Università Commerciale
Luigi Bocconi

Lab 5: A VECM Analysis of the Sovereign Debt Crisis

(Reminder: this is optional)

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20192– Financial Econometrics

Winter/Spring 2019

The Goal

- Understand whether in normal vs. crisis times it is either the government bond or the credit default swaps (CDS) market that drives the process of price discovery
  - Process of price discovery == process of adjustment of prices to new, unobserved (macro, political, etc.) information
  - Crisis times in this lab: sovereign debt crisis between June 2011 and December 2012
- We do this by studying the time series of two spread series
- ① The government yield spread between the yield to maturity on a (synth) 5-year Italian BTp in USD and the 5-year riskless swap rate
  - It is a proxy of the (term) risk premium on the Italian public debt
  - Premium compensates for default risk at 5 years in excess of riskless
- ② The 5-year maturity CDS spread written on Italian Treasuries
  - It is the cost of protection against default (note, full, partial, or even technical in some definitions) by the Republic of Italy on its debt
- We shall aim at adopting a VECM/Cointegration framework

The Goal

- The CDS spreads are expressed in USD because sovereign CDS tend to be denominated in currencies the hedge currency denomination risk

- The rationale is that by buying CDS protection, an investor «removes» (to a large extent, modulo subtle legal clauses) the default risk from his ptf. positions in 10-year BTp, at a 5-year horizon
- Therefore in the absence of frictions, a ptf composed of a 5-year BTp and a 5-year CDS (both in USD) should yield the 5-year USD swap rate (R_t^f), so that

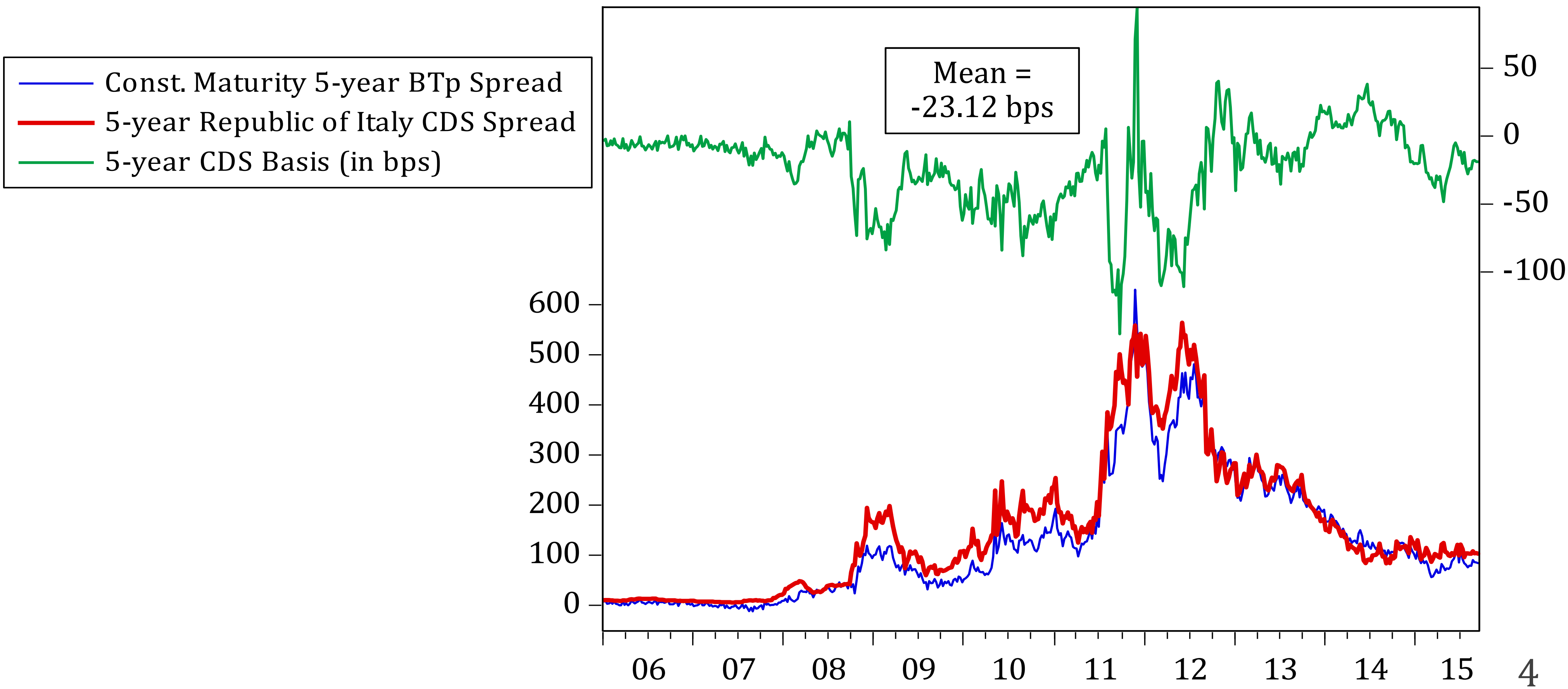
$$\underbrace{Bond\_S_t + R_t^f}_{Total\ Bond\ yield} - CDS_t = R_t^f \Rightarrow \underbrace{Bond\_S_t - CDS_t}_{CDS\ Basis} = 0$$

