Macro factors and sovereign bond spreads: a quadratic no-arbitrage model*

Peter Hördahl[a], Oreste Tristani[b]

[a]Bank for International Settlements,
[b]European Central Bank

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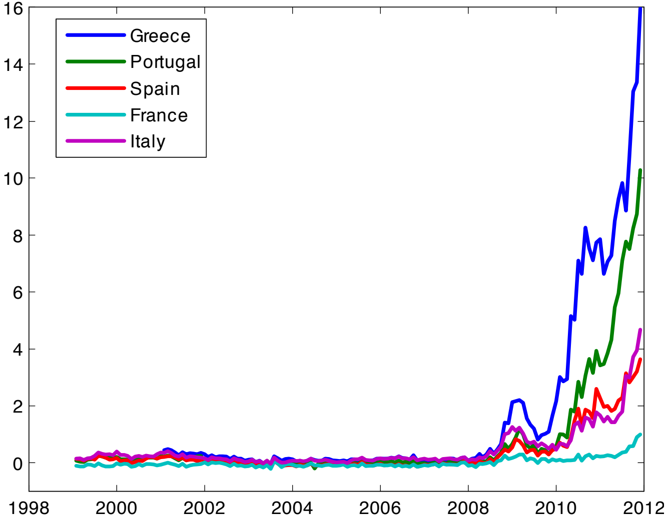
*All opinions are personal and should not be attributed to the BIS or the ECB.

Motivation

10-year yield spreads vs Germany



Motivation

- Peripheral euro area sovereign bond yields have risen sharply above comparable yields on German government bonds.
- These spread increases have coincided with rapidly deteriorating fiscal conditions and eroding market confidence.
- Can country-specific fundamentals explain the rise in spreads? Or do factors unrelated to fundamentals play an important role (e.g. self-fulfilling dynamics)?
- Attempts to model the dynamics of sovereign yields/spreads as functions of observable fundamentals have been challenging.

Motivation (cont.)

- We examine the drivers of euro area sovereign bond spreads, including observable macro fundamentals
- key features:
  (i) allow sovereign spreads to depend on observable fundamentals (debt/GDP, economic growth)
  (ii) allow for non-linear effects of fiscal fundamentals on spreads
  (iii) include a common credit factor
  (iv) let all factors affect debt/GDP to allow us to capture feedback of higher spreads on debt (to a first approximation)

Outline

- Methodology / Literature / Model
- Data and estimation method
- Results: model fit, estimated common factor, quantification of nonlinear effects, risk premia estimates, spread decompositions
- Conclusions

Methodology & literature

- Starting point: reduced-form credit models (Lando (1994), Duffie & Singleton (1998), Duffee (1999), ...), in which assumptions are made about the process for default intensity.
- Default is doubly stochastic: default arrives randomly, and the arrival intensity process Λ_t varies randomly over time.
- Advantage: tractable bond pricing; for zero recovery & discrete time:

$$P_t(n) = E_t^{\mathbb{Q}}\left[\exp\left(-\sum_{j=1}^{n}\left(r_{t+j-1}+\Lambda_{t+j}\right)\right)\right]$$

- The intensity Λ_t may be a function of a set of factors.

Methodology & literature (cont.)

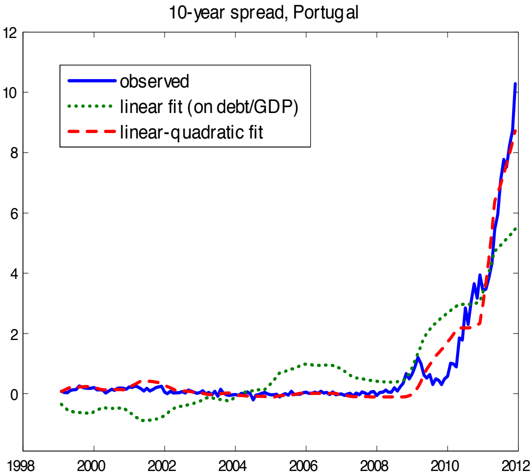
- We apply this framework to euro sovereign bonds. Much of the available literature on sovereign credit has focused on emerging markets (Duffie, Pedersen & Singleton (2003), Pan & Singleton (2008), Longstaff et al. (2011)); Dai and Philippon (2006) focused on US, but assumed no credit risk.
- More recent interest in advanced economies, in particular the euro area: Laubach (2011), Monfort & Renne (2011) Borgy et al. (2011), Ang & Longstaff (2011), ...
- These studies typically model default intensities and sovereign spreads as affine functions of some unobservable factors (Borgy et al. use observable macro factors)

