The response of euro area sovereign spreads to the ECB unconventional monetary policies *

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*The opinions expressed are strictly those of the authors and do not necessarily reflect the views of the National Bank of Belgium

Motivation, research question and contribution

Motivation: Why UMPs in the EA?

- Fragmented response to changes in ECB policy rate (MRO)

  Lehman Brothers collapse: heightened concerns about counterparty credit and liquidity risk on EA interbank market

  $\Rightarrow$ Disconnect between main policy rate and interbank rate
  $\Rightarrow$ Some banks couldn't access market funding
  $\Rightarrow$ Threat to financial stability $\Rightarrow$ implication for medium-term price stability

  Sovereign credit rating affects rating of domestic banks

  $\Rightarrow$ Impact on borrowing and lending conditions
  $\Rightarrow$ Transmission to real economy
  $\Rightarrow$ Implication for medium-term price stability

  Redenomination risk negative feedback loop

  $\Rightarrow$ Markets require higher compensation for redenomination/breakout risk
  $\Rightarrow$ Worsening of sovereign borrowing conditions
  $\Rightarrow$ Upward revision of redenomination/default probability

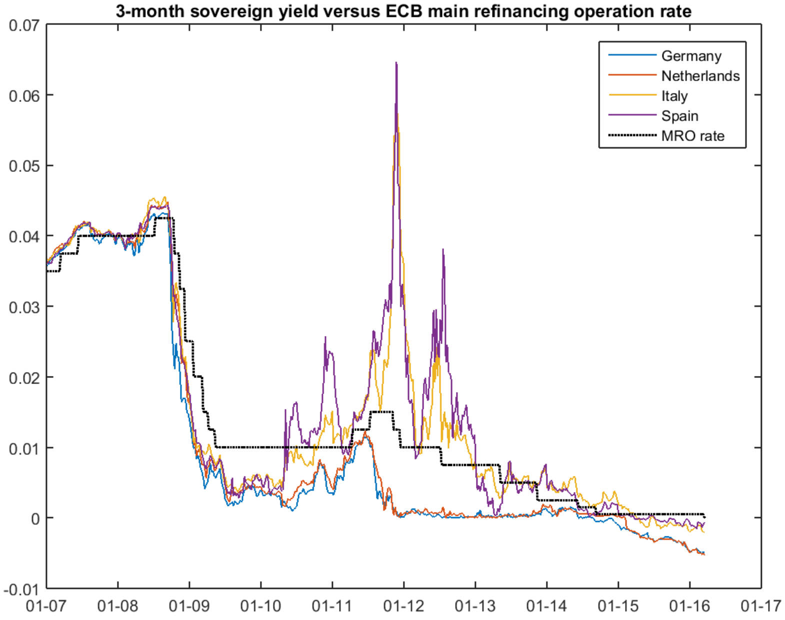
3-month sovereign yield versus ECB main refinancing operation rate
Germany
Netherlands
Italy
Spain
MRO rate
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
01-07
01-08
01-09
01-10
01-11
01-12
01-13
01-14
01-15
01-16
01-17

Table: Identified event dates for unconventional monetary policy announcements

Announcement date	Program	Event
10/05/2010	SMP	Initial announcement
8/08/2011	SMP	Extension to Italy and Spain
1/12/2011	VLTRO	Draghi's speech at European parliament
8/12/2011	VLTRO	Announcement of 3-year LTROs
26/07/2012	OMT	Draghi's "whatever it takes" speech
2/08/2012	OMT	OMT mentionned at conference press
6/09/2012	OMT	Official announcement
4/07/2013	FG	"expects the key ECB interest rates to remain at present or lower levels for an extended period of time"
9/01/2014	FG	Governing Council "firmly reiterated" its forward guidance
6/03/2014	FG	Governing Council reinforced the guidance formulation
5/06/2014	TLTRO	ABSPP and announcement of 4-year TLTROs
22/08/2014	APP	Draghi's speech at Jackson Hole
4/09/2014	APP	ABSPP and CBPP3
2/10/2014	APP	ABSPP and CBPP3
6/11/2014	APP	"Should it become necessary (...) commitment to using additional unconventional instruments within its mandate.". Also mention of preparatory work for additional measures.
21/11/2014	APP	Draghi's speech at the Frankfurt European Banking Congress
22/01/2015	APP	PSPP
10/03/2016	APP	CSPP and announcement of new 4-year TLTROs

