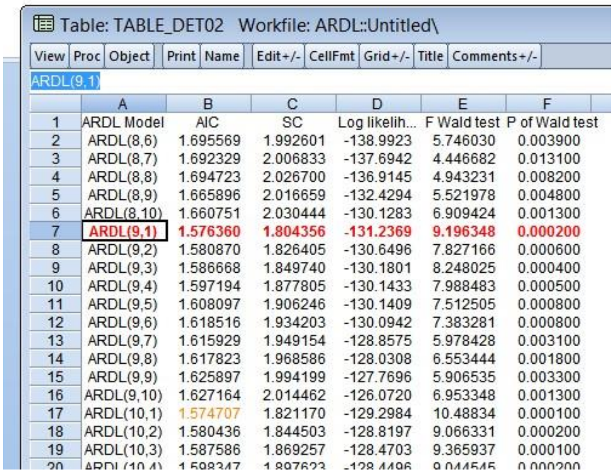


Table: TABLE_DET02 Workfile: ARDL::Untitled\

	A	B	C	D	E	F
1	ARDL Model	AIC	SC	Log likelih...	F Wald test	P of Wald test
2	ARDL(8,6)	1.695569	1.992601	-138.9923	5.746030	0.003900
3	ARDL(8,7)	1.692329	2.006833	-137.6942	4.446682	0.013100
4	ARDL(8,8)	1.694723	2.026700	-136.9145	4.943231	0.008200
5	ARDL(8,9)	1.665896	2.016659	-132.4294	5.521978	0.004800
6	ARDL(8,10)	1.660751	2.030444	-130.1283	6.909424	0.001300
7	ARDL(9,1)	1.576360	1.804356	-131.2369	9.196348	0.000200
8	ARDL(9,2)	1.580870	1.826405	-130.6496	7.827166	0.000600
9	ARDL(9,3)	1.586668	1.849740	-130.1801	8.248025	0.000400
10	ARDL(9,4)	1.597194	1.877805	-130.1433	7.988483	0.000500
11	ARDL(9,5)	1.608097	1.906246	-130.1409	7.512505	0.000800
12	ARDL(9,6)	1.618516	1.934203	-130.0942	7.383281	0.000800
13	ARDL(9,7)	1.615929	1.949154	-128.8575	5.978428	0.003100
14	ARDL(9,8)	1.617823	1.968586	-128.0308	6.553444	0.001800
15	ARDL(9,9)	1.625897	1.994199	-127.7696	5.906535	0.003300
16	ARDL(9,10)	1.627164	2.014462	-126.0720	6.953348	0.001300
17	ARDL(10,1)	1.574707	1.821170	-129.2984	10.48834	0.000100
18	ARDL(10,2)	1.580436	1.844503	-128.8197	9.066331	0.000200
19	ARDL(10,3)	1.587586	1.869257	-128.4703	9.365937	0.000100

The result indicates an ARDL(9,1).

This means that the preffered model should be like:

Dependent Variable: D(IPC)
Method: Least Squares
Date: 03/19/15 Time: 16:39
Sample (adjusted): 11 193
Included observations: 183 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	36.03298	10.32689	3.489239	0.0006
D(IPC(-1))	-0.519534	0.108609	-4.783515	0.0000

D(IPC(-2))	-0.420500	0.113504	-3.704717	0.0003
D(IPC(-3))	-0.228819	0.114481	-1.998756	0.0472
D(IPC(-4))	-0.435719	0.107424	-4.056056	0.0001
D(IPC(-5))	-0.424513	0.100170	-4.237929	0.0000
D(IPC(-6))	-0.215106	0.091502	-2.350836	0.0199
D(IPC(-7))	-0.162366	0.086356	-1.880203	0.0618
D(IPC(-8))	-0.209656	0.075204	-2.787837	0.0059
D(IPC(-9))	-0.204095	0.061556	-3.315575	0.0011
D(CURS(-1))	1.284576	0.648895	1.979636	0.0494
IPC(-1)	-0.349305	0.098460	-3.547698	0.0005
CURS(-1)	-0.242985	0.118885	-2.043858	0.0425