Methodology

- We want to allow macro fundamentals to play an important role for spreads; in particular (expected) debt/GDP.
- A linear relationship may not be optimal: theoretical results suggest a non-linear relationship (e.g. Bi, 2011, Juessen et al., 2011, Corsetti et al., 2012)
- As economies approach the *fiscal limit* – the point where a government no longer has the ability to finance its debt by raising taxes – bond yields become steeply non-linear.
- There is also empirical evidence of a non-linear relationship between bond yields and fiscal fundamentals (Alesina et al., 1992; Ardagna et al. 2007; Bernoth et al., 2004).

Methodology (cont.)

- Looking at recent euro area developments: challenging to assume a linear relationship between spreads and fiscal fundamentals – a quadratic specification seems more promising:



Model

- We start with the result of Duffie and Singleton (1999): under RMV, credit risky bonds can be priced as default-free bonds using a default-adjusted discount rate $r_t^* = r_t + \Lambda_t$,
- Λ_t is a "recovery-adjusted default intensity"
- We assume that Λ_t depends on:
  - country-specific expected GDP growth: g_t
  - country-specific expected debt/GDP: d_t
  - debt-to-GDP squared: d_t^2
  - a common latent factor: C_t
- We assume VAR factor dynamics for g, d and C.

Model (cont.)

Default intensities and state variables

- Default intensity: $\Lambda_t^i = \lambda_0^i + \lambda^{i} X_t^i + \left(X_t^i\right)' \Xi^i X_t^i$
- State vector, country j: $X_t = \left[C_t, g_t^j, d_t^j\right]'$
- State dynamics: $X_t = \Phi X_{t-1} + \varepsilon_t$ with restrictions:
  C_t : AR(1); independent of macro fundamentals
  g_t : AR(1) [interactions not significant]
  d_t : allowed to depend on all factors

Model (cont.)

Bond prices

- Assuming a standard SDF, and affine market prices of risk (Duffee, 2002), $\psi_t = \psi_0 + \psi_1 X_t$, we can price risky bonds using exponential quadratic bond prices of Ahn, Dittmar & Gallant (2002) and Leippold & Wu (2002) (Realdon (2006) in discrete time):

$$
\begin{aligned}
P_t^n &= \exp\left(A_n + B_n X_t + X_t' C_n X_t\right) \\
A_n &= A_{n-1} + \ldots \\
B_n &= B_{n-1}\Phi + \ldots \\
C_n &= \Phi' C_{n-1}\Phi + \ldots
\end{aligned}
$$

Data

- Monthly data, January 1999 – November 2011.
- 2, 3, 4, 5, 7, 10-year zero-coupon yields on Greek, Portuguese, Spanish, Italian and French government bonds (NS estimates), minus corresponding German yields.
- g_t^j : one-year ahead expected GDP growth; constructed from semi-annual European Commission forecasts; monthly data obtained using the Kalman filter (VAR)
- d_t^j : one-year ahead expected debt-to-GDP ratio (constructed in the same way).
- g and d are in deviation from sample mean (pre-crisis mean for d)

