Measuring sovereign contagion in Europe

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Debt Restructuring and Contagion

- How much contagion to countries in the European Monetary Union could be expected as a result of a possible credit event in Greece or Italy or Spain?
- How much France and Germany are going to be affected?
- How about countries outside the European Union?
- Through which channel is the shock going to be transmitted?

Clearly these are important questions for economists, policy makers, and practitioners. The empirical challenges to address these questions are extraordinary!

Contagion

- First challenge: What is exactly contagion?
- Is it the ‘normal’ or ‘usual’ propagation of shocks, or is it the transmission that takes place under unusual circumstances?
- Contagion:
  - the comovement that takes place under extreme conditions – or tail events.
  - how different the propagation of shocks is after normal and rare events.

Contagion

- Second challenge: the empirical one.
- If the correlation between two variables is different in normal and crisis times, how can we be sure that this is the outcome of a shift in the propagation and not the result of the fact that correlations are not neutral to shifts in volatility?
- Crisis times are usually associated with higher volatility and simple correlations are unable to deal with this problem.

Our contributions: measuring spillovers in (European) cds's and bonds

- We investigate contagion in the cds's of 8 EU countries: seven countries within the Euro area, PT, GR, IE, IT, ES, DE, FR, and UK (in the slides results only for FR and DE).

- **Objective**: Measure the risk of contagion of a Debt Restructuring!

- **First challenge**, definitions of contagion:
    - comovements that take place under tail events;
    - differences in the propagation of shocks after normal and rare events.

- We follow the second approach and focus on European sovereign debt through CDS and bond spreads.

Our contributions: measuring spillovers in (European) cds's and bonds

- **Second challenge**, problem of measuring contagion in cds's:
  - Correlation is not a good measure.
  - Contagion as a non-linear event.
  - Adjustments in the literature need strong assumptions about the source of shock.
- Parametric methods:
  - Focus on a reduced-form approach
  - Non-linear regressions.
  - Frequentist quantile regression.
  - Bayesian quantile regression with heteroscedasticity.

CDS results

- No change in the intensity of the transmission of shocks among European countries during the onset of the current fiscal crisis.

- Sovereign risk contagion is largely a linear phenomenon:
    - linearity cannot be rejected;
    - non-linear regressions give statistically significant outcomes but they are economically irrelevant;
    - quantile estimates are similar among different quantiles.

- Thus, risk spillover among countries is not affected by the size of the shock (see quantile estimates).

- This does not mean that the situation might not change, but the common shift in CDS spreads that we have observed in the data is **the outcome of interdependence that has been present all the time**.

Bond results

- Extend the analysis using bond returns over the sample 2003-2011.
- Evidence of breaks during the Great financial crisis:
    - Change in the intensity of the propagation of shocks in the pre crisis period (2003-2006) and the post Lehman one (2008-2011).
    - The coefficients actually come down, not up!
    - Were different country bonds perfect substitutes in the pre crisis period?

Data

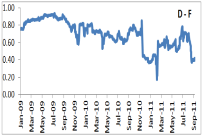
Daily cds's over the sample 10.11.2008 - 20.09.2011.

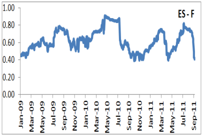
	Mean	Std	Min	Max	Med(Abs)
France	0.15	3.12	-17.66	22.19	1.00
Germany	0.04	2.28	-13.89	19.02	0.63
Greece	6.53	64.70	-462.83	764.06	6.36
Ireland	0.96	16.93	-137.21	101.18	5.00
Italy	0.46	9.35	-79.98	63.91	2.98
Portugal	1.30	20.76	-199.91	174.71	4.00
Spain	0.37	10.14	-75.24	48.80	3.50
U.K.	0.03	3.25	-18.89	18.00	1.01

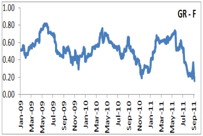
Correlations

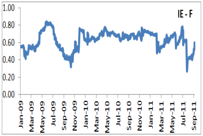
	FR	DE	GR	IE	IT	PO	SP
DE	0.57						
GR	0.28	0.19					
IE	0.50	0.38	0.40				
IT	0.64	0.45	0.39	0.60			
PO	0.50	0.37	0.49	0.74	0.70		
SP	0.61	0.46	0.36	0.63	0.86	0.73	
UK	0.54	0.52	0.23	0.45	0.57	0.40	0.52

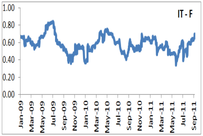
Non-parametric inference: 60-days rolling correlations, FR

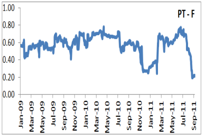


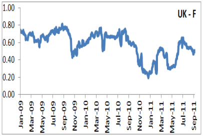






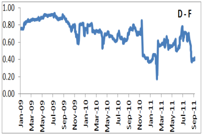


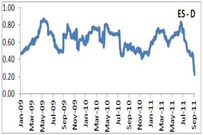


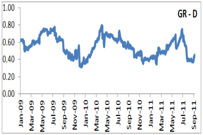


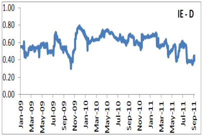
Correlation with IT increases after July 2011. In general, correlations with Greece and Ireland show larger movements.