- The quantity $Bond\_S_t - CDS_t$ is the CDS basis and, at least in the long-run, when the forces of no arbitrage operate, it should $\longrightarrow 0$
  - However, at each point in the time, the basis can be $\gtrless 0$
  - Often we say that under the EMH the basis should go to zero
- We interpret «$\longrightarrow 0$» as meaning that the bond and CDS spreads are I(1), are cointegrated, and the cointegrating vector is [1 -1]

Step 0: The Data

- We shall use a January 2006 – Sept. 2015 weekly sample, for a total of 506 observations
  - The data are expressed in basis points, i.e., 1% = 100
- The basis was volatile and mostly negative during sovereign crisis and the converged back to 0

5-year BTp vs. CDS Spread (in bps)



Step 1: The Order of Integration of the Series

- We start by performing unit root tests: VECM and cointegration make sense only if applied to I(1) series
- The ADF test (in this case BIC selects no lags, so ADF = DF) does not reject the null of a unit root
- Note that while the DF non-standard p-value is 0.416, the standard p-value would be 0.084 but would lead to identical conclusion
- If use AIC in selection of *p* lags in ADF, p = 10 but the ADF p-value remanins 0.379

Null Hypothesis: ITALY_BOND has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.729468	0.4158
Test critical values:	1% level	-3.443072	
	5% level	-2.867044	
	10% level	-2.569763	

*MacKinnon (1996) one-sided p-values.
Augmented Dickey-Fuller Test Equation
Method: Least Squares
Sample (adjusted): 1/13/2006 9/11/2015

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ITALY_BOND(-1)	-0.010964	0.006340	-1.729468	0.0843
C	1.571118	1.147001	1.369761	0.1714

R-squared	0.005911	Mean dependent var	0.152059
Adjusted R-squared	0.003935	S.D. dependent var	18.04646
Sum squared resid	163169.7	Schwarz criterion	8.640516
Log likelihood	-2175.506	Hannan-Quinn criter.	8.630348
F-statistic	2.991058	Durbin-Watson stat	2.162302
Prob(F-statistic)	0.084339		

Step 1: The Order of Integration of the Series

- We reach identical conclusions using either a Phillips-Perron or a KPSS test with number of lags in the standard error of the test statisics selected automatically by Eviews
- This means that in the case of the PP test, we fail to reject the null of a unit root, while...
- In the case of the KPSS test we reject the null of a stationary series
- Therefore the 5-year Italian government spread appears to be I(1)

Null Hypothesis: ITALY_BOND has a unit root
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.693592	0.4339
Test critical values:	1% level	-3.443072	
	5% level	-2.867044	
	10% level	-2.569763	

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

Residual variance (no correction)	323.1083
HAC corrected variance (Bartlett kernel)	307.4505

Null Hypothesis: ITALY_BOND is stationary
Exogenous: Constant
Bandwidth: 17 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.339301
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)	15954.42
HAC corrected variance (Bartlett kernel)	268352.9

Step 1: The Order of Integration of the Series

- The same conclusion applies to CDS spread, which turns out to be I(1)
  - Recall that I(1) means stochastic trend and specifically that both spread series follow a random walk (possibly with drift, although this less than obvious)

Null Hypothesis: ITALY_CDS has a unit root
Exogenous: Constant
Lag Length: 8 (Automatic - based on AIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.053875	0.2638
Test critical values:	1% level	-3.443281	
	5% level	-2.867136	
	10% level	-2.569812	

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

Null Hypothesis: ITALY_CDS has a unit root
Exogenous: Constant
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.665599	0.4482
Test critical values:	1% level	-3.443072	
	5% level	-2.867044	
	10% level	-2.569763	

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

Null Hypothesis: ITALY_CDS is stationary
Exogenous: Constant
Bandwidth: 17 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.191685
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

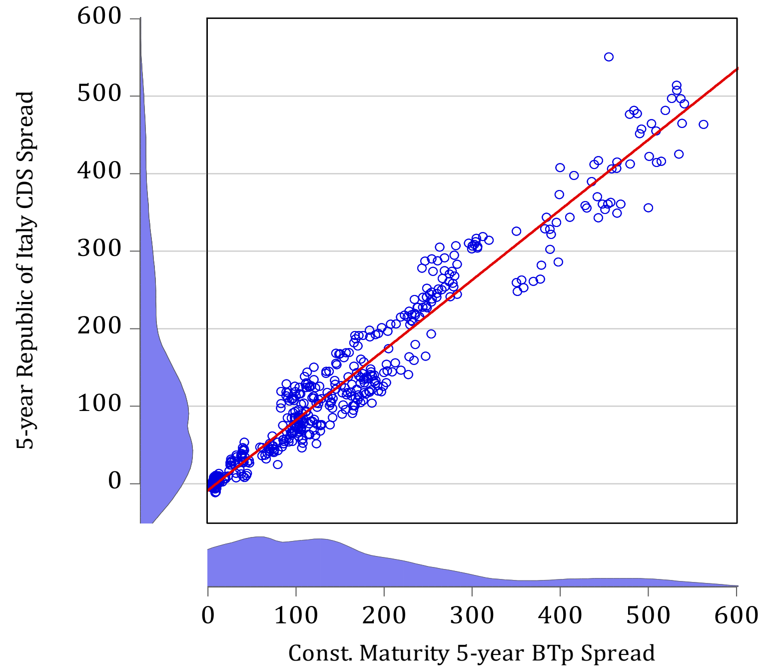
Step 2: Can We Learn From their Levels?