Estimation

- Joint ML estimation assuming Gaussian shocks.
- Allow all spreads and macro factors to be imperfectly observed: Gaussian measurement errors
- Spreads are not linear in the factors: we can't use a regular Kalman filter
- We use the unscented Kalman filter (Julier & Uhlmann (1997, 2004)):
    - deterministic sampling of 'sigma points' around the mean of the state variables
    - propagate points through the non-linear function
    - recover first two moments of the non-linear system
    - use this to update the filter

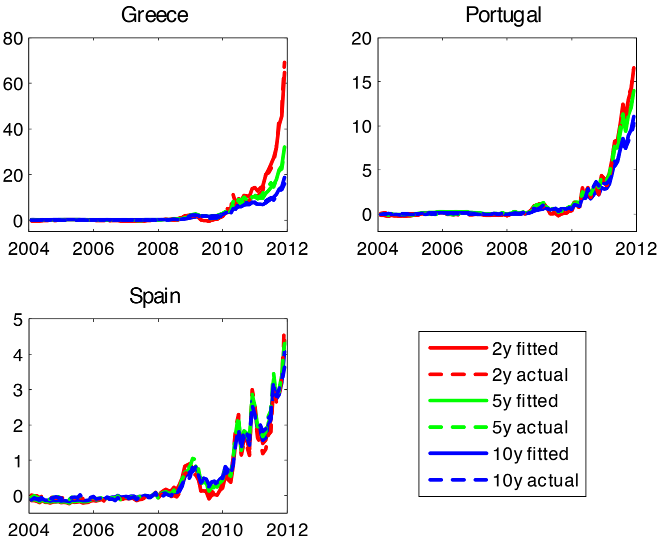
Parameter estimates: default intensities

$$\Lambda_t = \lambda_0 + \lambda X_t + (X_t)' \, \Xi X_t; \qquad \lambda = (\lambda_C, \lambda_g, \lambda_d)$$

Parameter	Greece	Portugal	Spain	France	Italy
$\lambda_0 \times 10^2$	0.036 (0.030)	0.021** (0.007)	0.039** (0.002)	0.003** (0.001)	0.026** (0.002)
$\lambda_C \times 10^2$	−0.220 (1.739)	−0.074 (0.220)	−0.017** (0.005)	−0.008 (0.013)	−0.024** (0.000)
$\lambda_g \times 10^2$	−0.031** (0.003)	−0.001** (0.000)	−0.015** (0.000)	−0.004** (0.000)	−0.003 (0.003)
$\lambda_d \times 10^2$	−0.020 (0.059)	−0.019 (0.027)	0.441** (0.117)	0.019** (0.006)	0.410** (0.045)
$\Xi_{d,d}$	0.116** (0.019)	0.041** (0.002)	0.021** (0.004)	0.003** (0.000)	0.094** (0.009)

