Changing systemic risks in Chinese bond market and risk premia in Treasury yields (Work in progress)

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Outline

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Introduction

- **The big questions**
  - Debt crisis: will China follow US and Europe?
  - Fiscal stimulus in China: an alternative QE, for growth or for bust?
  - Understanding evolvement of systemic risks in Chinese financial market

- **A special perspective**
  - Changes in the systemic risks reflected in bond yields
  - Comparative study of bond yields in a no-arbitrage framework on Treasury vs. Chengtou bonds (quasi municipal government bonds)

Three trends of Chinese debt market: 2009 - 2017

- First, the main driving force for overall debt issuance and outstanding volume is public sector debt (state-owned enterprises and local government related).

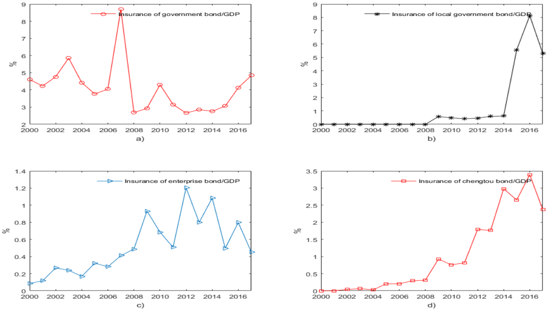

Figure 1: Bond Issuance as percentage of GDP (2000 – 2017)

Three trends of Chinese debt market: 2009 - 2017

- A pertaining structural imbalance of fiscal power and responsibility between central and local governments.

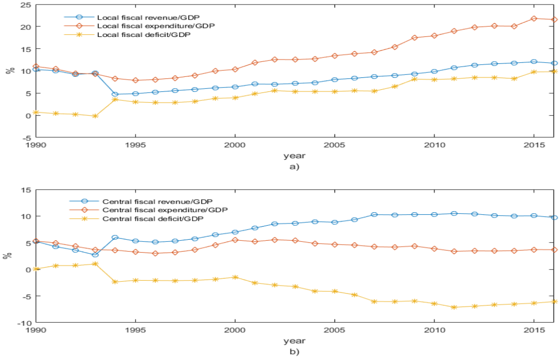

Figure 2: Fiscal deficit of local and central governments (1990-2016)

Three trends of Chinese debt market: 2009 - 2017

- Since 2015, legal issuance of local government bonds hand in hand with the debt replacement program lead to increased transparency but skyrocketing scale.

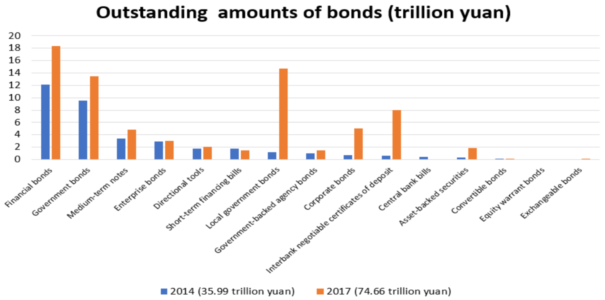

Figure 3: Outstanding debt volume: 2014 vs. 2017

Three trends of Chinese debt market: 2009 - 2017

Second, as debt grows, credit structure deteriorates, most evident from Chengtou bond with high degree of marketization.