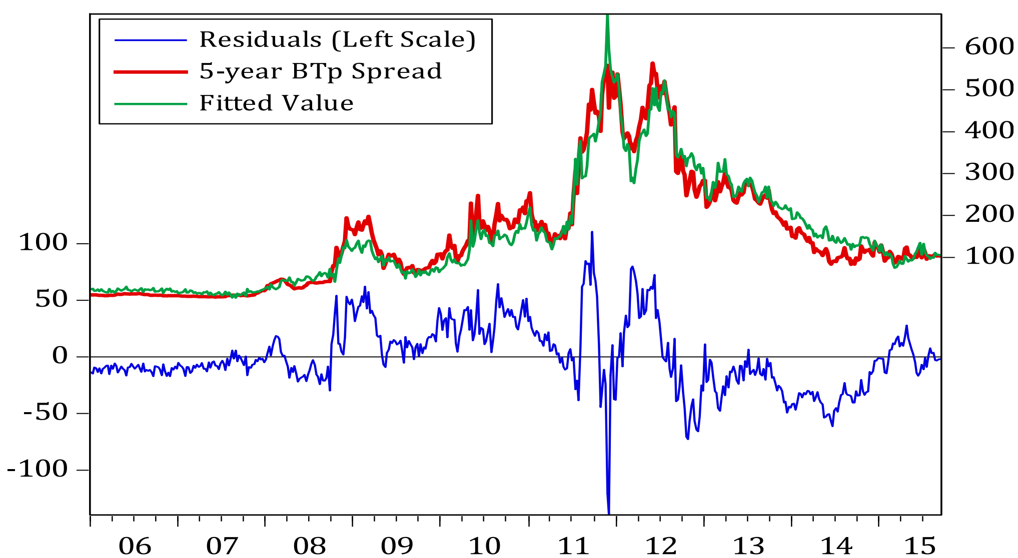
- Now whatever the underlying story may be, it is tempting to regress one series on the other– is the resulting regression an example of the infamous spurious regression
  - Story could be that the bond spread goes up, cost of protection goes up

Dependent Variable: ITALY_CDS
Method: Least Squares
Sample: 1/06/2006 9/11/2015

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	16.36652	1.898657	8.620052	0.0000
ITALY_BOND	1.052214	0.010503	100.1867	0.0000

R-squared	0.952188	Mean dependent var	152.4538
Adjusted R-squared	0.952094	S.D. dependent var	136.3367





- The point is now: are the residuals stationary or not, i.e., can we learn something more than the series' stochastic trends?

Step 2: Can We Learn From their Levels?

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.889	0.889	402.06	0.000
		2	0.796	0.029	725.22	0.000
		3	0.747	0.165	1010.7	0.000
		4	0.716	0.087	1272.9	0.000
		5	0.647	-0.142	1487.6	0.000
		6	0.580	-0.022	1660.4	0.000
		7	0.522	-0.040	1800.7	0.000
		8	0.473	-0.010	1916.4	0.000
		9	0.424	-0.004	2009.4	0.000
		10	0.373	-0.030	2081.3	0.000
		11	0.360	0.166	2148.6	0.000
		12	0.340	-0.024	2208.9	0.000

Null Hypothesis: RESID_SPURIOUS_REG has a unit root
Exogenous: Constant
Lag Length: 10 (Automatic - based on AIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.576132	0.0066
Test critical values:	1% level	-3.443334	
	5% level	-2.867159	
	10% level	-2.569825	

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

- Although it is hard to tell, from the SACF/SPACF the residuals seem to follow a nice AR(1) (or AR(5) with «holes») process
- Indeed ADF (as well as PP and KPSS) tests all lead to reject the null of a unit root in residuals

- When a regression of I(1) on I(1) yields stationary residuals, this is an indication that the series are cointegrated
  - This is a naive way to discover Engle-Granger's univariate cointe-gration tests approach
  - In fact, the regression above is not only valid, but the OLS estimators of the coefficients are in fact superconsistent (they converge at rate T)

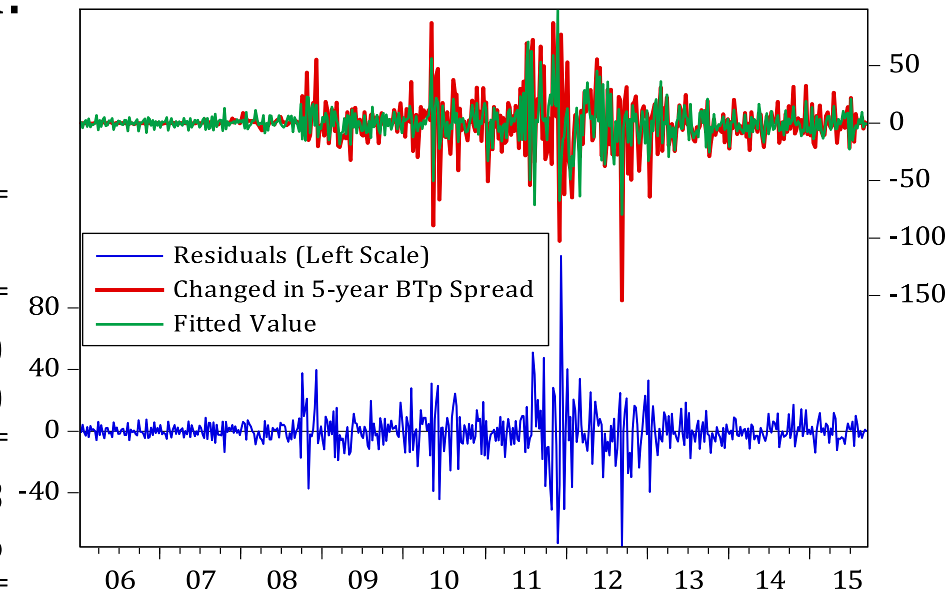
Step 2: Can We Learn From their Levels?