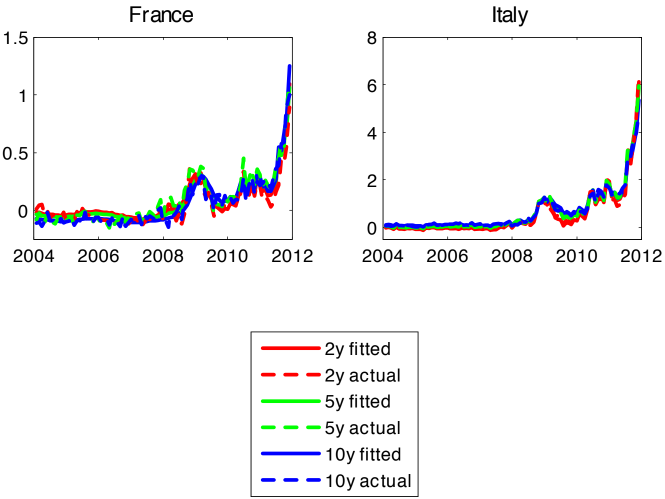
Results: model validation

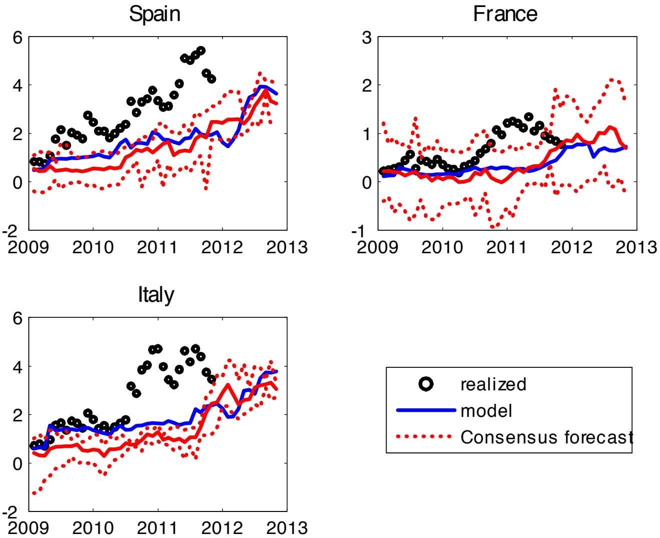
Estimated and observed spreads



Results: model validation

Estimated and observed spreads (cont.)

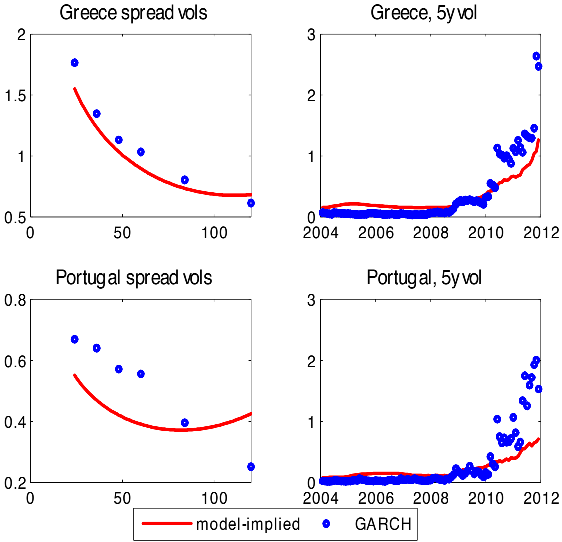




Spain
6
4
2
0
-2
2009
2010
2011
2012
2013
France
3
2
1
0
-1
2009
2010
2011
2012
2013
Italy
6
4
2
0
-2
2009
2010
2011
2012
2013
realized
model
Consensus forecast

