Decomposing Euro-Area Sovereign Spreads: Credit and Liquidity Risks

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Introduction
Credit and / vs Liquidity

Source: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Introduction
Credit and / vs Liquidity

Google searches

"Liquidity crisis"
"Credit crisis"

Introduction
Motivations

1. Are euro-area sovereign yields affected by liquidity-pricing effects (and to what extent)?

2. Interactions between credit-related and liquidity-related risk factors?

3. How to extract probabilities of default (PDs) from bond prices?

4. Do the default compensations include risk premia? [credit-spread puzzle, Huang and Huang 2012, Chen et al. 2009]
Disentangling credit and liquidity risks: what for?

- **Policy implications** of a rise in spreads depend on the source:
  - Liquidity problems $\Rightarrow$ improve market functioning
  - Credit concerns $\Rightarrow$ enhance the solvency of the debtors (Codogno, Favero and Missale, 2003)

- **Investment decisions** (Longstaff, 2009):
  - Buy-and-hold investors seek bonds whose price is low because of poor liquidity
  - Bond A and Bond B have the same credit quality but A is less liquid $\Rightarrow$ buy-and-hold investors buy A because less expensive than B for the same final payoff distribution
Introduction
Overview of connected literature

- **Disentangling credit/liquidity risks**: (using spreads that are known to be liquidity-driven)

  Spreads between bonds of the same maturity but different ages (Fontaine and Garcia, 2012), between T-bill rates and repo rates (Liu, Longstaff and Mandel, 2006), between govies and swaps (Feldhütter and Lando, 2008)


- **Extraction of PDs from market prices**: Litterman and Iben (1991)

- **Sovereign risk premia**: Borri and Verdelhan (2012), Longstaff et al. (2011), Ang and Longstaff (2011)
Introduction

Outline

1. Model
2. Data and estimation
3. Results
   1. Credit/liquidity decomposition
   2. Probabilities of default
4. Concluding remarks
Model

Variables

- **N** debtors (countries) that issue defaultable and illiquid bonds
- **Credit risk**: Debtors may default
  - Default variable: \( d_t^{(n)} = 1 \) if in debtor \( n \) in default at \( t \) (0 otherwise)
  - Default intensity: \( \lambda_{c,t}^{(n)} \)
  - Fractional loss given default (LGD): \( 1 - \zeta \)
- **Liquidity risk**: Bondholders may have to liquidate hastily [Ericsson and Renault (2006)]
  - Liquidity-shock variable: \( \ell_t \)
  - Liquidity-shock intensity: \( \lambda_{\ell,t} \)
  - Fractional loss given liquidation (LGL): \( 1 - \theta^{(n)} \)
- \( r_t \): risk-free short-term rate
- \( z_t \): crisis-regime variable
Credit risk: Fractional-loss credit intensity $\lambda^{(n)}_{fc,t}$:

$$\lambda^{(n)}_{fc,t} = (1 - \zeta) \times \lambda^{(n)}_{c,t}$$

fractional LGD \hspace{1cm} default intensity

Liquidity risk: Fractional-loss liquidity intensity $\lambda^{(n)}_{f\ell,t}$:

$$\lambda^{(n)}_{f\ell,t} = (1 - \theta^{(n)}) \times \lambda_{\ell,t}$$

fractional loss \hspace{1cm} liq.-shock intensity
Model
Historical dynamics of the regimes

- Liquidity-related stress: $z_{\ell,t}$
- Credit-related stress: $z_{c,t}$
- For $i$ in $\{\ell, c\}$, three stress levels:
  
  $$
  z_{i,t} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} : \text{low stress} \\
  z_{i,t} = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} : \text{distress} \\
  z_{i,t} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} : \text{severe stress}
  $$

- 9 unobserved regimes $z_t = z_{\ell,t} \otimes z_{c,t}$
- The two chains ($z_{\ell,t}$ and $z_{c,t}$) cause each other:
  
  $$
  \begin{cases}
    P(Z_{\ell,t} | Z_{\ell,t-1}) \neq P(Z_{\ell,t} | Z_{\ell,t-1}, Z_{c,t-1}) \\
    P(Z_{c,t} | Z_{c,t-1}) \neq P(Z_{c,t} | Z_{\ell,t-1}, Z_{c,t-1})
  \end{cases}
  $$
Model

Historical dynamics of the intensities

Generic process followed by the intensities (the $\lambda_{c,t}^{(n)}$'s and $\lambda_{l,t}$):

$$\lambda_t = \mu' z_t + \rho \lambda_{t-1} + \sigma \epsilon_t$$

Simulated example:

with $\mu = [0.01 \ 0.03 \ 0.10]$, $P = \begin{bmatrix} 0.98 & 0.02 & 0 \\ 0.05 & 0.90 & 0.05 \\ 0 & 0.30 & 0.70 \end{bmatrix}$, and $\epsilon_t \sim \text{i.i.d. } \mathcal{N}(0, 0.01^2)$.