- The risk that we are running, if we failed to test for cointegration, is to differentiate the series and estimate a regression of changes in the CDS spread on the Bond spread:

Dependent Variable: D(ITALY_CDS)
Method: Least Squares
Sample (adjusted): 1/13/2006 9/11/2015

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.054649	0.604277	0.090437	0.9280
D(ITALY_BOND)	0.847031	0.033517	25.27204	0.0000

R-squared	0.559420	Mean dependent var	0.183448
Adjusted R-squared	0.558544	S.D. dependent var	20.43726



  - The slope coefficient is different and the relationship (as measured by the R-square) much less strong vs. when the levels are regressed
- This is a general principle, when cointegrated I(1) series are differenced before using them, information is lost
- Is a univariate, naive, regression-based approach the most effective one? Stay tuned, but a VECM will also allow us to recover information on the speed of adjustment

Step 3: Formal, Univariate Cointegration Tests

- Independently of which variable is placed on the LHS and of whether any deterministi trends are considered, the null of no cointegration is always rejected by Engle-Granger tests

Series: ITALY_CDS ITALY_BOND
Sample: 1/06/2006 9/11/2015
Null hypothesis: Series are not cointegrated
Deterministic trend component: C @TREND @TREND^2
Lags specification based on Schwarz criterion (maxlag=17)

Dependent	z-statistic	Prob.*
ITALY_CDS	-54.24505	0.0008
ITALY_BOND	-66.34223	0.0001

*MacKinnon (1996) p-values.

Intermediate Results:

	ITALY_CDS	ITALY_BOND
Rho - 1	-0.116567	-0.131371
Rho S.E.	0.024503	0.022211
Residual variance	172.6326	158.2518
Long-run residual v...	148.9412	158.2518
Number of lags	4	0.000000
Number of observat...	501	505.0000
Number of stochast...	2	2.000000

**Number of stochastic trends in asymptotic distribution

Series: ITALY_CDS ITALY_BOND
Sample: 1/06/2006 9/11/2015
Null hypothesis: Series are not cointegrated
Lags specification based on Schwarz criterion (maxlag=17)

Dependent	z-statistic	Prob.*
ITALY_CDS	-51.31190	0.0000
ITALY_BOND	-51.31895	0.0000

*MacKinnon (1996) p-values.

Intermediate Results:

	ITALY_CDS	ITALY_BOND
Rho - 1	-0.101608	-0.101622
Rho S.E.	0.019571	0.019568
Residual variance	197.2085	154.1888
Long-run residual variance	197.2085	154.1888
Number of lags	0	0.000000
Number of observations	505	505.0000
Number of stochastic trends**	2	2.000000

**Number of stochastic trends in asymptotic distribution

Step 3: Formal, Multivariate Cointegration Tests

- Yet, if the goal is to build a VECM, it is always best (also with 2 series) to apply **Johansen's method**
  - In Eviews, there are a number of options related to Johansen's test
  - The beauty is that we can test across these choices
  - The evidence tilts in favor of cointegration, when the ECM is not trending over time (as in the lectures)
  - Netting out for deterministic trends does not matter
  - BIC leaves some doubts
  - Also in the light of the Engle-Granger test,

Sample: 1/06/2006 9/11/2015
Included observations: 493
Series: ITALY_CDS ITALY_BOND
Lags interval: 1 to 12

Assumed deterministic component

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	0	1	0	1
Max-Eig	1	0	1	0	0

*Critical values based on MacKinnon-Haug-Michelis (1999)

Information Criteria by Rank and Model

Data Trend:	None	None	Linear	Linear	Quadratic
Rank or No. of CEs	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
	Log Likelihood by Rank (rows) and Model (columns)				
0	-4043.644	-4043.644	-4043.618	-4043.618	-4043.299
1	-4036.817	-4036.054	-4036.030	-4035.334	-4035.040
2	-4036.263	-4034.322	-4034.322	-4033.573	-4033.573
	Akaike Information Criteria by Rank (rows) and Model (columns)				
0	16.59896	16.59896	16.60697	16.60697	16.61379
1	16.58749*	16.58846	16.59241	16.59365	16.59651
2	16.60147	16.60171	16.60171	16.60679	16.60679
	Schwarz Criteria by Rank (rows) and Model (columns)				
0	17.00794*	17.00794*	17.03298	17.03298	17.05685
1	17.03055	17.04003	17.05251	17.06227	17.07365
2	17.07861	17.09589	17.09589	17.11801	17.11801

Step 4: Estimate a VECM(4)

Date: 05/01/19 Time: 22:17
Sample (adjusted): 2/10/2006 9/11/2015
Included observations: 501 after adjustments
Trend assumption: No deterministic trend
Series: ITALY_BOND ITALY_CDS
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.047859	25.57305	12.32090	0.0002
At most 1	0.002000	1.003109	4.129906	0.3674

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.047859	24.56994	11.22480	0.0002
At most 1	0.002000	1.003109	4.129906	0.3674

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

- Warning: Eviews doesn't stan-dardize adjustment coefficients, but both series adjusts to devia-tions from long-run equilibrium