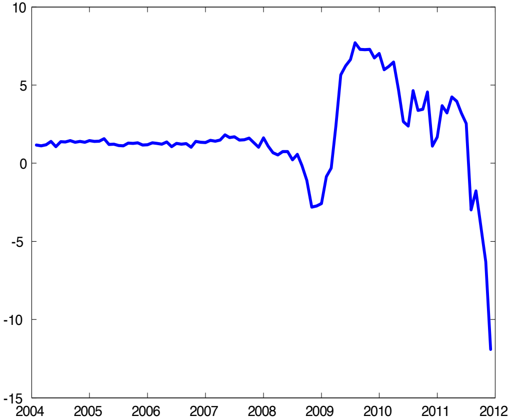
Results: model validation

Conditional spread volatilities



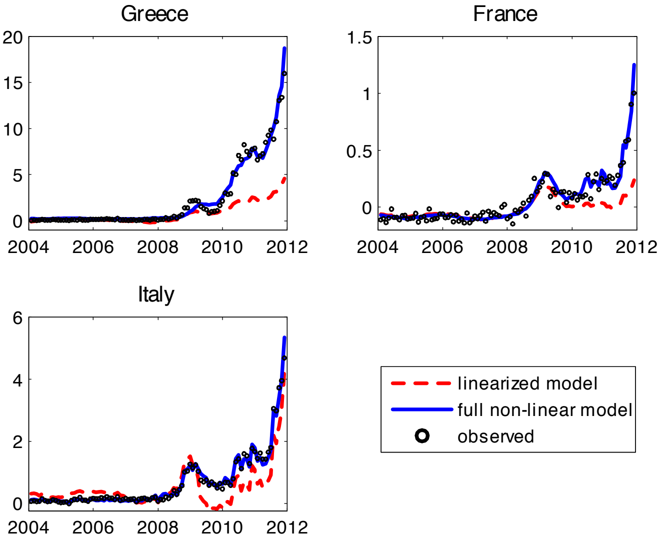
Results

Estimated common factor



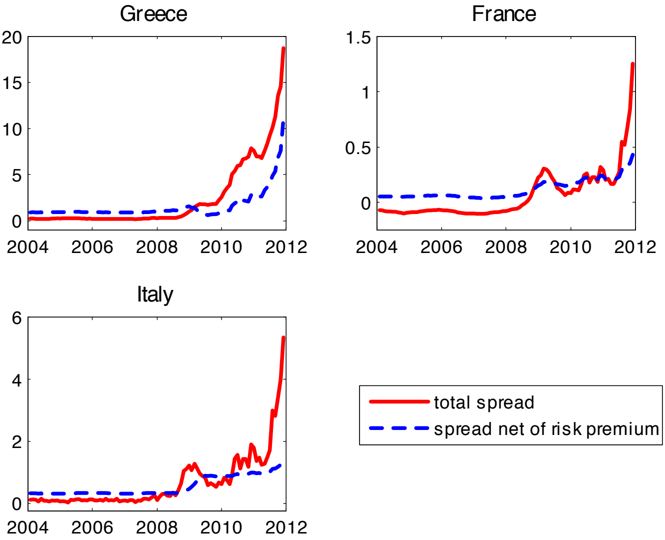
Results

Is allowing for nonlinearities important?



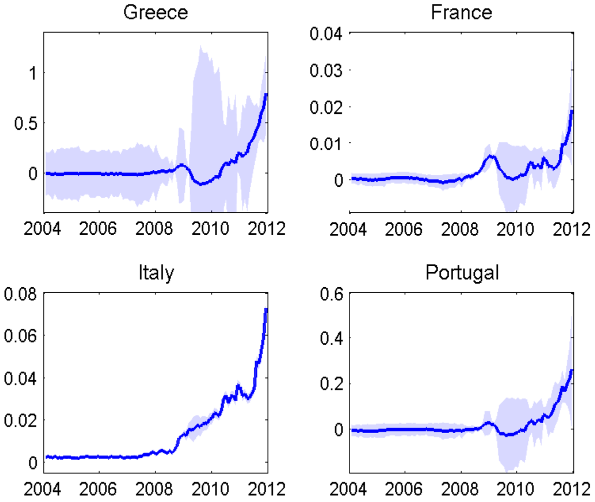
Results

The role of the distress risk premium: 10-year spreads



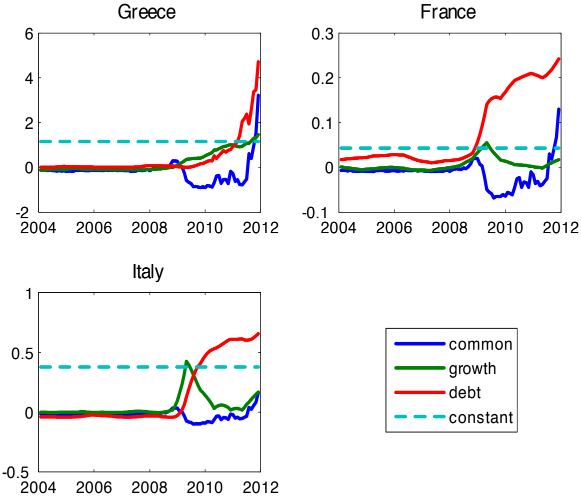
Results

One-year (risk-neutral) default probabilities (50% loss assumed)