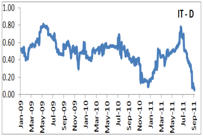
Non-parametric inference: 60-days rolling correlations, DE

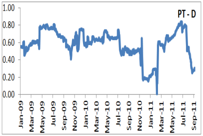


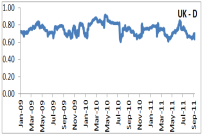










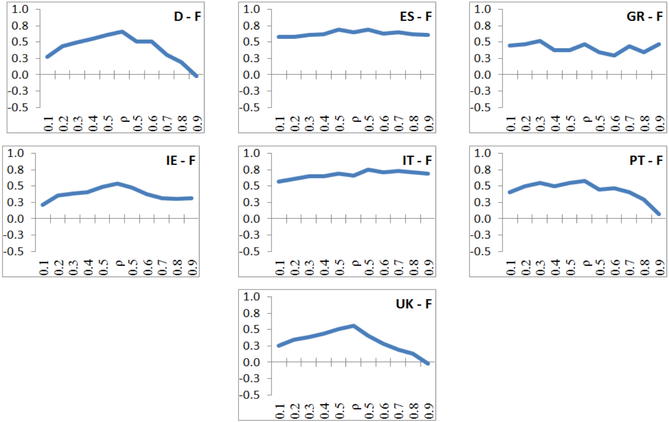


Non-parametric inference: exceedence correlation

Given a quantile level q, the exceedence correlations (Longin and Solnik (2001)) are computed as follow:

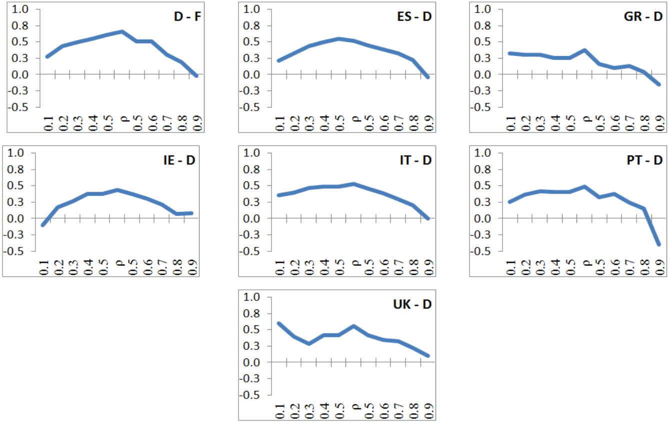
$$\begin{aligned} \rho^- &= Corr\left[\Delta CDS_{i,t}, \Delta CDS_{j,t} | F_i\left(\Delta CDS_{i,t}\right) < q, F_j\left(\Delta CDS_{j,t}\right) < q\right], \\ \rho^+ &= Corr\left[\Delta CDS_{i,t}, \Delta CDS_{j,t} | F_i\left(\Delta CDS_{i,t}\right) > 1-q, F_j\left(\Delta CDS_{j,t}\right) > 1-q\right]. \end{aligned}$$

Non-parametric inference: exceedence correlation, FR

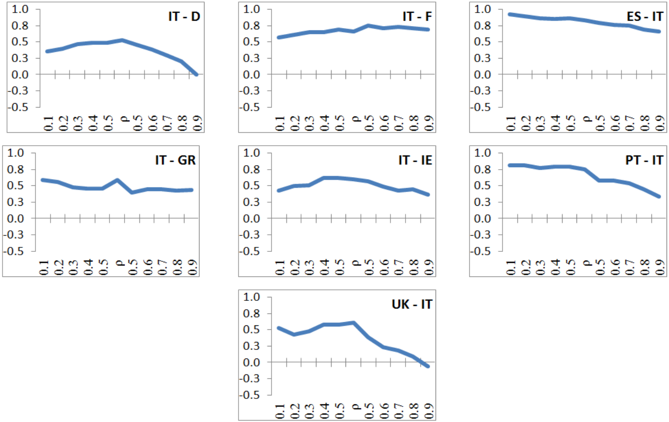


Exceedence correlation ρ^+ decreases as q decreases; but the evidence is somewhat opposite for large negative movements in the CDS changes. Non-linearity?

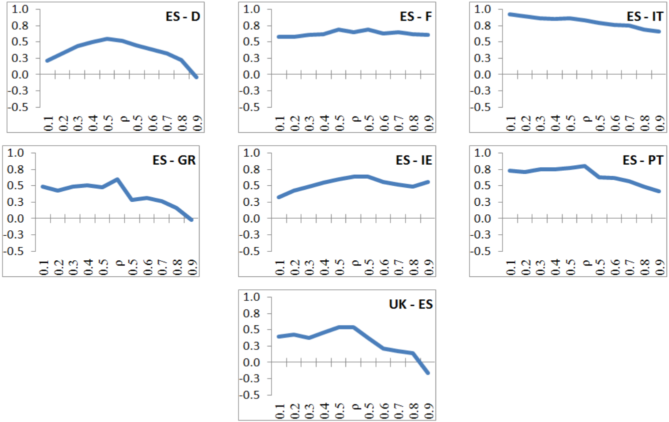
Non-parametric inference: exceedence correlation, DE



Non-parametric inference: exceedence correlation, IT



Non-parametric inference: exceedence correlation, SPAIN



Parametric inference: linear model

- The Delta-CDS volatility might differ during market turbulence compared to the volatility during tranquil market periods.
- The dependence between the changes in the CDS indices of any two countries could be estimated with a simple linear model:

$$\begin{aligned}
\Delta CDS_{i,t} &= \beta_0 + \beta_1 \Delta CDS_{j,t} + \gamma' X_{t-1} + \varepsilon_t \\
\varepsilon_t | I^{t-1} &\sim D\left(0, \sigma_t^2\right) \\
\sigma_t^2 &= \theta_0 + \theta_1 \varepsilon_{t-1}^2 + \theta_2 \sigma_{t-1}^2
\end{aligned}$$

where i and j are two country identifiers

Parametric inference: linear model

- We include the following covariates in X_{t-1}: the change in the Euribor rate; the change in a Liquidity Risk proxy (Euribor minus EONIA);, and the change in a Risk Appetite index (VSTOXX minus the GARCH(1,1) volatility of the VSTOXX.
- However, such model assumes linearity and this might be problematic when talking about contagion.