Vector Error Correction Estimates
Sample (adjusted): 4/07/2006 9/11/2015
Included observations: 493 after adjustments

Cointegrating Eq:	CointEq1
ITALY_BOND(-1)	1.000000
ITALY_CDS(-1)	-0.927073
	(0.04129)
	[-22.4533]
C	12.18539

Looks promising in light of [1 -1]

Error Correction:	D(ITALY_BOND)	D(ITALY_CDS)
CointEq1	-0.105263	-0.014670
	(0.03848)	(0.04199)
D(ITALY_BOND(-1))	-0.021280	-0.008952
	(0.07375)	(0.08047)
...	...	...
D(ITALY_CDS(-12))	0.072997	-0.001184
	(0.06456)	(0.07045)
C	0.188028	0.197462
	(0.79815)	(0.87090)
R-squared	0.106752	0.171813

Determinant resid covariance (dof adj.)	49313.38
Log likelihood	-4036.030
Akaike information criterion	16.59241
Schwarz criterion	17.05251
Number of coefficients	54

Step 5: Test Whether the EMH Holds

- Now we **test the (cointegrating vector) restriction** such that CDS base has a long-term mean of zero, which we identify with market efficiency and/or arbitrage opps
- Because the null of $\boldsymbol{\kappa} = [1 \;\; -1]'$ cannot be rejected, then we have evidence that in the long run,

$$Bond\_S_t \;\; - CDS_t \longrightarrow 0 \quad \text{or}$$

$$CDS\ Basis \longrightarrow 0$$

- This establishes that the market for Italian sovereign bonds was efficient over our sample period
- However, under the restriction, while 5-year BTp rates adjusts to equilibrium deviations, the CDS spreads stop doing that

Vector Error Correction Estimates
Sample (adjusted): 4/07/2006 9/11/2015
Included observations: 493 after adjustments

Cointegration Restrictions:
B(1,1)=1, B(1,2)=-1
Convergence achieved after 1 iterations.
Restrictions identify all cointegrating vectors
LR test for binding restrictions (rank = 1):

Chi-square(1)	1.917117
Probability	0.166175

Null hypothesis of [1 -1] cannot be rejected!

Cointegrating Eq:	CointEq1
ITALY_BOND(-1)	1.000000
ITALY_CDS(-1)	-1.000000
C	23.56417

-1xMean of the basis

Error Correction:	D(ITALY_BOND)	D(ITALY_CDS)
CointEq1	-0.067294	0.014618
	(0.03375)	(0.03669)
R-squared	0.100101	0.171878

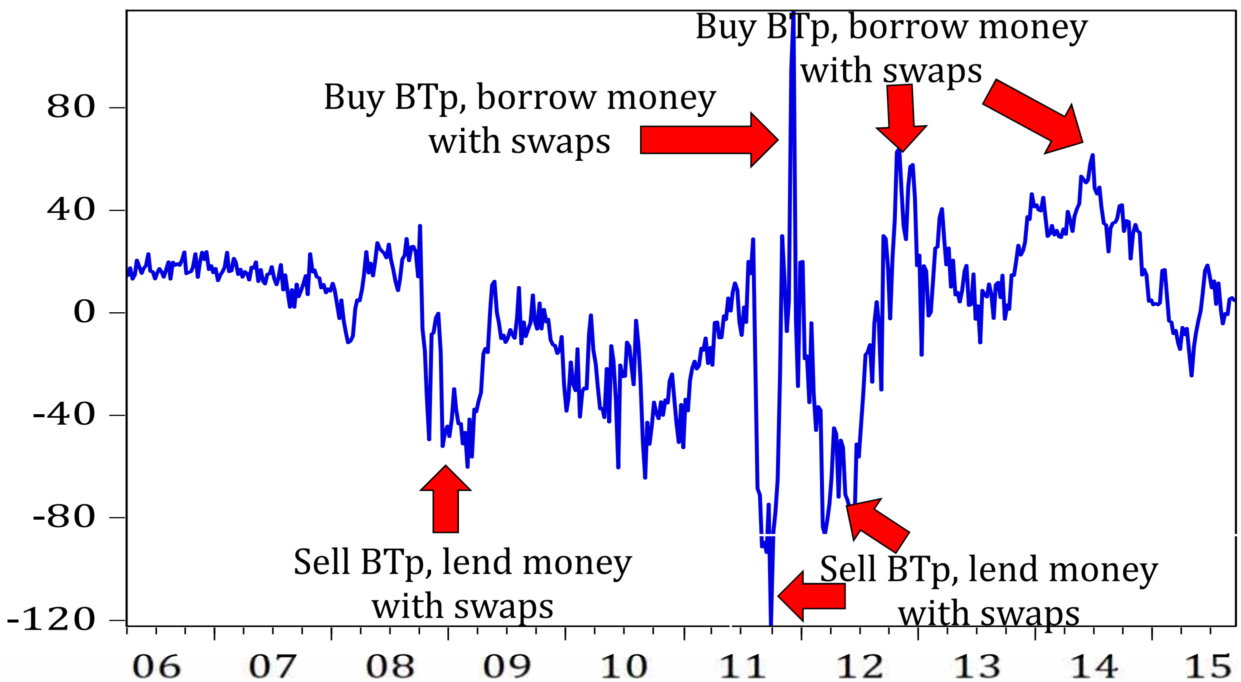
These are standard errors

Determinant resid covariance (dof adj.)	49505.52
Determinant resid covariance	44421.53
Log likelihood	-4036.988
Akaike information criterion	16.59630
Schwarz criterion	17.05640
Number of coefficients	54

Step 6: Estimate Any Trading Signals

- In fact, the joint restrictions of $\boldsymbol{\kappa} = [1 \;\; -1]'$ and of no adjustment of CDS spreads to disequilibrium cannot be rejected (p-value is 0.353)
- Under these restrictions, what are the estimated deviations of the base from the long-run equilibrium?