Table 1: Structure of Chengtou bonds with different credit ratings

a: Issuer's credit rating of Chengtou bond issuance (Percentage in volume)									
Level	2009	2010	2011	2012	2013	2014	2015	2016	2017
AAA	50.92%	28.61%	21.46%	14.62%	24.01%	22.08%	28.19%	31.09%	41.68%
AA+	28.42%	40.54%	39.49%	35.24%	30.71%	31.32%	34.25%	32.28%	27.11%
AA	19.99%	29.86%	35.33%	48.35%	44.59%	46.35%	37.34%	36.62%	30.90%
AA-	0.67%	0.99%	3.72%	1.79%	0.69%	0.24%	0.22%	0.02%	0.31%
b: Bond's credit rating of Chengtou bond issuance (Percentage in volume)									
Level	2009	2010	2011	2012	2013	2014	2015	2016	2017
AAA	46.76%	28.66%	27.47%	17.23%	19.77%	22.10%	27.57%	23.92%	29.81%
AA+	37.41%	46.34%	39.91%	36.32%	34.36%	28.06%	32.43%	30.09%	28.80%
AA	15.11%	23.78%	31.76%	43.92%	44.15%	49.10%	37.76%	42.93%	37.70%
AA-	0.72%	1.22%	0.86%	2.53%	1.73%	0.74%	2.24%	3.06%	3.68%
c: Bond's credit rating of outstanding Chengtou bond (Percentage in total volume)									
Level	2009	2010	2011	2012	2013	2014	2015	2016	2017
AAA	63.62%	41.24%	36.75%	25.77%	30.71%	29.05%	31.40%	28.08%	23.14%
AA+	26.93%	38.85%	37.41%	34.98%	33.46%	28.43%	25.18%	25.19%	35.77%
AA	8.99%	19.47%	25.31%	37.83%	35.38%	42.31%	39.85%	43.00%	37.06%
AA-	0.46%	0.44%	0.53%	1.41%	0.45%	0.21%	3.56%	3.73%	4.02%

Data source: Wind Database

Three trends of Chinese debt market: 2009 - 2017

- Third, as a tip of the iceberg of public sector debt, credit risks began to be gradually priced into Chengtou bond yield spreads.

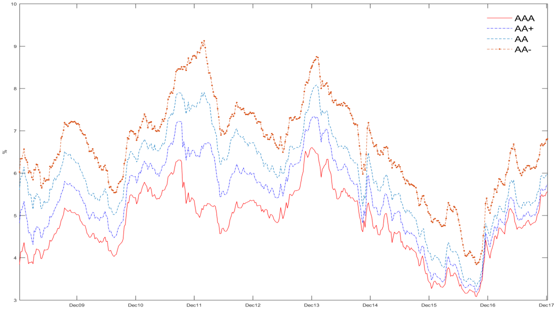

Figure 4: Chengtou bond spread (5-year yield spreads of various ratings)

Introduction

- **A specific question**

  To which extent the public sector debt problem exposes China's fiscal and financial system to risks?

- **Steps to approaching the answer with bond yield data**
  1) Constructing systemic bond risk measures from Chengtou bond spreads (liquidity risk, credit risk, maturity risk)
  2) Modeling Joint dynamics of systemic bond risks and Treasury yields with no-arbitrage restrictions
  3) How do systemic bond risks evolve?
  4) How do systemic bond risks affect Treasury yield curve and vice versa?
  5) Pricing of systemic bond risks in Treasury bond risk premia.

Outline

Literature Review

1) **Accumulation of local governmental debt and systemic risks**

龚强(2011) literature survey, 徐高& 王艺伟(2013) on detailed development of chengtou bonds, 范剑勇& 莫家伟(2014) on local debt, land market and regional industrial growth with distortion and systemic risks, 郭玉清(2011) on financial stability linked to non-performing bank loans of LGFVs

Literature Review

2) **Determinants of chengtou bond spreads and the relationship with risk free rates**

- Ang et. al (2016), panel data analysis on chengtou bond spreads across regions. Risk factors： real estate market, degree of corruption
- Relationship between credit spread and risk free yields: Merton (1974), Longstaff & Schwartz (1995) , Duffee(1998) , etc.
- Negative relationship found between corporate bond spreads and Treasury yields (Dai and Sun, 2011, Wang et al, 2014) within a reduced-form model

Literature Review

3) **Macro-finance study on Treasury yield curves**

- Interaction between macro fundamentals and yield factors: Taylor (1993), Ang & Piazzesi (2003), Diebold et al. (2005), etc.
- Dai & Philippon (2004): US fiscal deficit as a macro factor for yield curve modeling

Literature Review

- **What we do in this paper**
  - Using price information to investigate systemic risks caused by local public debt accumulation and their impacts on Treasury yields: quick, market expectation
  - Jointly modeling multiple Chengtou yield curves with Treasury yield curve in a parsimouneous no-arbitrage framework (in progress)

The framework is derived from

- Affine arbitrage-free Nelson-Siegel (AFNS) term structure model (Christensen, et al., 2009)
- AFNS in discrete time (Hong, Niu and Zeng, 2015)
- Affine arbitrage-free extended Nelson-Siegel (AFENS) model with additional factors beyond the NS three yield factors (Li, Niu and Zeng, 2012).