Research question

- By what channels of transmission have ECB's unconventional monetary policies impacted EA yields/spreads?
- Channel(s) of transmission?

$$y_t^i(\tau) = ec_t^{rf}(\tau) + tp_t^{rf}(\tau) + es_t^{spr}(\tau) + rr_t^{spr}(\tau)$$

  - $ec_t^{rf}(\tau) =$ Signalling channel
  - $tp_t^{rf}(\tau) =$ Portfolio rebalancing channel
  - $es_t^{spr}(\tau) =$ Fragmentation channel: Expected average short term spread
  - $rr_t^{spr}(\tau) =$ Repricing of risk channel: risk premium for unexpected changes in average future short term spreads

Summary of results

- Accounting for the lower bound results in less volatile and less negative term premia
- For Spain and Italy UMP worked both via the ES and RR components
- For Belgium and France UMP worked via the RR component

Methodology and Contribution

- Methodology
  - Event study: Christensen and Rudebusch (2012)
  - Spread decomposition: Expected component and risk premium (Pan and Singleton (2008), Dubecq et al. (2016))
  - Multi-market SR-DTSM with default risk
- Contribution
  - Comprehensive study of ECB's unconventional monetary policy interventions
  - Impact of the different programs on EA yield spreads
  - Multi market EA model + SR-DTSM

Modelling

Summary of modelling strategy

Mix of two models

- Shadow-rate (SR) model OIS
- Affine specification for spreads

Modeling strategy: two-step procedure

- First estimate the OIS curve
- Fix the OIS parameters/factors and estimate country yield curve

ML estimation

- KF (affine specification)
- EKF (SR model)

Linear and non-linear models

The **instantaneous risk-free rate** is constrained by a lower bound:

$$\underline{r}_t = \max\left(r_t, r_t^{lb}\right),\ r_t^{lb} = \min\left(r_t^d, 0\right) \tag{1}$$

The **shadow short rate** r_t is function of two factors:

$$r_t = x_{l,t}^{ois} + x_{s,t}^{ois}$$

The **instantaneous interest rate for country i** is linear in the pricing factors:

$$r_t^i = r_t + \lambda_t^i \tag{2}$$

$$\begin{aligned} \lambda_t^i &= \boldsymbol{\rho}_1^{i\intercal}\ \tilde{\boldsymbol{x}}_t^i \\ &= \rho_{ois,l}^i\ x_{l,t}^{ois} + \rho_{ois,s}^i\ x_{s,t}^{ois} + x_{l,t}^i + x_{s,t}^i \end{aligned} \tag{3}$$

Shadow rate and observed margin deposit rate

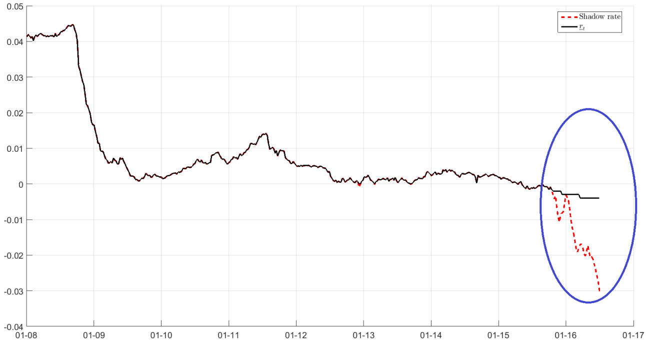

Figure: Observed/constrained rate (Black) - Shadow rate (Red)

Pricing the yield curves

Given the instantaneous risk-free rate (additional elements) bond yields are expressed as (Duffie and Kan, 1996):

$$
\begin{aligned}
y_t^{ois}(\tau) &= -\frac{1}{\tau}\log \mathbb{E}^{\mathbb{Q}}\left[exp\left(-\int_t^{t+\tau} r_v \; dv\right)\right] \\
&= -\frac{1}{\tau}a^{ois}(\tau) - \frac{1}{\tau}\boldsymbol{b}^{ois}(\tau)^{\intercal}\boldsymbol{x}_t^{ois} \qquad (4)
\end{aligned}
$$

Were $\mathbb{E}^{\mathbb{Q}}$ is the expectation taken under the "risk neutral" world, i.e. by changing the probability measure while to into account of risk pricing.