Deviations from Restricted Long-Run Equilibrium (i.e., the Base)



Because -0.067 is relatively large, such strategies generally take only 18-24 months to yield profits

- Yet, this plot has already been seen before: the base emerges as the correct way to forecast CDS spreads from bond spreads and vice-versa, and as such the very base is an expression of disequilibrium

Step 7: Stability Analysis

- What happened during the 2011-2013 sovereign crisis?

Series: ITALY_BOND ITALY_CDS
Sample: 12/31/2010 12/27/2013
Included observations: 157
Null hypothesis: Series are not cointegrated
Deterministic component: C @TREND @TREND^2
Lags specification based on Schwarz criterion (maxlag=...

Dependent	z-statistic	Prob.*
ITALY_BOND	-28.05499	0.0931
ITALY_CDS	-27.67224	0.0994

*MacKinnon (1996) p-values.

Sample: 12/31/2010 12/27/2013
Included observations: 157
Series: ITALY_BOND ITALY_CDS
Lags interval: 1 to 12

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	0	0	0
Max-Eig	0	0	0	0	0

*Critical values based on MacKinnon-Haug-Michelis (1999)

- As one may have predicted, during the sovereign debt crisis there is no cointegration between bond and CDS spreads $\Rightarrow$ the CDS base becomes non-stationary and as such it temporarily diverged
- Equivalently, the CDS base stops being an indicator for a virtually riskless arbitrage opportunities
- The prevalent interpretation is that the vector of spreads contain regimes and that in one of such regimes, markets stop self-correcting and the EMH fails (see Guidolin, Pedio, and Tosi, 2019)

Università Commerciale
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Lab 5: Debriefing

Prof. Massimo Guidolin

20192– Financial Econometrics

Winter/Spring 2019

Reminder: the Goal

- Understand whether in normal vs. crisis times it is either the government bond or the credit default swaps (CDS) market that drives the process of price discovery
- We replicate for Spain the analysis previously developed for Italy
- As in the Italian case, we consider two series:

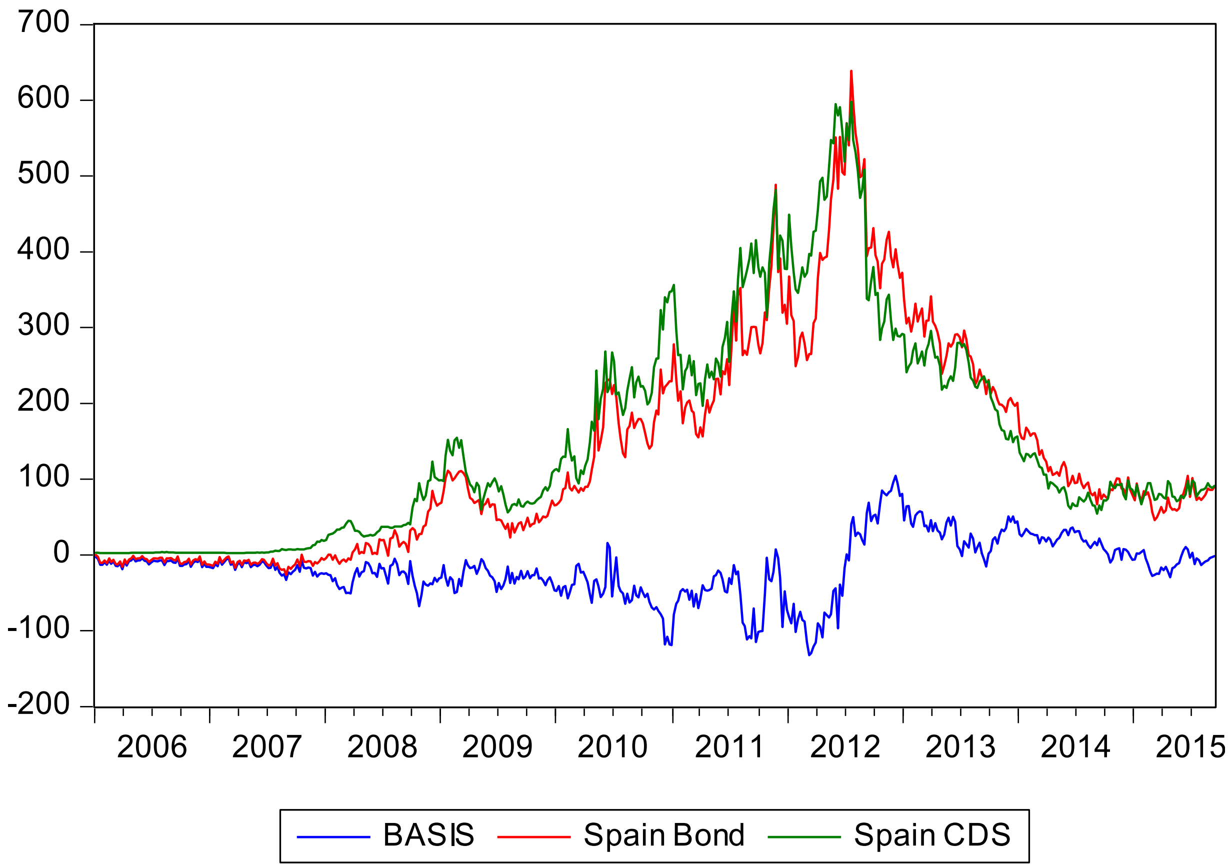
  ① The Spanish constant maturity 5-year government yield spread