Outline

Data description

- **Sample period:** beginning of 2009 to the end of 2017
- **Frequency:** weekly
- **Treasury yields:** interbank spot rate 1-10 years
- **Chengtou yields of AAA, AA+, AA, AA- ratings:** interbank 1-7 years
- **Data source:** WIND financial database

Data description

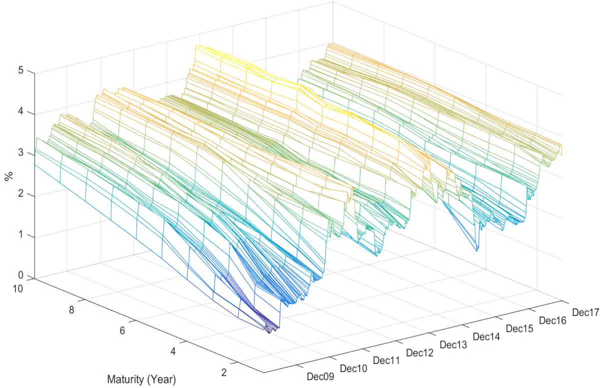

Figure 5: Treasury yield curve in China (2009 – 2017)

Risk factor proxy of Chengtou spreads

Liquidity factor (Lq): Average spread between AAA Chengtou yields and Treasury yields $Lq_t = \bar{y}_t^{AAA} - \bar{y}_t^{T}$

Credit risk factor (Cr):

1) Average spreads between lower rating Chengtou yields and AAA Chengtou yields: $S_t^{AAA-} = \bar{y}_t^{AAA-} - \bar{y}_t^{AAA}$, S_t^{AA+}, S_t^{AA}, S_t^{AA-}
2) Residual from the regression of S_t^{AAA-}, S_t^{AA+}, S_t^{AA} and S_t^{AA-} on Lq_t
3) Extract the first principle component from the residuals of step 2)

Risk factor proxy of Chengtou spreads

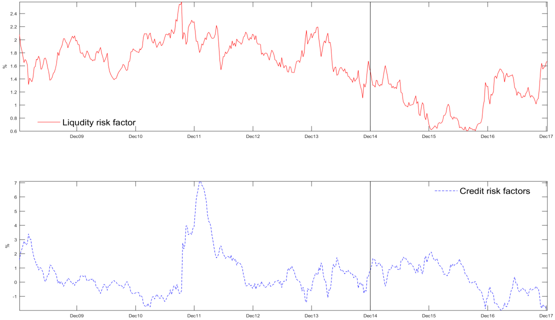

Figure 6: Two risk proxies constructed from Chengtou spreads

Break test on the risk factors around the end of 2014

Table 2: Break test on the risk factors

Chow Breakpoint Test: 12/31/2014				
Null Hypothesis: No breaks at specified breakpoints				
Varying regressors: All equation variables				
Equation Sample: 1/16/2009-1/05/2018				
Liquidity factor	F-statistic	3.750	Prob. F(6,454)	0.001
	Log likelihood ratio	22.540	Prob. Chi-Square(6)	0.001
	Wald Statistic	22.499	Prob. Chi-Square(6)	0.001
Credit risk factor	F-statistic	1.686	Prob. F(6,454)	0.123
	Log likelihood ratio	10.272	Prob. Chi-Square(6)	0.114
	Wald Statistic	10.118	Prob. Chi-Square(6)	0.120

Outline

Building blocks

- State variables:

  NS factors $X_t^{NS} = [L_t, S_t, C_t]$ of the Treasury yields and the chengtou risk factor $Sp_t = [Lq_t,\ Cr_t]$

- Short rate equation

  $r_t = \delta_0 + \delta_1' X_t$ where δ_0 is a scale and $\delta_1 = \left[1, \frac{1-e^{-\lambda}}{\lambda}, \frac{1-e^{-\lambda}}{\lambda} - e^{-\lambda}, \delta_1^{Sp}\right]'$.