Parametric inference: non-linear models

We extend the previous model such as:

$$\Delta CDS_{i,t} = \beta_0 + \beta_1 \Delta CDS_{j,t} + \gamma' X_{t-1} + \sum_{l=2}^{p} \phi_l \left(\Delta CDS_{j,t}\right)^l + \varepsilon_t$$

$$\varepsilon_t | I^{t-1} \sim D\left(0, \sigma_t^2\right)$$

$$\sigma_t^2 = \theta_0 + \theta_1 \varepsilon_{t-1}^2 + \theta_2 \sigma_{t-1}^2$$

where σ_t^2 follows a GARCH(1,1) process. The linearity is associated with the null hypothesis $H_0 : \phi_l = 0 \forall l = 2, \ldots p$. We evaluate the null hypothesis using a Likelihood Ratio test (similar results when using a Ramsey (1969) test, $(\Delta CDS_{j,t})^l$ replaced by $(\Delta CDS_{i,t})^l$.

Parametric inference: non-linear models

i	j	P-value	X	X^2	X^3
FRANCE	GERMANY	0.000	**0.898**	0.000	0.000
FRANCE	GREECE	0.000	**0.036**	**0.000**	**0.000**
FRANCE	IRELAND	0.015	**0.102**	0.000	**0.000**
FRANCE	ITALY	0.008	**0.226**	**0.001**	0.000
FRANCE	PORTUGAL	0.000	**0.083**	0.000	**0.000**
FRANCE	SPAIN	0.005	**0.201**	**0.001**	**0.000**
FRANCE	UK	0.654	**0.358**	0.000	0.000

The coefficients are statistically significant in many cases, but they are extremely small.

Parametric inference: non-linear models

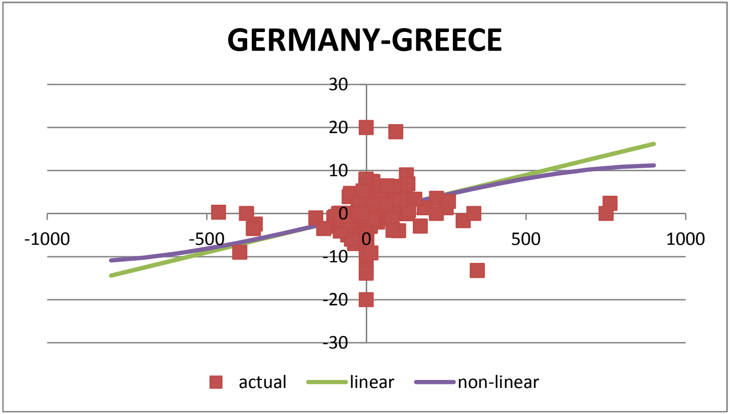
	France	
	quadratic	cubic
	$\phi_2 * X^2$	$\phi_3 * X^3$
GERMANY	0.000	0.000
GREECE	**0.000**	**0.000**
IRELAND	0.001	**0.000**
ITALY	**0.008**	0.000
PORTUGAL	0.000	**0.000**
SPAIN	**0.010**	**-0.001**
UK	-0.002	0.059

The economic values are very small.

Parametric inference: non-linear models

i	j	P-value	X	X^2	X^3
GERMANY	FRANCE	0.000	**0.539**	0.002	**-0.001**
GERMANY	GREECE	0.000	**0.018**	0.000	**0.000**
GERMANY	IRELAND	0.004	**0.059**	0.000	**0.000**
GERMANY	ITALY	0.001	**0.144**	0.000	**0.000**
GERMANY	PORTUGAL	0.000	**0.063**	0.000	**0.000**
GERMANY	SPAIN	0.050	**0.119**	0.000	**0.000**
GERMANY	UK	0.955	**0.370**	-0.001	0.000

Parametric inference: non-linear models



Parametric inference: quantile regressions

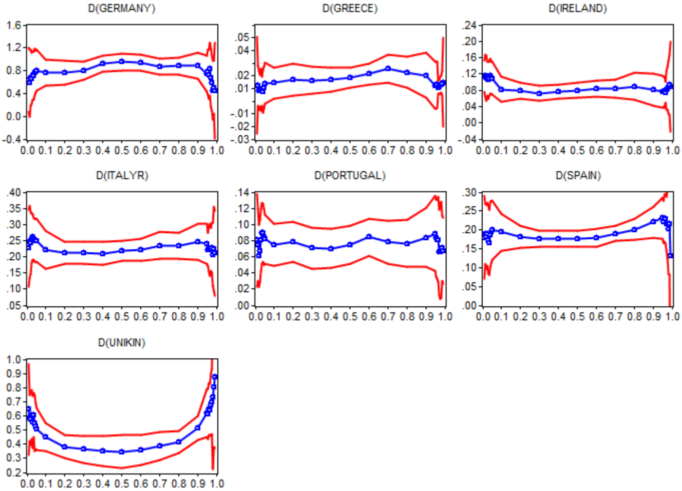
During large market movements, the relation between the Delta-CDS of the selected European countries might not follow a linear relation.
We consider Quantile Regressions between the CDS changes of any two countries.