R-squared	0.539363	Mean dependent var	-0.020601
Adjusted R-squared	0.506848	S.D. dependent var	0.732359
S.E. of regression	0.514298	Akaike info criterion	1.576360
Sum squared resid	44.96535	Schwarz criterion	1.804356
Log likelihood	-131.2369	Hannan-Quinn criter.	1.668778
F-statistic	16.58786	Durbin-Watson stat	2.022467
Prob(F-statistic)	0.000000		

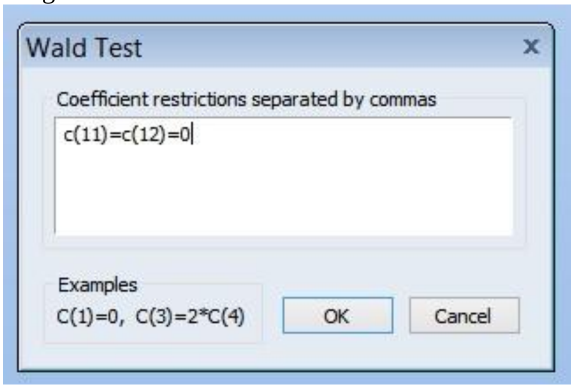
Eviews output, author's calculations

Next step implies to check if the errors are serially independent. We use from the Menu, View, Residual Diagnostics, Serial Correlation Lm Test:

For 1 lag included - probability: 0.43
For 2 lags included - probability: 0.73
For 3 lags included - probability: 0.18
For 4 lags included - probability: 0.25
For 5 lags included - probability: 0.37
For 6 lags included - probability: 0.11
For 7 lags included - probability: 0.17
For 8 lags included - probability: 0.21
For 9 lags included - probability: 0.28
So, there is no serial correlation.

Next, we test the bound itself. The test implies that coefficients for both variables to be not null.

The Wald test can be called: View-Coefficient Diagnostics-Wald Test:



And the output is:

Wald Test:
Equation: EQ02

Test Statistic	Value	df	Probability
F-statistic	7.155299	(2, 170)	0.0010
Chi-square	14.31060	2	0.0008

Null Hypothesis: C(11)=C(12)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(11)	1.284576	0.648895
C(12)	-0.349305	0.098460

Restrictions are linear in coefficients.
Eviews output, author's calculations

The values of D-statistics is 7.155, in the model there are (k+1)=2 variables and we search in the Bound Test tables of critical values, for k=1.

For interpretation, we use Giles suggestions, to use Table CI (iii) on p.300 of Pesaran et al. (2001). The model does not constrain the intercept, and there is no linear trend term included in the ECM.

The lower and upper limits for the F-test statistic at the 10%, 5%, and 1% significance levels are [4.04, 4.78], [4.94, 5.73], and [6.84, 7.84] respectively.

As the value of our F-statistic exceeds the upper bound at the 1% significance level, we can conclude that there is evidence of a long-run relationship between the two time-series (at this level of significance or greater).

In addition, the t-statistic on IPC(-1) is -3.5476. Using the Table CII (iii) on p.303 of Pesaran et al. (2001), we find that the I(0) and I(1) limits for the t-statistic at the 10%, 5%, and 1% significance levels are [-2.57, -2.91], [-2.86, -3.22], and [-3.43, -3.82] respectively. So, with a confidence exceeding 99%, this result reinforces our conclusion that there is a long-run relationship between CPI and exchange rate.

Using these results, we can conclude that the long-run relationship between EUR/RON exchange rate and the Consumer Price Index is 0.24985/0.349305=0.6956. So, on the long run, an increase with 1% in the exchange rate should lead to an increase of aprox. 0.7% in the CPI rate.

3. Conclusions

When analyzing the relationship between time-series variables, the researcher usually has to deal with situations like some of the variables are stationary, some may be I(1) and there is a possibility of cointegration among the I(1) variables. The solution is to use this ARDL approach, to find the bound between the variables and to identify the econometrically correct relationship.

In this particular situation, we found that the relation between exchange rate Eur/Ron and the CPI is: an increase with 1% in the exchange rate should lead to an increase of aprox. 0.7% in the CPI rate.

Further development of this research should include other explanatory variables and an interesting approach should be to test this correlation during electoral moments. If the estimators show a change during the pre-election periods, we may suspect a political intervention on macroeconomic variables.

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