- Dynamics of factors under the physical measure

$$X_t = \mu + \Phi X_{t-1} + v_t \qquad v_t \sim N(0, \Omega) \tag{1}$$

where $X_t = \left[X_t^{NS}, Sp_t\right]'$.

Building blocks

- Dynamics of factors under the risk-neutral measure

$$\begin{bmatrix} X_t^{NS} \\ Sp_t \end{bmatrix} = \begin{bmatrix} \mu^{NS^Q} \\ \mu^{Sp^Q} \end{bmatrix} + \begin{bmatrix} \Phi^{NS^Q} & 0 \\ \Phi^{SpNS^Q} & \Phi^{Sp^Q} \end{bmatrix} \begin{bmatrix} X_{t-1}^{NS} \\ Sp_{t-1} \end{bmatrix} + v_t^Q \qquad v_t^Q \sim N(0, \Omega) \tag{2}$$

where $\mu^{NS^Q} = \begin{bmatrix} \mu^{L^Q} & 0 & 0 \end{bmatrix}'$, $\Phi^{NS^Q} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & e^{-\lambda} & \lambda e^{-\lambda} \\ 0 & 0 & e^{-\lambda} \end{bmatrix}$

Building blocks

- Treasury yield curve determination

$$
\begin{aligned}
y_t^n &= a_n^{NS} + b_n^{NS\prime} X_t^{NS} \\
&= -\frac{1}{n}\left(A_n^{NS} + B_n^{NS\prime} X_t^{NS}\right)
\end{aligned} \tag{3}
$$

where

$$
\begin{cases}
A_{n+1}^{NS} &= A_n^{NS} + B_n^{NS\prime}\mu^{NS^Q} + \frac{1}{2} B_n^{NS\prime}\Omega^{NS} B_n^{NS} + A_1^{NS} \\
B_{n+1}^{NS\prime} &= B_n^{NS\prime}\Phi^{NS^Q} + B_1^{NS\prime}
\end{cases}, \tag{4}
$$

$A_1^{NS} = -\delta_0^{NS}$ and $B_1^{NS} = -\delta_1^{NS}$.

Building blocks

- Yield decomposition: expectation and risk premium

$$\tilde{y}_t^n = -\frac{1}{n}\left(\tilde{A}_n + \tilde{B}_n' X_t\right) \tag{5}$$

where

$$\begin{cases} \tilde{A}_{n+1} = \tilde{A}_n + \tilde{B}_n'\mu + \frac{1}{2}\tilde{B}_n'\Omega\tilde{B}_n - \delta_0 \\ \tilde{B}_{n+1} = \Phi'\tilde{B}_n - \delta_1 \end{cases}$$

$$\begin{aligned} RP_t^n &= y_t^n - \tilde{y}_t^n \\ &= -\frac{1}{n}\left(A_n^{NS} + B_n^{NS\prime} X_t^{NS}\right) + \frac{1}{n}\left(\tilde{A}_n + \tilde{B}_n' X_t\right) \end{aligned}$$

Econometric representation

The econometric representation of the model given by Equations (1 -5) can be expressed as follows,

$$\begin{cases} Y_t = A + BX_t + \epsilon_t & \epsilon_t \sim N(0, \sigma^2 I) \\ X_t = \mu + \Phi X_{t-1} + v_t & v_t \sim N(0, \Omega) \end{cases} \quad (6)$$

where Y_t is the column vector containing the yields of government bonds, A and B are determined by the parameters μ^{L^Q}, λ and Ω.