$$min_{\Theta} \sum_{t=1}^{T} \rho_{\tau} \left(\Delta CDS_{i,t} - \beta_0 - \beta_1 \Delta CDS_{j,t} - \gamma' X_{t-1} \right)$$

where $\rho_{\tau}(a)$ is the *check* function for quantile τ defined as $\rho_{\tau}(a) = a \times (\tau - I(a < 0))$ and $\Theta = \{\beta_0, \beta_1, \gamma'\}$. The minimization problem results in:

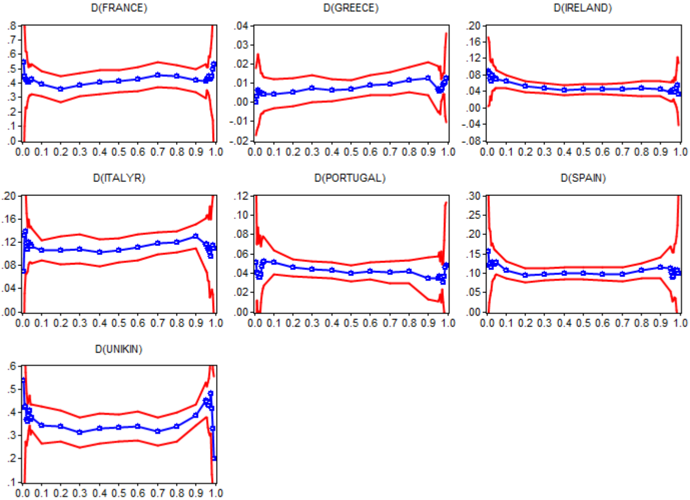
$$Q_t(\tau) = \widehat{\beta}_{\tau,0} + \widehat{\beta}_{\tau,1} \Delta CDS_{j,t} + \widehat{\gamma'}_{\tau} X_{t-1}$$

Parametric inference: FRANCE

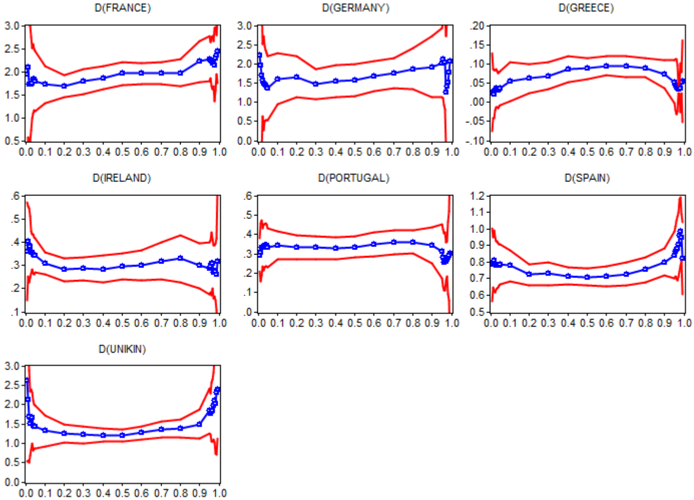


Absence of variability across quantiles suggests a linear relation.

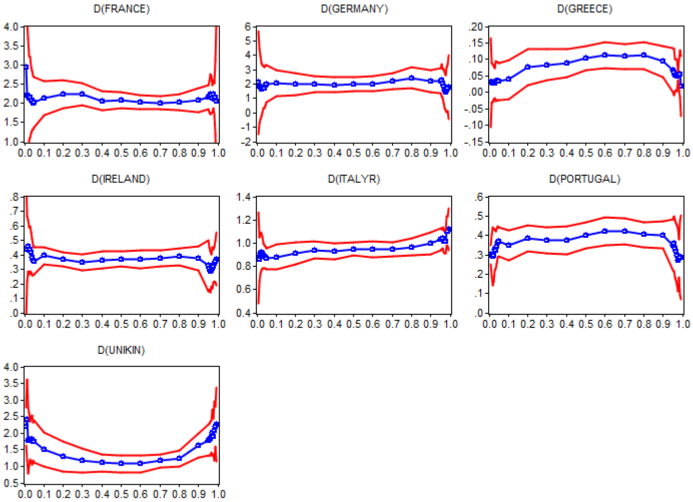
Parametric inference: GERMANY



Parametric inference: ITALY



Parametric inference: SPAIN



Parametric inference: quantile regressions

- The previous regression assumes time-invariant coefficients and, in particular, homoscedasticity.
- Estimation could be repeated over different samples and regression windows, such as rolling window.
- Estimates might, however, be biased or at the least inefficient.
- Inefficiency might be higher for low and high quantile levels

Parametric inference: heteroscedastic quantile regressions

As in Hiemstra and Jones (1994) and Chen, Gerlack and Wei (2010), we allow for heteroscedasticity

$$min_{\Theta} \sum_{t=1}^{T} \left(\rho_{\tau} \left(\frac{\Delta CDS_{i,t} - \beta_0 - \beta_1 \Delta CDS_{j,t} - \gamma' X_{t-1}}{\sigma_t (\tau)} \right) + log \left(\sigma_t (\tau) \right) \right)$$

where the term $\sigma^2_{t,\tau}$ is modeled with a GARCH(1,1) representation:

$$\sigma^2_{t,\tau} = \theta_{0,\tau} + \theta_{1,\tau} \varepsilon^2_{t-1,\tau} + \theta_{2,\tau} \sigma^2_{t-1,\tau} \qquad (1)$$

Parametric inference: Bayesian quantile regressions

The likelihood of the model has not a closed form solution and estimation of the model via frequentist inference might be particular difficult.