Change of measure

Idea of changing probabilities is counter-intuitive, illustrate with example of loading a die

- Suppose you make a bet where you roll a dice and you get an amount of money (Euro) equal to the face of the dice
- Expected value of the bet is **3.5** Euro, Variance is 2.9
- By loading the dice, it is possible to change the expected value of the bet while keeping the variance the same (Change of measure). For example the expected value can become **2.5**.
- In term structure models the change of measure is made in order to take into account of risk and in order to price bonds in a "risk adjusted world"

Expected and risk premium components

We can compute the expected and risk premium component for this dice example

- The **expected** component is computed without taking into account of risk: the outcome of the bet without loading the dices, **3.5**.
- The **term premium** component is computed as the difference between the outcome of the bet with loaded dices and fair dices, so $2.5 - 3.5 = 1$

This technique is applied in our model to obtain the decomposition of countries' yield:

$$y_t^i(\tau) = ec_t^{rf}(\tau) + tp_t^{rf}(\tau) + es_t^{spr}(\tau) + rr_t^{spr}(\tau)$$

- $ec_t^{rf}(\tau) =$ Signalling channel
- $tp_t^{rf}(\tau) =$ Portfolio rebalancing channel
- $es_t^{spr}(\tau) =$ Fragmentation channel: Expected average short term spread
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Yield curve modelling

Affine specification for the OIS yield curve (1/2)

The short rate is given by the level and slope factors

$$r_t = \boldsymbol{\rho}_1^{ois\intercal}\ \boldsymbol{x}_t^{ois}$$
$$r_t = x_{l,t}^{ois} + x_{s,t}^{ois} \tag{5}$$

The state dynamics of $\boldsymbol{x}_t^{ois} = \left(x_{l,t}^{ois}\ x_{s,t}^{ois}\ x_{c,t}^{ois}\right)^\intercal$ under the historical $\mathbb{P}$-measure solve the following SDEs :

$$d\boldsymbol{x}_t^{ois} = \kappa_{ois}^{\mathbb{P}}\left(\boldsymbol{\theta}_{ois}^{\mathbb{P}} - \boldsymbol{x}_t^{ois}\right)dt + \boldsymbol{\sigma}_{ois}\ d\boldsymbol{w}_t^{ois,\mathbb{P}} \tag{6}$$

The market price of risk vector $\boldsymbol{\gamma}_t$ is essentially affine (Duffee (2002))

$$\boldsymbol{\gamma}_t = \boldsymbol{\gamma}_0 + \boldsymbol{\gamma}_1\ \boldsymbol{x}_t^{ois} \tag{7}$$

Assuming there exist an equivalent risk-neutral $\mathbb{Q}$-measure, we have:

$$d\boldsymbol{x}_t^{ois} = \boldsymbol{\kappa}_{ois}^{\mathbb{Q}}\left(\boldsymbol{\theta}_{ois}^{\mathbb{Q}} - \boldsymbol{x}_t^{ois}\right)dt + \boldsymbol{\sigma}_{ois}\ d\boldsymbol{w}_t^{ois,\mathbb{Q}} \tag{8}$$
$$\boldsymbol{\kappa}_{ois}^{\mathbb{Q}} = \boldsymbol{\kappa}_{ois}^{\mathbb{P}} + \boldsymbol{\sigma}_{ois}\boldsymbol{\gamma}_1$$
$$\boldsymbol{\kappa}_{ois}^{\mathbb{Q}}\boldsymbol{\theta}_{ois}^{\mathbb{Q}} = \boldsymbol{\kappa}_{ois}^{\mathbb{P}}\boldsymbol{\theta}_{ois}^{\mathbb{P}} - \boldsymbol{\sigma}_{ois}\boldsymbol{\gamma}_0$$