Estimation method: MCMC

Denote $\Theta_1 = \{\mu^{L^Q}, \lambda, \sigma\}$, $\Theta_2 = \{\mu, \Phi, \Omega\}$, we apply MCMC method to estimate the model. The main steps of the MCMC estimation are shown as follows,

- Given $\Theta_1^{(s-1)}$, $\Theta_2^{(s-1)}$ and the observable data Y_t, drawing $X_t^{(s)}$
- Given $\Theta_1^{(s-1)}$, $\Theta_2^{(s-1)}$, $X_t^{(s)}$, and the observable data Y_t, drawing $\Theta_2^{(s)}$
- Given $\Theta_1^{(s-1)}$, $\Theta_2^{(s)}$, $X_t^{(s)}$, and the observable data Y_t, drawing $\Theta_1^{(s)}$

Outline

The measurement equation representation

$$\left\{\begin{array}{lllllllll} y_{t,n}^{T} & = & a_n^{T} & + & b_n^{NS\prime} X_t^{NS} & & & & \\ y_{t,n}^{AAA} & = & a_n^{AAA} & + & b_n^{NS\prime} X_t^{NS} & + & b_n^{AAA\prime} Sp_t & + & c_n^{AAA\prime} f_t^{AAA} \\ y_{t,n}^{AA+} & = & a_n^{AA+} & + & b_n^{NS\prime} X_t^{NS} & + & b_n^{AA+\prime} Sp_t & + & c_n^{AA+\prime} f_t^{AA+} \\ y_{t,n}^{AA} & = & a_n^{AA} & + & b_n^{NS\prime} X_t^{NS} & + & b_n^{AA\prime} Sp_t & + & c_n^{AA\prime} f_t^{AA} \\ y_{t,n}^{AA-} & = & a_n^{AA-} & + & b_n^{NS\prime} X_t^{NS} & + & b_n^{AA-\prime} Sp_t & + & c_n^{AA-\prime} f_t^{AA-} \end{array}\right. \tag{7}$$

where Sp_t contains the common risk factors which are spanned for chengtou yield curve but unspanned for treasury yield curve, and f_t^{AAA}, f_t^{AA+}, f_t^{AA} and f_t^{AA-} are individual risk factors of chengtou yields with various credit ratings.

Outline

Full sample estimation of model parameters

Table 3: **Parameters estimation under risk-neutral and physical measures**

Θ_1	μ_L^Q	λ	σ		
	-4.85E-07 ***	8.15E-03 ***	9.18E-06 ***		
Θ_2					
	L	S	C	Lq	Cr
μ	3.34E-05 ***	-2.32E-05	-9.94E-05 **	-2.86E-05 **	1.53E-04 **
	0.959 ***	-0.003	0.003	0.027	0.001
	0.029	0.987 ***	0.011	-0.031	-0.009
Φ	0.115	0.016	0.930 ***	-0.119 *	-0.010
	0.050 ***	0.007	0.008 **	0.944 ***	0.001
	-0.252 ***	-0.018	-0.009	0.333 **	0.971 ***
	3.63E-10 ***	-2.15E-10 ***	-8.01E-10 ***	4.99E-11 **	-2.34E-10 ***
	-2.15E-10 ***	9.16E-10 ***	-3.89E-10 **	3.71E-11	-6.29E-11
Ω	-8.01E-10 ***	-3.89E-10 **	5.01E-09 ***	-3.05E-10 ***	1.13E-09 ***
	4.99E-11 **	3.71E-11	-3.05E-10 ***	2.53E-10 ***	-7.84E-10 ***
	-2.34E-10 ***	-6.29E-11	1.13E-09 ***	-7.84E-10 ***	3.76E-09 ***

Note: This table presents the parameters estimation by MCMC method. $*$, $**$ and $***$ represent significantly rejecting the null hypothesis at levels of the 10%, 5% and 1%, respectively.

Goodness of fit for Treasury yields

Table 4: **Goodness of fit for Treasury yields**

Maturity (Year)	Mean of error	Std of error	MAE	RMSE
1-y	0.53	3.87	3.02	3.90
2-y	-0.95	6.08	4.61	6.15
3-y	-0.51	4.44	3.33	4.46
4-y	-0.10	3.62	2.71	3.62
5-y	3.16	4.73	4.76	5.68
6-y	-1.68	4.42	3.63	4.73
7-y	-0.47	3.88	3.20	3.90
8-y	-0.52	2.90	2.20	2.94
9-y	0.25	2.23	1.66	2.24
10-y	0.27	3.57	2.74	3.58
Average	0.00	3.97	3.19	4.12

Note: The unit is bp.