Light grey: crisis regime ($z_t = [0, 1, 0]'$), Dark grey: severe crisis regime ($z_t = [0, 0, 1]'$)
Stochastic discount factor (s.d.f.) between $t - 1$ and $t$:

$$M_{t-1,t} = \exp \left[ -r_{t-1} - \frac{1}{2} \nu_t \nu_t' + \nu_t' \varepsilon_t + (\delta z_{t-1})' z_t \right]$$

The risk-sensitivity matrix $\delta$ and the vectors $\nu_t$ respectively price the regimes $z_t$ and the (standardized) Gaussian innovations $\varepsilon_t$ of $\lambda_t$.

Under $Q$:

- $z_t$ follows a time-homogenous Markovian chain whose dynamics is described by transition probabilities $\pi_{ij}^*$ (given by $\pi_{ij} \exp \delta_{ij}$)
- The intensities follow:

$$\lambda_{i,t} = \mu_i^* z_t + \rho_i^* \lambda_{i,t-1} + \sigma_i \varepsilon_{i,t}^*$$

where $\varepsilon_{i,t}^* \sim \mathcal{N}^Q(0,1)$, $\mu_i^* = \mu_i + \sigma_i \nu_{z,i}'$ and $\rho_i^* = \rho_i + \sigma_i \nu_{\lambda,i}$

($\nu_{i,t} = \nu_{\lambda,i} \lambda_{i,t-1} + \nu_{z,i}' z_t$)
Model
Risk-neutral dynamics of $d_t$ and $\ell_t$

**P and Q intensities in this framework**

- The conditional distributions of $d_t$ and $\ell_t$, given $(\lambda_{c,t}, \lambda_{\ell,t}, W_{t-1})$, are the same functions of $\lambda_{c,t}$ and $\lambda_{\ell,t}$ under $\mathbb{P}$ and $\mathbb{Q}$.
- The default and liquidity intensities are the same process in both worlds.

- This stems from the fact that the variables $d_t$ and $\ell_t$ do not enter the s.d.f.
Model

Risk-neutral dynamics of $d_t$ and $\ell_t$

$\mathbb{P}$ and $\mathbb{Q}$ intensities in this framework

- The conditional distributions of $d_t$ and $\ell_t$, given $(\lambda_{c,t}, \lambda_{\ell,t}, W_{t-1})$, are the same functions of $\lambda_{c,t}$ and $\lambda_{\ell,t}$ under $\mathbb{P}$ and $\mathbb{Q}$.
- The default and liquidity intensities are the same process in both worlds.

- This stems from the fact that the variables $d_t$ and $\ell_t$ do not enter the s.d.f.
- The intensities are the same processes under both measures but their $\mathbb{Q}$- and $\mathbb{P}$-dynamics are different. (Hence $\mathbb{Q}$- and $\mathbb{P}$-PDs are different.)
Model

Markov-switching State-space model

Bond spreads formulas

\[ y_{t,h}^{(n)} - r_{t,h} = -\frac{1}{h} \ln E_t^Q \exp \left( -\lambda_{fc, t+1}^{(n)} - \ldots - \lambda_{fc, t+h}^{(n)} - \lambda_{f\ell, t+1}^{(n)} - \ldots - \lambda_{f\ell, t+h}^{(n)} \right) \]

\[ = a_h^{(n)'} z_t + b_h^{(n)'} \lambda_t \]

where the \( a_h^{(n)} \)'s and the \( b_h^{(n)} \)'s are computed recursively.