  ② The 5-year spread on CDS giving protection against the default by the Republic of Spain
- In absence of frictions, a portfolio composed by a Tresury and a CDS written on it should yield the swap rate (R_t^f)
- Thus, the CDS basis should $\longrightarrow 0$ at least in the long-run, when arbitrage forces come into play
- We interpret «$\longrightarrow 0$» as meaning that the bond and CDS spreads are I(1), are cointegrated, and the cointegrating vector is [1 -1]
- Our goal is estimating a VECM and assess whether the above holds

The Data

- Like in the Italian case, we consider weekly data from Jan 2006 to Sep 2015, for a total of 506 observations
- The basis was volatile and mostly negative during the sovereign crisis and then converged back to 0

	SPAIN_BOND	SPAIN_CDS	BASIS
Mean	135.30	152.04	-16.74
Median	87.77	94.97	-15.71
Maximum	639.20	598.41	104.39
Minimum	-26.42	2.41	-132.18
Std. Dev.	141.46	143.30	38.79
Skewness	1.01	1.01	-0.05
Kurtosis	3.39	3.28	3.79
Jarque-Bera	88.98	87.84	13.40
Probability	0.00	0.00	0.00
Sum	68461.26	76931.14	-8469.88
Sum Sq. Dev.	10105153.85	10370154.38	759826.99
Observations	506.00	506.00	506.00



The Order of Integration of the Series

- We start by performing unit root tests on the Spanish government bond spread
- Differently from Italy, the ADF test (based on BIC) selects one lag for the first difference
- Given a p-value of 0.553, we cannot reject the null of a unit root
- Notice that the same conclusion would be reached using the standard p-value of 0.145, but this is special to this example

Null Hypothesis: SPAIN_BOND has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.461593	0.5525
Test critical values:	1% level	-3.443098	
	5% level	-2.867055	
	10% level	-2.569769	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SPAIN_BOND)
Method: Least Squares
Date: 05/02/19 Time: 10:36
Sample (adjusted): 1/20/2006 9/11/2015
Included observations: 504 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SPAIN_BOND(-1)	-0.009249	0.006328	-1.461593	0.1445
D(SPAIN_BOND(-1))	-0.220140	0.043544	-5.055568	0.0000
C	1.474840	1.238397	1.190927	0.2342

R-squared	0.054393	Mean dependent var	0.182579
Adjusted R-squared	0.050618	S.D. dependent var	20.57671
S.E. of regression	20.04917	Akaike info criterion	8.840188
Sum squared resid	201386.7	Schwarz criterion	8.865322
Log likelihood	-2224.727	Hannan-Quinn criter.	8.850047
F-statistic	14.40919	Durbin-Watson stat	1.971762
Prob(F-statistic)	0.000001		

The Order of Integration of the Series

- We reach identical conclusions using either a Phillips-Perron or a KPSS test with number of lags in the standard error of the test statistic selected automatically by Eviews
- This means that in the case of the PP test, we fail to reject the null of a unit root, while...
- ... in the case of the KPSS test we reject the null of a stationary series
- Therefore the Spanish government bond spread appears to be I(1)

Null Hypothesis: SPAIN_BOND has a unit root
Exogenous: Constant
Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.578183	0.4930
Test critical values:	1% level	-3.443072	
	5% level	-2.867044	
	10% level	-2.569763	

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

Residual variance (no correction)	419.1568
HAC corrected variance (Bartlett kernel)	323.0240

Null Hypothesis: SPAIN_BOND is stationary
Exogenous: Constant
Bandwidth: 17 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.344261
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)	19970.66
HAC corrected variance (Bartlett kernel)	340633.1

The Order of Integration of the Series

- The same conclusion applies to CDS spread, which turns out to be I(1)

Null Hypothesis: SPAIN_CDS has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.467732	0.5494
Test critical values:	1% level	-3.443098	
	5% level	-2.867055	
	10% level	-2.569769	

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

Null Hypothesis: SPAIN_CDS has a unit root
Exogenous: Constant
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.501881	0.5321
Test critical values:	1% level	-3.443072	
	5% level	-2.867044	
	10% level	-2.569763	

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

Null Hypothesis: SPAIN_CDS is stationary
Exogenous: Constant
Bandwidth: 17 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.134067
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Formal, Univariate Cointegration Tests

- Compared to the Italian case, the p-values are significantly higher and the evidence of cointegration is weaker when a quadratic deterministic trend is included

Series: SPAIN_BOND SPAIN_CDS
Sample: 1/06/2006 9/11/2015
Included observations: 506
Null hypothesis: Series are not cointegrated
Cointegrating equation deterministics: C @TREND @TREND^2
Automatic lags specification based on Schwarz criterion (maxlag=17)

Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
SPAIN_BOND	-3.612377	0.1801	-26.71996	0.1346
SPAIN_CDS	-3.126421	0.3961	-20.48686	0.3229

*MacKinnon (1996) p-values.