Factor dynamics (full sample)

Figure 7: Factor dynamics (full sample)

Comparison on subsample 1 (2009-2014) and subsample 2 (2015 – 2017)

Table 5: **Estimation of model parameters in the state VAR (2009-2014)**

	L	S	C	Lq	Cr
μ	4.32E-05 **	2.36E-05	-1.47E-04 *	1.15E-05	2.19E-05
	0.954 ***	-0.003	0.004	-0.001	0.003
	-0.005	0.986 ***	0.015	-0.058	-0.006
Φ	0.147	0.017	0.920 ***	-0.012	-0.015
	0.017	0.004	0.012 **	0.935 ***	0.003
	-0.157 *	-0.007	-0.017	0.351 ***	0.967 ***
	2.86E-10 ***	-1.97E-10 ***	-5.72E-10 ***	4.18E-11	-2.01E-10 *
	-1.97E-10 ***	9.55E-10 ***	-3.71E-10 *	4.72E-11	-1.80E-10
Ω	-5.72E-10 ***	-3.71E-10 *	4.69E-09 ***	-3.95E-10 ***	1.52E-09 ***
	4.18E-11	4.72E-11	-3.95E-10 ***	2.74E-10 ***	-8.72E-10 ***
	-2.01E-10 *	-1.80E-10	1.52E-09 ***	-8.72E-10 ***	4.50E-09 ***

Note: This table presents the parameters estimation by MCMC method. $*$, $**$ and $***$ represent significantly rejecting the null hypothesis at levels of the 10%, 5% and 1%, respectively.

Comparison on subsample 1 (2009-2014) and subsample 2 (2015 – 2017)

Table 6: **Estimation of model parameters in the state VAR (2015-2017)**

	L	S	C	Lq	Cr
μ	1.09E-04 ***	-2.98E-05	-4.15E-04 ***	-7.25E-05 ***	2.50E-04 ***
	0.876 ***	-0.001	0.024 *	0.056	-0.017
	0.025	0.951 ***	0.012	-0.045	-0.029 *
Φ	0.502 **	0.042	0.861 ***	-0.332	0.040
	0.125 **	0.006	0.006	0.822 ***	-0.019 ***
	-0.446 ***	-0.057	-0.006	0.645 ***	1.010 ***
	5.63E-10 ***	-2.73E-10 ***	-1.36E-09 ***	4.31E-11	-2.43E-10 **
	-2.73E-10 ***	1.13E-09 ***	-8.19E-10 ***	4.47E-11	3.31E-11
Ω	-1.36E-09 ***	-8.19E-10 ***	6.97E-09 ***	-1.34E-10	4.91E-10
	4.31E-11	4.47E-11	-1.34E-10	1.98E-10 ***	-5.85E-10 ***
	-2.43E-10 **	3.31E-11	4.91E-10	-5.85E-10 ***	2.36E-09 ***

Note: This table presents the parameters estimation by MCMC method. $*$, $**$ and $***$ represent significantly rejecting the null hypothesis at levels of the 10%, 5% and 1%, respectively.

Impulse responses of yields to liquidity shock (2009-2014)

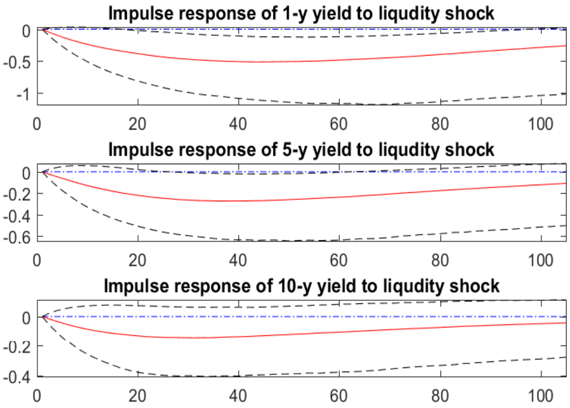

Figure 8: Impulse responses of yields to liquidity shock (2009-2014)

Impulse responses of yields to liquidity shock (2015-2017)