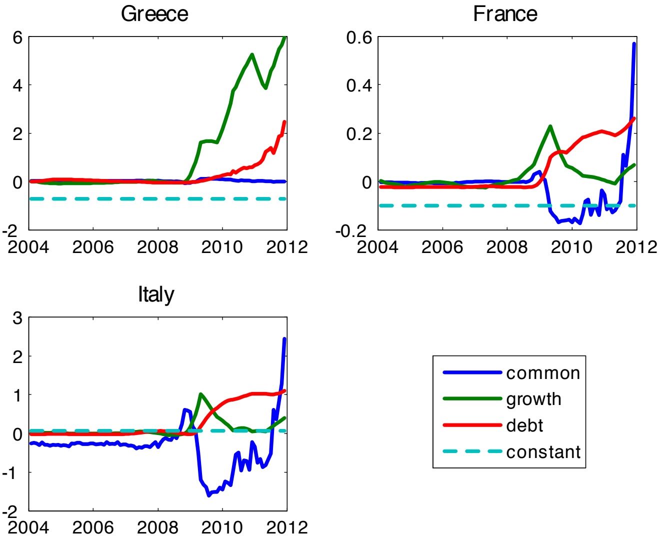
Results

Decomposition of default risk component (10y spread less premium)



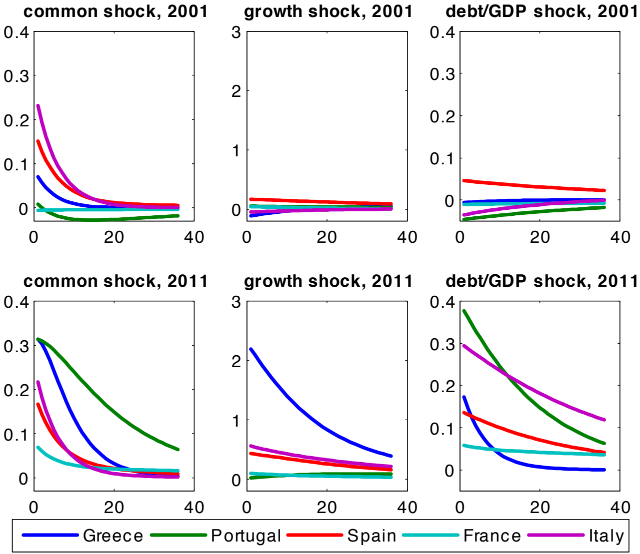
Results

Decomposition of distress risk premium (10y)