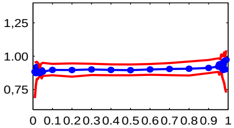
We apply Bayesian inference and therefore

- Account for parameter uncertainty.
- Exact inference for finite samples.
- Efficient and flexible of non-standard parameters.
- Efficient and valid inference under parameter constraints.

Parametric inference: Bayesian quantile regressions

We apply an algorithm similar to the Chen, Gerlack and Wei (2010) algorithm, which combines Gibbs sampling steps for model coefficients with a random walk Metropolis-Hastings (MH) algorithm and an independent kernel (IK)MH algorithm.

Parametric inference: FRANCE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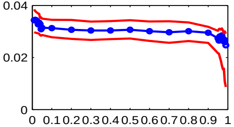
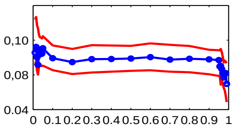
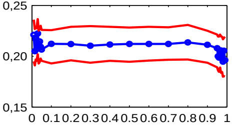
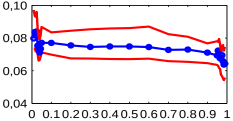
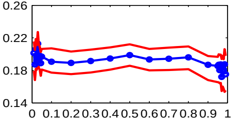
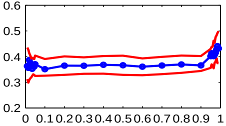

D(GREECE)


D(IRELAND)


D(ITALY)

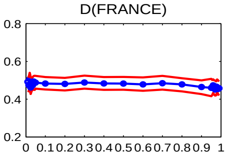

D(PORTUGAL)

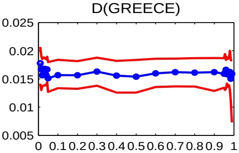

D(SPAIN)

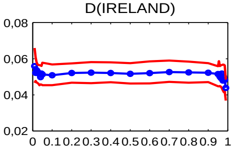

D(UK)

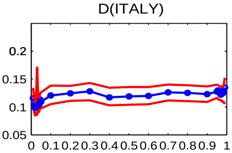
Linearity is confirmed!

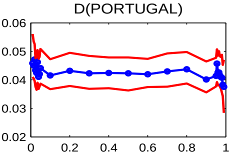
Parametric inference: GERMANY

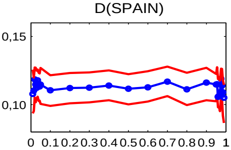

D(FRANCE)

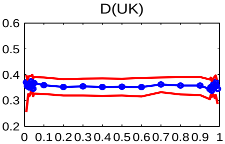

D(GREECE)


D(IRELAND)

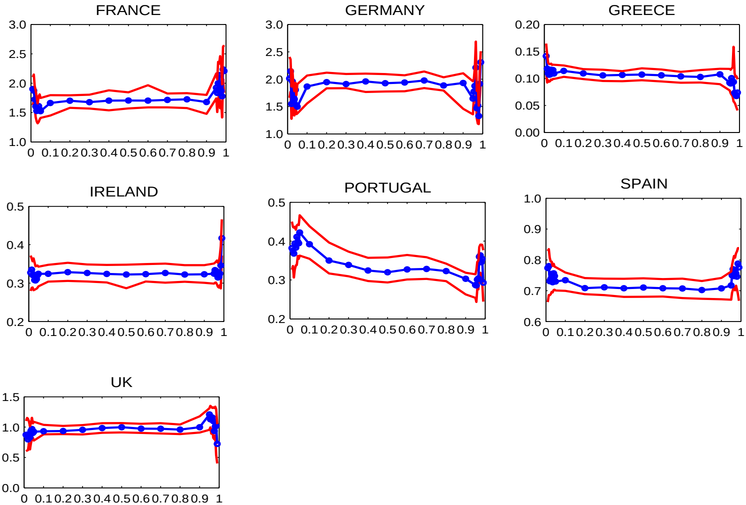

D(ITALY)


D(PORTUGAL)

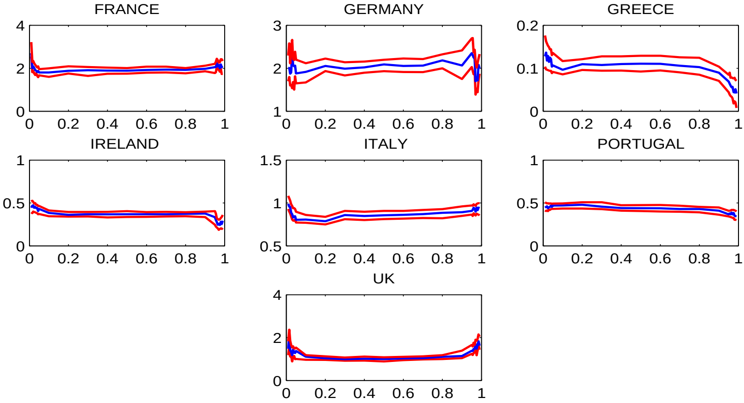

D(SPAIN)


D(UK)

Parametric inference: ITALY



Parametric inference: SPAIN



Robustness checks

Results are similar when:

- Using $\Delta ln(CDS)$.
- Using the covariates in Ang and Longstaff (2011): Eutostoxx 50, Vstoxx, CDS China, CDS Japan, Euro Swap rate, CDS index emerging markets, Itraxx index on corporate EU CDS.