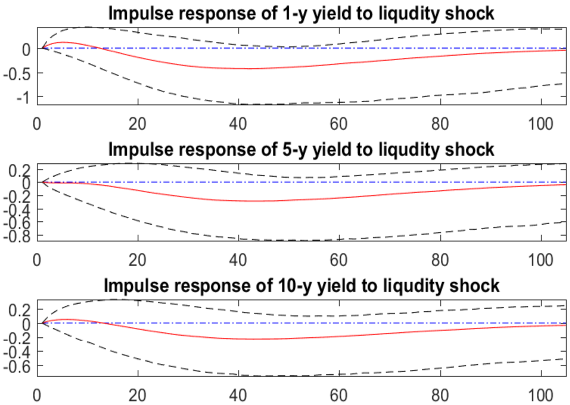

Figure 9: Impulse responses of yields to liquidity shock (2015-2017)

Impulse responses of yields to credit risk shock (2009-2014)

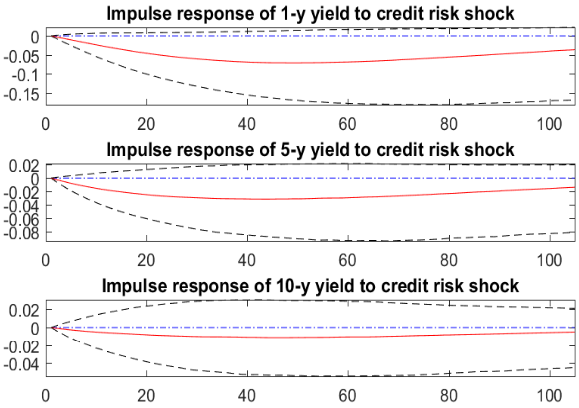

Figure 10: Impulse responses of yields to credit risk shock (2009-2014)

Impulse responses of yields to credit risk shock (2015-2017)

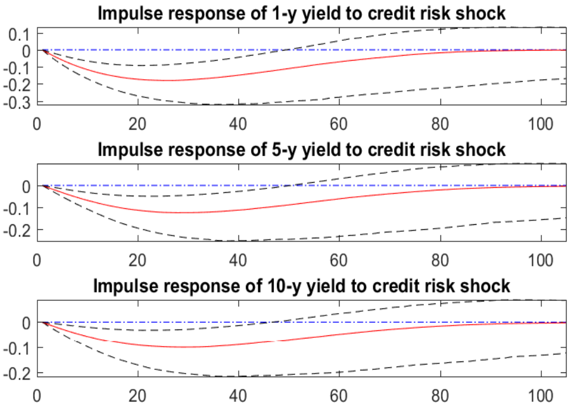

Figure 11: Impulse responses of yields to credit risk shock (2015-2017)

Impulse responses of yield expectation and risk premia to liquidity shock (2009-2014)

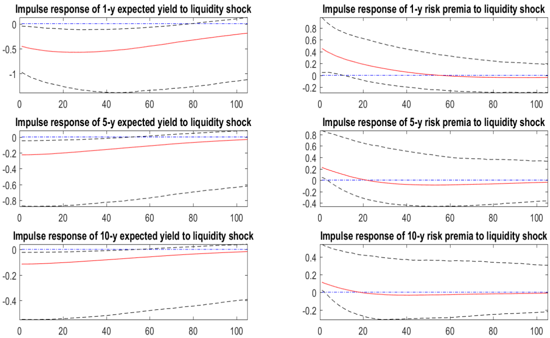

Figure 12: Impulse responses of yield expectation and risk premia to liquidity shock (2009-2014)

Impulse responses of yield expectation and risk premia to liquidity shock (2015-2017)

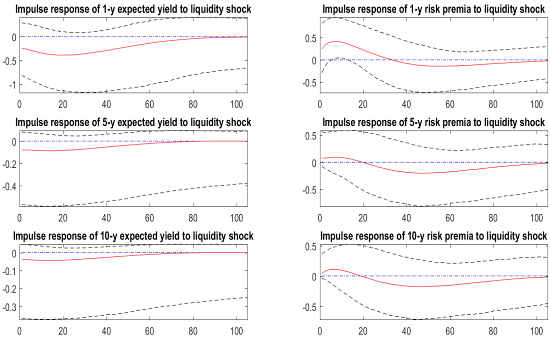

Figure 13: Impulse responses of yield expectation and risk premia to liquidity shock (2015-2017)