- Model in state-space form (\( S_t \): vector of spreads):

\[
\begin{align*}
\lambda_t &= \mu' z_t + \Phi \lambda_{t-1} + \Sigma \varepsilon_t \\
S_t &= A z_t + B \lambda_t + \xi_{S,t}
\end{align*}
\]
**Model**

Markov-switching State-space model

**Bond spreads formulas**

\[
y_{t,h}^{(n)} - r_t = \frac{1}{h} \ln E_t^\mathbb{Q} \exp \left( -\lambda_{fc,t+1}^{(n)} - \ldots - \lambda_{fc,t+h}^{(n)} - \lambda_{f\ell,t+1}^{(n)} - \ldots - \lambda_{f\ell,t+h}^{(n)} \right) \\
= a_h^{(n)'} z_t + b_h^{(n)'} \lambda_t
\]

where the \(a_h^{(n)}\)'s and the \(b_h^{(n)}\)'s are computed recursively.

- Model in state-space form (\(S_t\): vector of spreads):

\[
\begin{align*}
\lambda_t &= \mu' z_t + \Phi \lambda_{t-1} + \Sigma \varepsilon_t \\
CF_t &= A_{CF} z_t + B_{CF} \lambda_t + \xi_{CF,t} \\
S_t &= A z_t + B \lambda_t + \xi_{S,t}
\end{align*}
\]

⇒ Small-sample persistence bias problem: survey-based forecast are introduced [Kim and Orphanides, 2012]
Weekly data July 2006 – February 2013

Eight euro-area countries: Austria, Belgium, Finland, France, Germany, Italy, the Netherlands and Spain

Riskfree yields $r_{t,h}$:

$$r_{t,h} = \text{German yields} - \text{German CDS}$$

12-month-ahead forecasts of 10-year sovereign yields (France, Germany, Italy, Netherlands and Spain) are exploited

**MLE estimation**: Log-likelihood of the Markov-Switching State-Space model computed by means of Kim’s (1994) algorithm

**Liquidity-factor identification**: KfW bonds feature the same credit quality as Germany but are less liquid
Data and estimation
Liquidity factor: spreads between gov-guaranteed bonds and goovies

Panel A – KfW–Bund spreads across maturities

Panel B – Liquidity spreads across countries
Data and estimation
Liquidity factor $\lambda_{\ell,t}$

- - - - Liquidity factor
- - - - Bid–ask spread on 10-year French–government benchmark bond

Data and estimation

Estimated crisis regimes
## Data and estimation

### Transition probabilities

<table>
<thead>
<tr>
<th></th>
<th>Under $\mathbb{P}$</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$NL_{t+1}$</td>
<td>$L_{t+1}$</td>
<td>$LL_{t+1}$</td>
</tr>
<tr>
<td>$NC_t$</td>
<td>0.999***</td>
<td>0.00106</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.0011)</td>
<td>(0.0011)</td>
<td>-</td>
</tr>
<tr>
<td>$NL_t$</td>
<td>0.96***</td>
<td>0.043***</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.012)</td>
<td>-</td>
</tr>
<tr>
<td>$C/CC_t$</td>
<td>0.037***</td>
<td>0.85***</td>
<td>0.109***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.042)</td>
<td>(0.042)</td>
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<tr>
<td>$L_t$</td>
<td>0.0061</td>
<td>0.89***</td>
<td>0.105***</td>
</tr>
<tr>
<td></td>
<td>(0.0055)</td>
<td>(0.034)</td>
<td>(0.034)</td>
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<tr>
<td>$LL_t$</td>
<td>-</td>
<td>0.69***</td>
<td>0.31***</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>(0.092)</td>
<td>(0.092)</td>
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</tbody>
</table>
## Data and estimation

### Transition probabilities

<table>
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<tr>
<th></th>
<th>Under $\mathbb{Q}$</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$NL_{t+1}$</td>
<td>$L_{t+1}$</td>
<td>$LL_{t+1}$</td>
<td></td>
</tr>
<tr>
<td>$NC_t$</td>
<td>0.999***</td>
<td>0.0015***</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>$NL_t$</td>
<td>(0.00035)</td>
<td>(0.00035)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>$C/CC_t$</td>
<td>0.98***</td>
<td>0.021***</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0056)</td>
<td>(0.0056)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>$NC_t$</td>
<td>0.019***</td>
<td>0.000049</td>
<td>0.98***</td>
<td></td>
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<tr>
<td>$L_t$</td>
<td>(0.004)</td>
<td>(0.12)</td>
<td>(0.11)</td>
<td></td>
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<tr>
<td>$C/CC_t$</td>
<td>0.000048</td>
<td>0.00004</td>
<td>0.9999***</td>
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<td></td>
<td>(0.0046)</td>
<td>(0.13)</td>
<td>(0.13)</td>
<td></td>
</tr>
<tr>
<td>$LL_t$</td>
<td>-</td>
<td>1***</td>
<td>0.000049</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.088)</td>
</tr>
</tbody>
</table>
### Credit/Liquidity Risk Premia Analysis (5-year maturity)