Affine specification for the OIS yield curve (2/2)

Duffie and Kan (1996):

$$y_t^{ois}(\tau) = -\frac{1}{\tau} \log \mathbb{E}^{\mathbb{Q}} \left[exp \left(- \int_t^{t+\tau} r_v \, dv \right) \right]$$
$$= -\frac{1}{\tau} a^{ois}(\tau) - \frac{1}{\tau} \boldsymbol{b}^{ois}(\tau)^{\intercal} \boldsymbol{x}_t^{ois} \quad (9)$$

with $a^{ois}(\tau)$ and $\boldsymbol{b}^{ois}(\tau)$ solving the following system of ODEs :

$$\frac{da^{ois}(\tau)}{d\tau} = \boldsymbol{b}^{ois}(\tau)^{\intercal} \boldsymbol{\kappa}_{ois}^{\mathbb{Q}} \boldsymbol{\theta}_{ois}^{\mathbb{Q}} + \frac{1}{2} tr \left(\boldsymbol{\sigma}_{ois}^{\intercal} \boldsymbol{b}^{ois}(\tau) \boldsymbol{b}^{ois}(\tau)^{\intercal} \boldsymbol{\sigma}_{ois} \right), \quad a^{ois}(0) = 0 \quad (10)$$

$$\frac{d\boldsymbol{b}^{ois}(\tau)}{d\tau} = -\boldsymbol{\rho}_1^{ois} - \boldsymbol{\kappa}_{ois}^{\mathbb{Q}\intercal} \boldsymbol{b}^{ois}(\tau), \quad \boldsymbol{b}^{ois}(0) = 0 \quad (11)$$

Following Christensen et al. (2011):

- OIS factor loadings $\boldsymbol{B}^{ois}(\tau) \equiv -\frac{1}{\tau} \boldsymbol{b}^{ois}(\tau)$ are N-S level, slope and curvature:

$$\boldsymbol{B}^{ois}(\tau) = \left[1 \quad \frac{1 - e^{-\kappa^{ois}\tau}}{\kappa^{ois}\tau} \quad \frac{1 - e^{-\kappa^{ois}\tau}}{\kappa^{ois}\tau} - e^{-\kappa^{ois}\tau} \right]^{\intercal}$$

- We restrict $\boldsymbol{\sigma}_{ois}$ to be diagonal

OIS and 1 country: affine specification

In the spirit of Christensen et al. (2014), we add 2 country-specific factors (level and slope).

The short rate for country i is given by:

$$r_t^i = r_t + \lambda_t^i \tag{12}$$

$$\lambda_t^i = \boldsymbol{\rho}_1^{i\intercal}\ \tilde{\boldsymbol{x}}_t^i$$

$$= \rho_{ois,l}^i\ x_{l,t}^{ois} + \rho_{ois,s}^i\ x_{s,t}^{ois} + x_{l,t}^i + x_{s,t}^i \tag{13}$$

The joint state dynamics of the OIS risk factors and of the country-specific factors $\boldsymbol{x}_t^i$ under the historical $\mathbb{P}$-measure solve the following SDEs :

$$d\begin{pmatrix} \boldsymbol{x}_t^{ois} \\ \boldsymbol{x}_t^i \end{pmatrix} = \begin{pmatrix} \boldsymbol{\kappa}_{ois}^{\mathbb{P}} & \mathbf{0} \\ \boldsymbol{\kappa}_{ois\to i}^{\mathbb{P}} & \boldsymbol{\kappa}_i^{\mathbb{P}} \end{pmatrix} \left[\begin{pmatrix} \boldsymbol{\theta}_{ois}^{\mathbb{P}} \\ \boldsymbol{\theta}_i^{\mathbb{P}} \end{pmatrix} - \begin{pmatrix} \boldsymbol{x}_t^{ois} \\ \boldsymbol{x}_t^i \end{pmatrix} \right] dt + \begin{bmatrix} \boldsymbol{\sigma}_{ois} & 0 \\ 0 & \boldsymbol{\sigma}_i \end{bmatrix} \begin{bmatrix} d\boldsymbol{w}_t^{ois,\mathbb{P}} \\ d\boldsymbol{w}_t^{i,\mathbb{P}} \end{bmatrix}$$