Impulse responses of yield expectation and risk premia to credit risk shock (2009-2014)

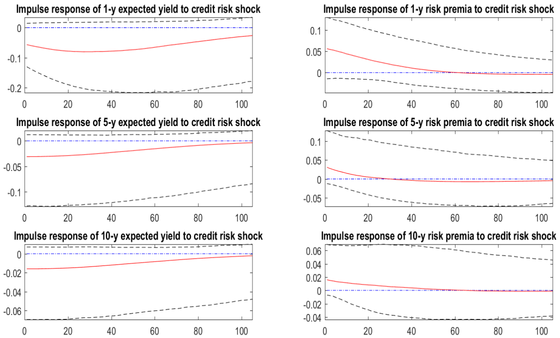

Figure 14: Impulse responses of yield expectation and risk premia to credit risk shock (2009-2014)

Impulse responses of yield expectation and risk premia to credit risk shock (2015-2017)

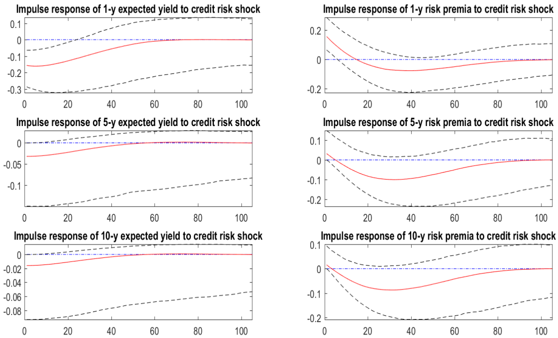

Figure 15: Impulse responses of yield expectation and risk premia to credit risk shock (2015-2017)

Impulse responses of liquidity risk and credit risk (2009-2014)

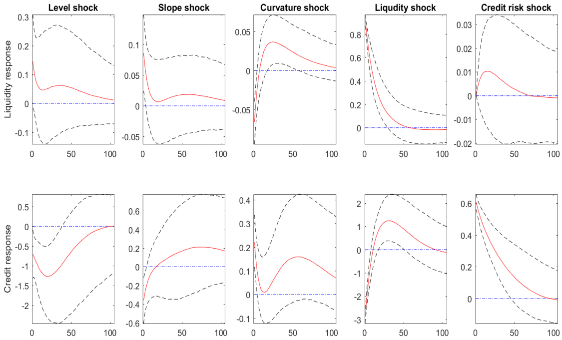

Figure 16: Impulse responses of liquidity risk and credit risk (2009-2014)

Impulse responses of liquidity risk and credit risk (2015-2017)

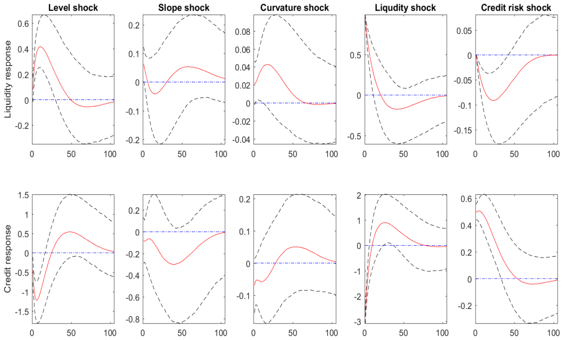

Figure 17: Impulse responses of liquidity risk and credit risk (2015-2017)

Outline

Conclusions (for now)

- Evolving systemic bond market risks from liquidity risk (2009-2014) to credit risk (2015-2017)
- Risks from local public debt significantly affect the Treasury yields: flight to liquidity (2009-2014), flight to safety (2015-2017)
- Systemic risks significantly priced in Treasury bond risk premia
- Further work on jointly model the Treasury yield curve together with multiple Chengtou yield curves with a set of risk factors.