Results

10-year spread responses to adverse shocks

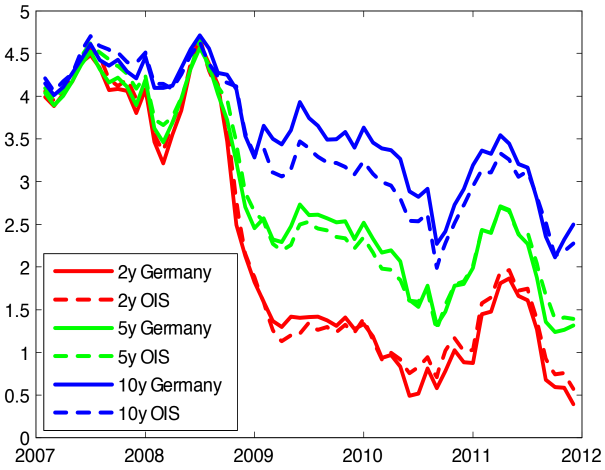


Conclusions

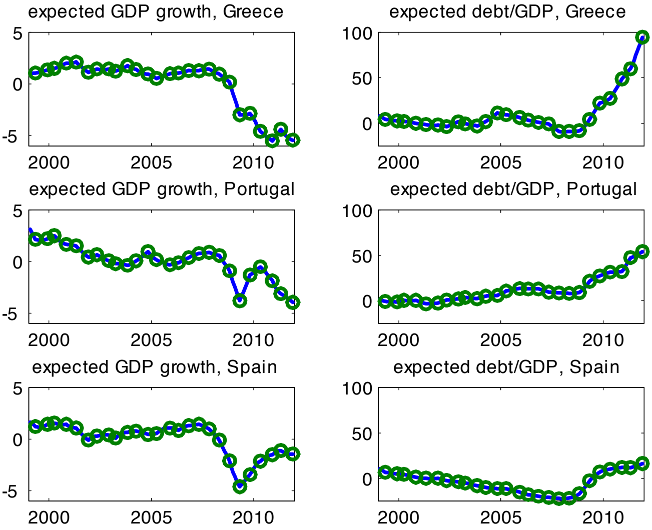
- We estimate a non-linear reduced-form credit model for sovereign spreads of five euro area countries.
- Using country-specific debt-to-GDP and GDP growth along with a common factor, our model can capture well features of sovereign spreads along several dimension.
- Macro factors are important drivers of sovereign spreads, mainly through the default risk component.
- In particular, spreads depend non-linearly on debt-to-GDP.
- For all countries, except Greece, the surge in spreads has mainly been due to rising distress risk premia. For this component, the common factor plays a central role.

Extra slides

German zero-coupon yields vs. OIS zero rates



Extra slides
Macroeconomic data: observed and filtered (KF)



Extra slides

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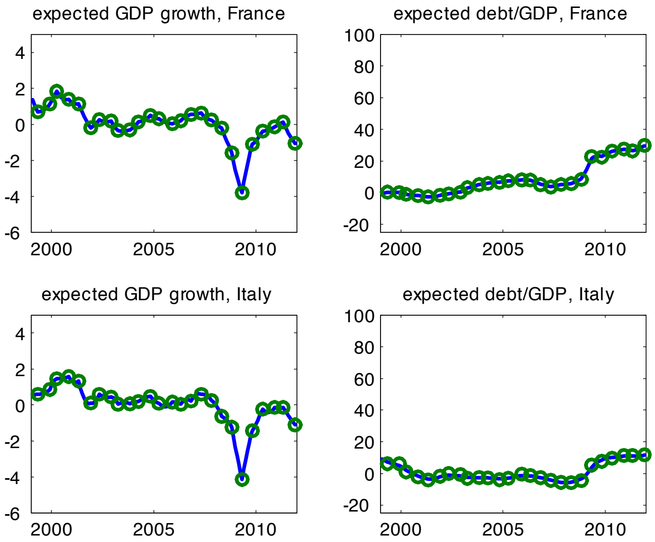
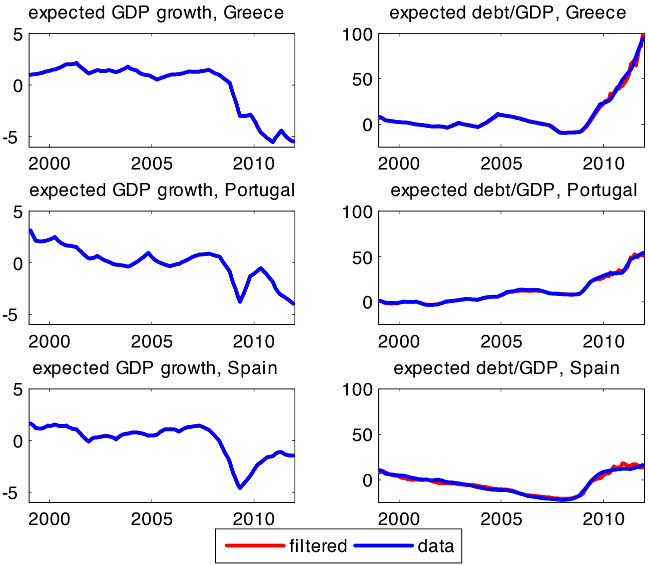


Extra slides

Filtered macro variables (UKF) and data



Extra slides

Filtered macro variables (UKF) and data