<table>
<thead>
<tr>
<th></th>
<th>Expectation part of the spreads</th>
<th>Risk premiums</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Credit</td>
<td>Liquidity</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Austria</td>
<td>0.06</td>
<td>0.09</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.17</td>
<td>0.26</td>
</tr>
<tr>
<td>Finland</td>
<td>0.03</td>
<td>0.05</td>
</tr>
<tr>
<td>France</td>
<td>0.11</td>
<td>0.16</td>
</tr>
<tr>
<td>Germany</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>Italy</td>
<td>0.49</td>
<td>0.63</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Spain</td>
<td>0.45</td>
<td>0.63</td>
</tr>
</tbody>
</table>
Credit/Liquidity
Risk Premia Analysis (5-year maturity)

![Graphs showing credit and liquidity premia for various countries over time](image-url)
Regression analysis suggests that the different parts of the spreads are related to macro-finance indicators:

<table>
<thead>
<tr>
<th></th>
<th>Expectation part</th>
<th>Risk premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit</td>
<td>VSTOXX, IBOR-OIS, BVOL</td>
<td>VSTOXX, EUROSTOXX, BVOL</td>
</tr>
<tr>
<td>Liquidity</td>
<td>EUROSTOXX</td>
<td>IBOR-OIS, EUROSTOXX</td>
</tr>
</tbody>
</table>
Credit/Liquidity
Extracting default probabilities

- Once the model is estimated, one can derive implicit default probabilities.
- In the spirit of Litterman and Iben (1991), various basic methodologies result in risk-neutral PDs (Chan-Lau, 2006).
- In our framework, we can compute both the risk-neutral and the actual (or real-world) PDs.

⇒ Results: significant differences between actual and risk-neutral PDs.
Credit/Liquidity
Extracting default probabilities

- The actual PD between time $t$ and time $t + h$ is:

$$
\mathbb{P}_t \left( d_{t+h}^{(n)} = 1 \mid d_t^{(n)} = 0 \right),
$$

that is:

$$
1 - E_t^{\mathbb{P}} \left( \exp \left\{ \frac{1}{1 - \zeta} (-\lambda_{fc,t+1}^{(n)} - \ldots - \lambda_{fc,t+h}^{(n)}) \right\} \right)
$$

- We use a recovery rate of 50%
Credit/Liquidity
Extracting default probabilities (5-year PDs)
Credit/Liquidity

Extracting default probabilities (Term Structures of PDs)
Credit/Liquidity

Extracting default probabilities (5-year PDs)
Credit/Liquidity

Extracting default probabilities (5-year PDs)
Concluding remarks

- One of the few attempts to model simultaneously sovereign EA spreads in a no-arbitrage framework
- Innovative use of regime-switching features to model interactions between credit and liquidity pricing effects
- Empirical results:
  - Liquidity effects account for a substantial part of EA-spreads fluctuations, but credit aspects have dominated over the last two years
  - The existence of risk premia results in significant differentials between risk-neutral and actual PDs
Thank you for your attention.
Bid-Ask spreads: KfW vs Bund
Bid-Ask spreads: Euro-area sovereigns
The liquidity-related fractional-cost intensity: \( \lambda_{\ell,t}^{(n)} = (1 - \theta^{(n)}) \lambda_{\ell,t} \)

Fractional cost: \( 1 - \theta^{(n)} \).

\( \ell_t = 1 \Rightarrow \) the investor has to exit by selling her bond holdings.

- This liquidation has to be done in a limited period of time, between \( t \) and \( t + \varepsilon \), say (where \( \varepsilon << 1 \)).
- Random number \( K \) of offers from traders, \( K \sim \mathcal{P}(\gamma^{(n)}) \),...
- ... each offer is a random fraction \( \omega_i \) (\( i \in \{1, \ldots, K\} \)) of \( B_{t,h}^{(n)} \), \( \omega_i \sim \mathcal{U}([0, 1]) \).

The selling price is: \( \max_{i \in \{1, \ldots, K\}} (\omega_i) B_{t,h}^{(n)} = \theta(\gamma^{(n)}) \times B_{t,h}^{(n)} \), where \( \theta \) is monotonically increasing and valued in \([0, 1]\).