Robustness checks

- Simultaneity and omitted variables might affect the previous results.
- Verify this issue by means of the Determinant of the Change in the Covariance matrix (DCC) test, see Rigobon (2003, REStat).
- The test verifies the stability but do not evaluate the size of the transmission mechanism.
- The test requires an assumption: some structural shocks are homoskedastic.
- In the period considered Germany shocks are homoskedastic because in the reduced form the heteroskedasticity in Germany is coming from periphery countries.

Robustness checks

- The test is based on the residuals of a reduced form model (a VARX(5)).
- The test split the samples on the basis of residuals volatility (high/low compared to a threshold) and test stability across the subsamples.
- Test statistic p-values evaluated with a bootstrap procedure.
- Results suggest stability for several thresholds.

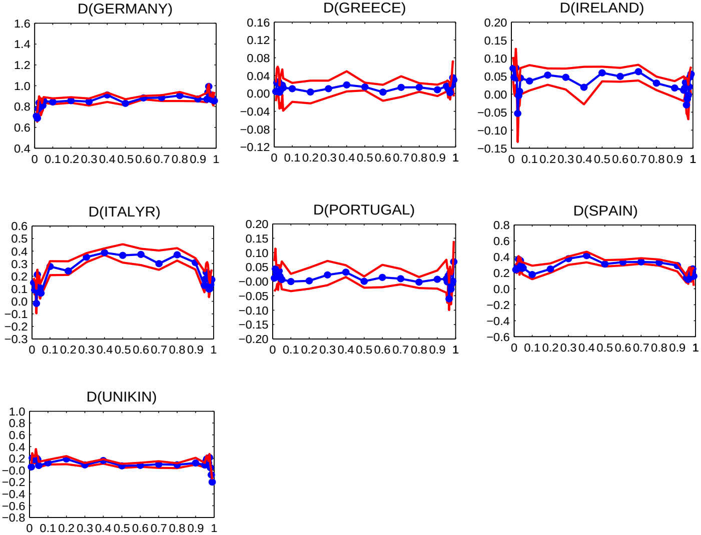
Robustness checks

Threshold	Tstat	Mass > 0
12.00	0.96	0.32
13.00	0.83	0.30
14.00	1.39	0.20
15.00	0.53	0.32
16.00	0.62	0.39
17.00	0.69	0.29
18.00	1.27	0.21
19.00	1.41	0.28
20.00	1.77	0.40
21.00	1.72	0.39
22.00	0.96	0.42
23.00	0.58	0.43
24.00	0.09	0.39

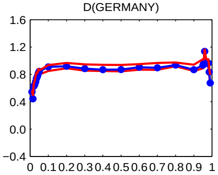
Government bond spreads

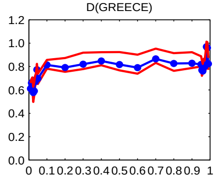
- Define bond spreads: bond yields on 5 years minus 5-year swap rate (risk-free rate as in Beber et al. (2009)).
- Repeat the analysis for three subperiods:
  - the pre crisis period (2003-2006);
  - the post crisis one (2008-2011);
  - full the sample (2003-2011).