which we write in compact form as:

$$d\tilde{\boldsymbol{x}}_t^i = \tilde{\boldsymbol{\kappa}}_i^{\mathbb{P}}(\tilde{\boldsymbol{\theta}}_i^{\mathbb{P}} - \tilde{\boldsymbol{x}}_t^i)dt + \tilde{\boldsymbol{\sigma}}_i^{\mathbb{P}} d\tilde{\boldsymbol{w}}_t^{i,\mathbb{P}} \tag{14}$$

Country i zero-coupon bond yield is given by:

$$y_t^i(\tau) = y_t^{ois}(\tau) + s_t^i(\tau) \tag{15}$$

$$s_t^i(\tau) = A^i(\tau) + \boldsymbol{B}^i(\tau)^\intercal\ \tilde{\boldsymbol{x}}_t^i \tag{16}$$

Yield Decomposition

Yield decomposition: affine case

Recall that we want to provide the following decomposition of country i yield at maturity τ:

$$y_t^i(\tau) = ec_t^{rf}(\tau) + tp_t^{rf}(\tau) + es_t^{spr}(\tau) + rr_t^{spr}(\tau) \tag{17}$$

From the OIS yield curve pricing we have:

$$\frac{da^{ois}(\tau)}{d\tau} = \boldsymbol{b}^{ois}(\tau)^{\intercal}(\boldsymbol{\kappa}_{ois}^{\mathbb{P}}\boldsymbol{\theta}_{ois}^{\mathbb{P}} - \boldsymbol{\sigma}_{ois}\gamma_0) + \frac{1}{2}tr\left(\boldsymbol{\sigma}_{ois}^{\intercal}\boldsymbol{b}^{ois}(\tau)\boldsymbol{b}^{ois}(\tau)^{\intercal}\boldsymbol{\sigma}_{ois}\right)$$

$$\frac{d\boldsymbol{b}^{ois}(\tau)}{d\tau} = -\boldsymbol{\rho}_1^{ois} - (\boldsymbol{\kappa}_{ois}^{\mathbb{P}} + \boldsymbol{\sigma}_{ois}\gamma_1)^{\intercal}\boldsymbol{b}^{ois}(\tau)$$

The expected component of the risk-free rate $ec_t^{rf}(\tau)$ is obtained by setting the market prices of risk to zero:

$$\frac{da^{ec}(\tau)}{d\tau} = \boldsymbol{b}^{ec}(\tau)^{\intercal}\boldsymbol{\kappa}_{ois}^{\mathbb{P}}\boldsymbol{\theta}_{ois}^{\mathbb{P}} + \frac{1}{2}tr\left(\boldsymbol{\sigma}_{ois}^{\intercal}\boldsymbol{b}^{ec}(\tau)\boldsymbol{b}^{ec}(\tau)^{\intercal}\boldsymbol{\sigma}_{ois}\right), \quad a^{ec}(0) = 0 \tag{18}$$

$$\frac{d\boldsymbol{b}^{ec}(\tau)}{d\tau} = -\boldsymbol{\rho}_1^{ois} - \boldsymbol{\kappa}_{ois}^{\mathbb{P}\intercal}\boldsymbol{b}^{ec}(\tau), \quad \boldsymbol{b}^{ec}(0) = 0 \tag{19}$$

Yield decomposition: affine case

The **expected** component of the **risk-free rate** is then:

$$ec_t^{rf}(\tau) = -\frac{1}{\tau}\left(a^{ec}(\tau) + \boldsymbol{b}^{ec}(\tau)^{\intercal}\ \boldsymbol{x}_t^{ois}\right) \tag{20}$$