Intermediate Results:

	SPAIN_BOND	SPAIN_CDS
Rho - 1	-0.061184	-0.053159
Rho S.E.	0.016937	0.017003
Residual variance	161.2660	155.8297
Long-run residual variance	121.0804	91.47663
Number of lags	1	2
Number of observations	504	503
Number of stochastic trends**	2	2

**Number of stochastic trends in asymptotic distribution

- Nonetheless, both p-values significantly decrease when we include as deterministic components either a constant only or a constant plus a linear deterministic trend
- Thus, we turn to Johansen's test for a more detailed analysis

Formal, Multivariate Cointegration Tests

- The output of the Johansen's test is reassuring regarding the presence of at least one cointegrating relationship regardless of the ECM specification
- Moreover, notice that the AIC and the BIC are almost always consistent in concluding that there exist one cointegrating relation
- Thus, there is sufficient evidence to conclude that it is appropriate to estimate a VECM

Sample: 1/06/2006 9/11/2015
Included observations: 501
Series: SPAIN_BOND SPAIN_CDS
Lags interval: 1 to 4

Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	1	2	1	2
Max-Eig	1	1	2	1	2

*Critical values based on MacKinnon-Haug-Michelis (1999)

Information Criteria by Rank and Model

Data Trend:	None	None	Linear	Linear	Quadratic
Rank or No. of CEs	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
	Log Likelihood by Rank (rows) and Model (columns)				
0	-4160.009	-4160.009	-4159.972	-4159.972	-4159.432
1	-4145.755	-4145.113	-4145.106	-4144.285	-4144.051
2	-4144.642	-4142.522	-4142.522	-4141.550	-4141.550
	Akaike Information Criteria by Rank (rows) and Model (columns)				
0	16.67069	16.67069	16.67853	16.67853	16.68436
1	16.62976*	16.63119	16.63515	16.63587	16.63893
2	16.64129	16.64080	16.64080	16.64491	16.64491
	Schwarz Criteria by Rank (rows) and Model (columns)				
0	16.80536	16.80536	16.83002	16.83002	16.85269
1	16.79809*	16.80793	16.82031	16.82944	16.84092
2	16.84328	16.85963	16.85963	16.88057	16.88057

Estimate a VECM(12)

Vector Error Correction Estimates
Date: 05/02/19 Time: 15:42
Sample (adjusted): 4/07/2006 9/11/2015
Included observations: 493 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	
SPAIN_BOND(-1)	1.000000	
SPAIN_CDS(-1)	-0.977320 (0.04641) [-21.0593]	
C	13.39095	
Error Correction:	**D(SPAIN_BOND)**	**D(SPAIN_CDS)**
CointEq1	-0.137277 (0.03028) [-4.53290]	-0.091982 (0.02979) [-3.08720]
D(SPAIN_BOND(-1))	-0.162063 (0.07661) [-2.11557]	0.003277 (0.07537) [0.04348]
...	...	...
D(SPAIN_CDS(-12))	0.052791 (0.07601) [0.69450]	0.099579 (0.07478) [1.33157]
C	0.337964 (0.88212) [0.38313]	0.276047 (0.86785) [0.31808]

R-squared	0.159357	0.152685
Adj. R-squared	0.114354	0.107326
Sum sq. resids	178814.1	173073.1
S.E. equation	19.56782	19.25114
F-statistic	3.541079	3.366111
Log likelihood	-2152.307	-2144.263
Akaike AIC	8.836947	8.804314
Schwarz SC	9.058474	9.025842
Mean dependent	0.214361	0.179392
S.D. dependent	20.79278	20.37557

Determinant resid covariance (dof adj.)	53749.92
Determinant resid covariance	48230.05
Log likelihood	-4057.265
Akaike information criterion	16.67856
Schwarz criterion	17.13866
Number of coefficients	54

- Notice that the estimated cointegrating equation is very close to the desired [1 -1]
- Moreover, the estimate is quite robust to the number of lags included in the VECM specification

Step 5: Test Whether the EMH Holds

- Like the Italian case, we test the (cointegrating vector) restriction such that CDS base has a long-term mean of zero
- Because the null of $\boldsymbol{\kappa} = [1 \ \ -1]'$ cannot be rejected, in the long run

$$Bond\_S_t \ - CDS_t \longrightarrow 0 \quad \text{or}$$

$$CDS\ Basis \longrightarrow 0$$

- This establishes that the market for Spanish sovereign bonds was efficient over our sample period
- Moreover, under the restriction, both coefficients in the cointegrating equation seem to be highly significant, although the spreads on Bonos seem to be more sensitive to disequilibrium

Vector Error Correction Estimates
Date: 05/02/19 Time: 16:10
Sample (adjusted): 4/07/2006 9/11/2015
Included observations: 493 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegration Restrictions:
B(1,1)=1,B(1,2)=-1
Convergence achieved after 1 iterations.
Restrictions identify all cointegrating vectors

LR test for binding restrictions (rank = 1):	
Chi-square(1)	0.188263
Probability	0.664366

Null hypothesis of [1 -1] cannot be rejected!

Cointegrating Eq:	CointEq1
SPAIN_BOND(-1)	1.000000
SPAIN_CDS(-1)	-1.000000
C	16.92444

Error Correction:	D(SPAIN_BOND)	D(SPAIN_CDS)
CointEq1	-0.133283	-0.085260
	(0.02983)	(0.02937)
	[-4.46775]	[-2.90340]