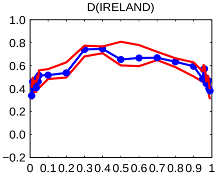
French bond spreads, 2008-2011

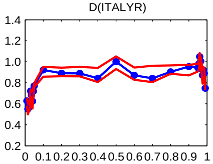


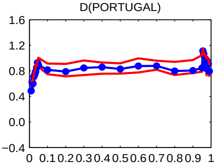
French bond spreads, 2003-2006

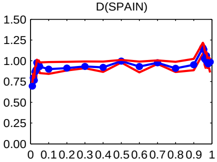


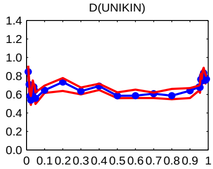






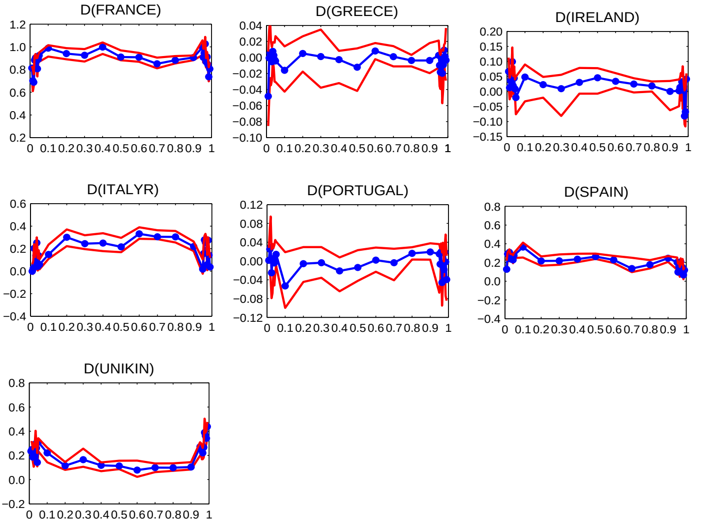




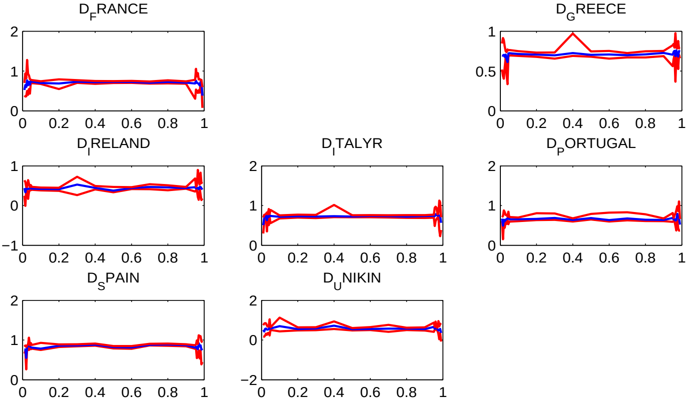


Coefficients assume higher values.

Germany bond spreads, 2008-2011

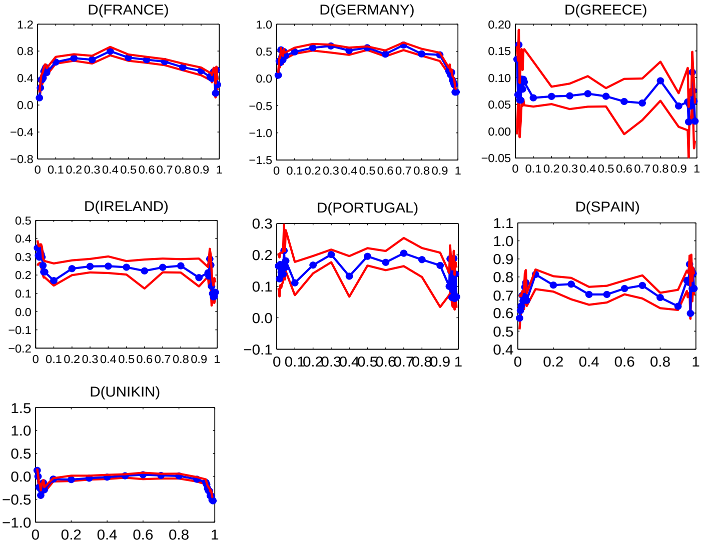


Germany bond spreads, 2003-2006

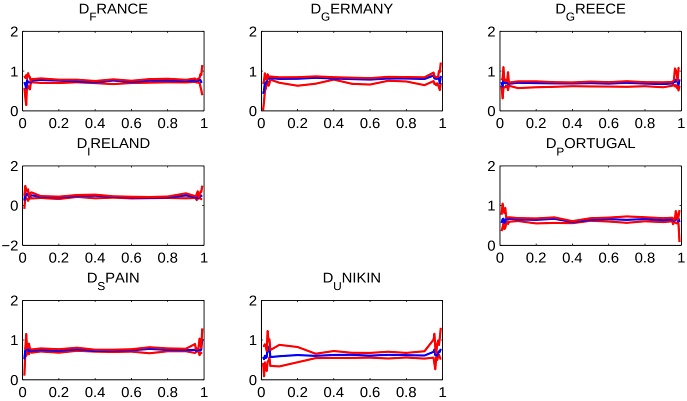


Coefficients assume higher values.

Italy bond spreads, 2008-2011



Italy bond spreads, 2003-2006



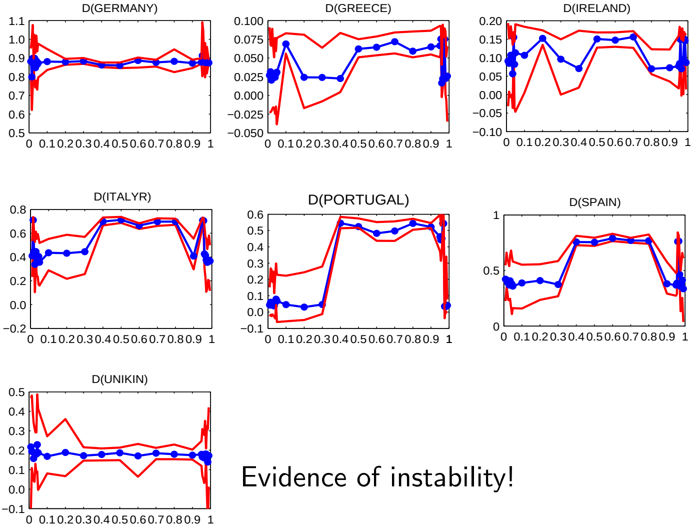
Coefficients assume higher values.

Government bond spreads

	2003-2006	2008-2011	CDS 2008-2011
Germany	0.800	0.800	0.800
Greece	0.800	0.020	0.015
Ireland	0.600	0.050	0.100
Italy	0.900	0.200	0.220
Portugal	0.900	0.020	0.060
Spain	0.900	0.230	0.200
UK	0.600	0.200	0.350

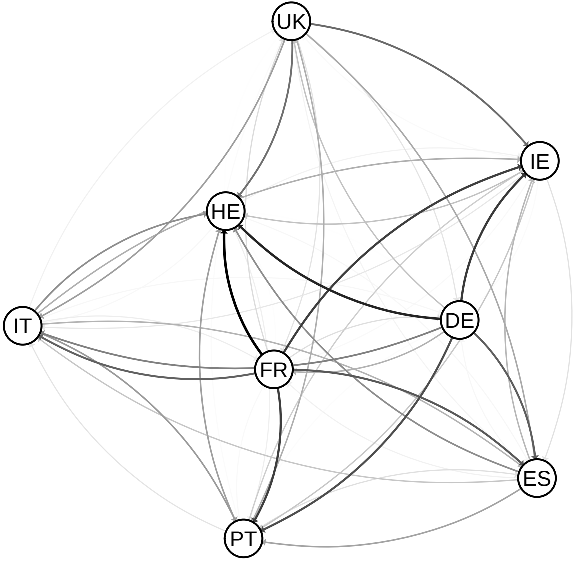
Table : Average daily bond spreads

French bond spreads, 2003-2011



Evidence of instability!