The **term premium** component of the **risk-free rate** is then given by the difference between the model-implied OIS yield at maturity τ and the corresponding expected component

$$tp_t^{rf}(\tau) = y_t^{ois}(\tau) - ec_t^{rf}(\tau) \tag{21}$$

The **expected** component of the **spread** is obtained in a similar fashion:

$$es_t^{spr}(\tau) = -\frac{1}{\tau}\left(a^{es}(\tau) + \boldsymbol{b}^{es}(\tau)^{\intercal}\ \tilde{\boldsymbol{x}}_t^{i}\right) \tag{22}$$

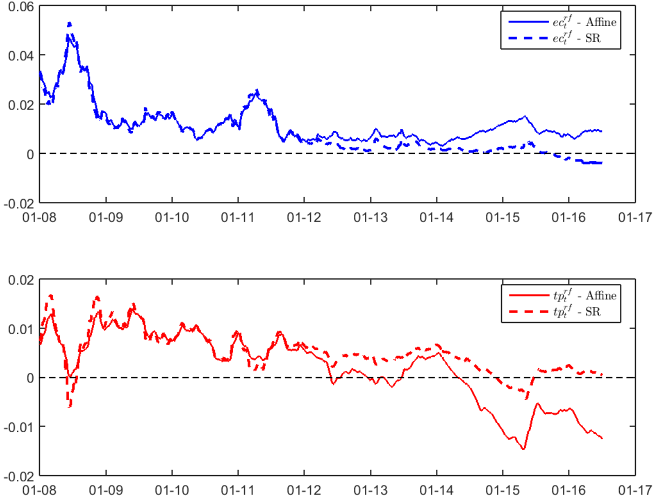
and the **repricing of risk** component is obtained as the difference between the model implied spread and the expected component:

$$rr_t^{spr}(\tau) = s_t^{i}(\tau) - es_t^{spr}(\tau) \tag{23}$$

Results

Yield decomposition for OIS: impact of lower bound

Figure: Comparison of decomposition for 5-year OIS yield



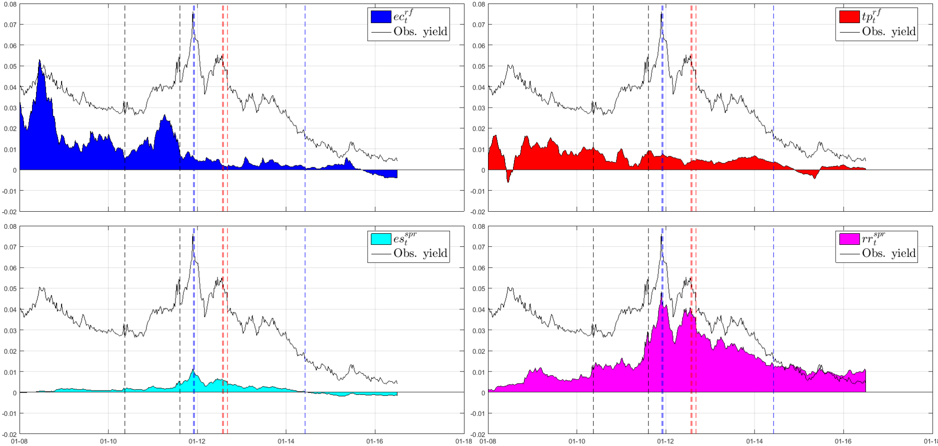
Yield decomposition for OIS: variations around UMPs

	Affine			SR		
Prog	Actu	ec_t^{rf}	$tp_t^{rf}(\tau)$	Actu	ec_t^{rf}	$tp_t^{rf}(\tau)$
SMP	-23	-37	14	-23	-36	13
(T)LTRO	5	-17	19	5	-18	19
OMT	3	-11	16	3	-9	14
FG	-6	3	-4	-6	0	-1
APP	4	24	-22	4	1	-7

Table: Cumulative weekly variations in $ec_t^{rf}(\tau)$ and $tp_t^{rf}(\tau)$ components for 5-y OIS yields around announcements (in basis points)