Network dependence: CDS, 2008-2011


UK
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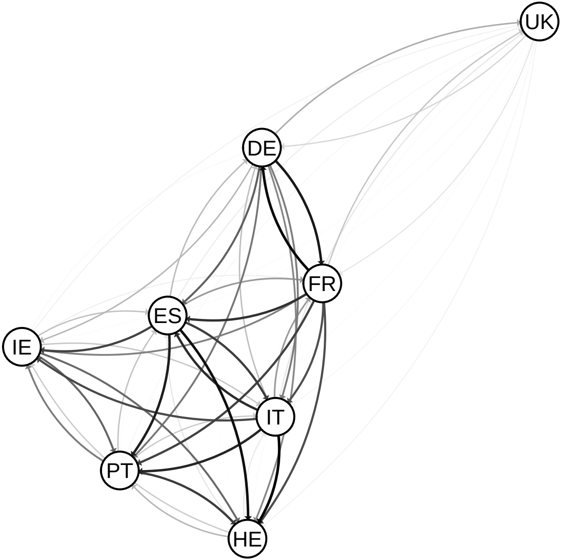
Network dependence: Bond, 2008-2011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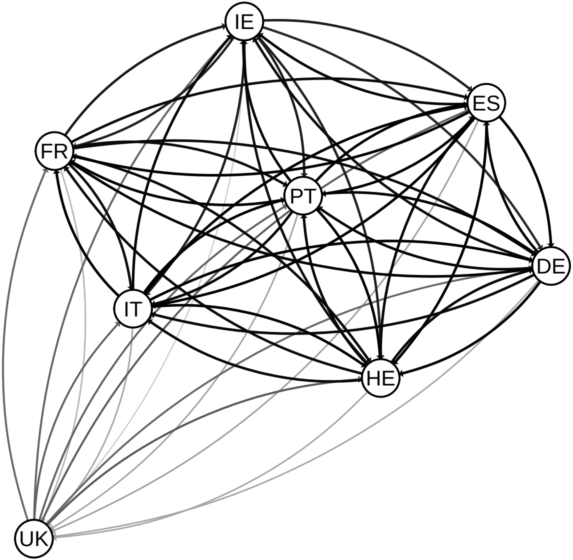
Network dependence: Bond, 2003-2006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Conclusions

- Sovereign risk contagion is largely a linear phenomenon.
- Risk spillover among countries is not affected by the size of the shock.
- The common shift in CDS spreads that we have observed in the data is the outcome of interdependence that has been present all the time.
- Results for bond spread support findings and highlight a change in the intensity (**reduction**) of the propagation of shocks in the 2008 and not during the fiscal crisis.

Future research

- Following the results on linearity,we propose the following model for CDS (bond) of the European countries

$$AY_t = BX_{t-1} + \Gamma Z_t + \varepsilon_t,\ \varepsilon_t \sim N(0,\Omega) \tag{2}$$

- Identify it as:
  - Estimate the reduced form VARX model:

$$Y_t = \sum_{j=1}^{5} \Phi Y_{t-j} + \sum_{j=1}^{5} \Gamma X_{t-j} + \eta_t,\ \eta_t \sim N(0,\Sigma) \tag{3}$$

  - Consider the relation between structural and reduced form residuals:

$$A\eta_t = \varepsilon_t + \Gamma Z_t \tag{4}$$

  - Identification through heteroscedasticity as in Rigobon (2003):

$$A\Sigma_s A' = \Omega_s + \Gamma \Omega_{Z,s} \Gamma' \tag{5}$$

Previous risk management models still apply

- Assume that a insurance to attend systemic risk is purchased conditional on a shock to Greece.
- If the insurance mechanism is estimated using the propagation that prevails during tranquil periods, and it changes during the crisis,
  - then even if the shock were correctly anticipated, the insurance mechanisms would have been inadequate.
- Because the structure is stable, then whatever contingency had been designed – both in the public and in the private sector – such policy actions are indeed adequate.
- So far we can say that the higher the risk is the result of larger shocks, and not stronger interconnectedness.

How policy makers should react...

- For example, in UK there has been an increase in the conditional variance.
- We show that this increase is the outcome of a shift in the variance of a subset of the shocks, and to a stable propagation mechanisms.
- Imagine the same increase in conditional variance is observed but the only volatility changing is the one from the British structural shock.

React to the crisis as in the same manner

- The fiscal authority and the monetary authority in the UK would respond to the shift in their own risk by building up buffer stocks – cash reserves to attend the higher risk.

- **Because the parameters are constant and the relationship is stable,** the authorities should **respond to the increase in risk from outside shocks in the exact same manner.**

- Compare this response to the response they should undertake if the propagation mechanisms is shifting:
  - **the risk profile of the assets is shifting – not only its variance – and therefore the size of the buffer, and its composition, need to respond..**