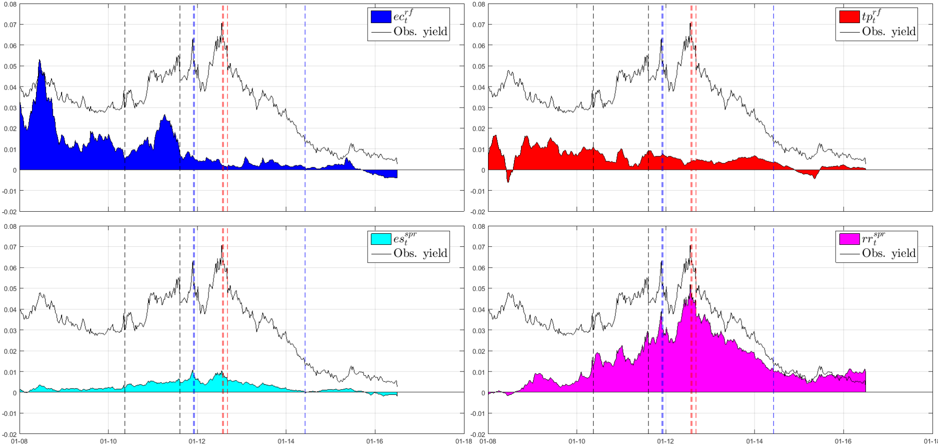
Yield decomposition for Italy

Figure: Impact of UMPs on each component of 5-year Italian yield (SMP = black, (T)LTROs = blue and OMT = red)



Yield decomposition for Spain

Figure: Impact of UMPs on each component of 5-year Spanish yield (SMP = black, (T)LTROs = blue and OMT = red)



Yield decomposition SR model: Italy and Spain

	Italy - SR				
Prog	Actu	ec_t^{rf}	$tp_t^{rf}(\tau)$	$es_t^{spr}(\tau)$	$rr_t^{spr}(\tau)$
SMP	-170	-36	13	-16	-65
(T)LTRO	-125	-18	19	-20	-85
OMT	-152	-9	14	-19	-86
FG	-46	0	-1	-7	-26
APP	-49	1	-7	-8	-35
	Spain - SR				
Prog	Actu	ec_t^{rf}	$tp_t^{rf}(\tau)$	$es_t^{spr}(\tau)$	$rr_t^{spr}(\tau)$
SMP	-195	-36	13	-31	-98
(T)LTRO	-162	-18	19	-38	-120
OMT	-170	-9	14	-42	-124
FG	-54	0	-1	-8	-35
APP	-45	1	-7	-5	-35

Table: Cumulative weekly variations in $ec_t^{rf}(\tau)$, $tp_t^{rf}(\tau)$, $es_t^{spr}(\tau)$ and $rr_t^{spr}(\tau)$ components for 5-y Italian and Spanish yields around announcements (in basis points)

Yield decomposition SR model: Belgium and France

	Belgium - SR				
Prog	Actu	ec_t^{rf}	$tp_t^{rf}(\tau)$	$es_t^{spr}(\tau)$	$rr_t^{spr}(\tau)$
SMP	-66	-36	13	-1	-20
(T)LTRO	-122	-18	19	-1	-104
OMT	-37	-9	14	0	-20
FG	-9	0	-1	0	-5
APP	-1	1	-7	0	-7
	France - SR				
Prog	Actu	ec_t^{rf}	$tp_t^{rf}(\tau)$	$es_t^{spr}(\tau)$	$rr_t^{spr}(\tau)$
SMP	-23	-36	13	-3	4
(T)LTRO	-43	-18	19	-3	-35
OMT	-23	-9	14	-1	-10
FG	-13	0	-1	0	-4
APP	2	1	-7	1	-6

Table: Cumulative weekly variations in $ec_t^{rf}(\tau)$, $tp_t^{rf}(\tau)$, $es_t^{spr}(\tau)$ and $rr_t^{spr}(\tau)$ components for 5-y Belgian and French yields around announcements (in basis points)

Conlusions

Research question

- via which channel has UMP actions worked in the EA government bond market?

Modelling strategy

- Non-linear model for OIS market
- Linear model for the spreads

UMP actions...

- ... worked mostly via the expectation channel in the OIS market
- ... worked mostly via risk repricing channel for the spreads variation

Future work...

- ... joint modelling of all euro area countries
- ... feedback from the spread factors to the OIS market