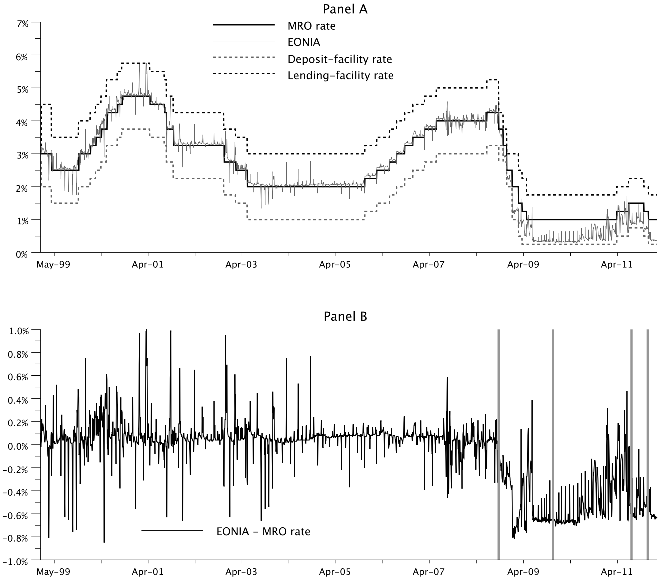
A model of the euro-area yield curve with discrete policy rates

J.-P. Renne[1]

Excess liquidity and money market functioning, ECB, 19/11/12

[1]Banque de France. The views expressed in the following do not necessarily reflect those of the Banque de France.

Excess-liquidity and the EONIA rate



Introduction

Excess-liquidity and the term-structure of interest rates

- Over the last four years, dramatic change in the EONIA spread dynamics (e.g. Beirne, 2012, Soares and Rodrigues, 2011)
- This change is related to the excess-liquidity situation of the aggregate banking system
- The short-term rate dynamics is affected. What about longer-term rates?
- All phenomena that persistently affect the short term rate have an impact on longer-term rates:

$$y_{t,h} = \log E_t^{\mathbb{Q}} \left[\exp(-r_t - \ldots - r_{t+h-1}) \right]$$

Introduction

Term-structure models at the current juncture

- Excess-liquidity situations are not easily integrated into standard TSM: breakpoint / non-linear features are required.
- To investigate these effects for a relatively high frequency (daily) and for relatively short maturities, one has to refine the dynamics of the short-term rate
  - step-like path of the policy rates,
  - schedule of the Governing-council meetings.
- Further, with the zero lower bound almost binding, models that do not preclude negative interest rates may be misleading.

$\Rightarrow$ Standard ATSM are not appropriate.

Introduction
This paper

- Novel model of the term structure of interest rates that puts the emphasis on the dynamics of the short-term rate (overnight interbank rate) and its relationships with monetary policy.
- Intensive and original use of regime switching features.
- The flexibility/tractability of the model is illustrated by estimating the model on high-frequency (daily) euro-area data.
- Excess-liquidity phenomena is taken into account. By-product: impact of the excess-liquidity regime on the yield curve.
- Applications: investigation of risk premia associated with changes in the policy rate, effects of (potential) forward guidance measures in a context of very low MRO rates.

Overview of connected literature

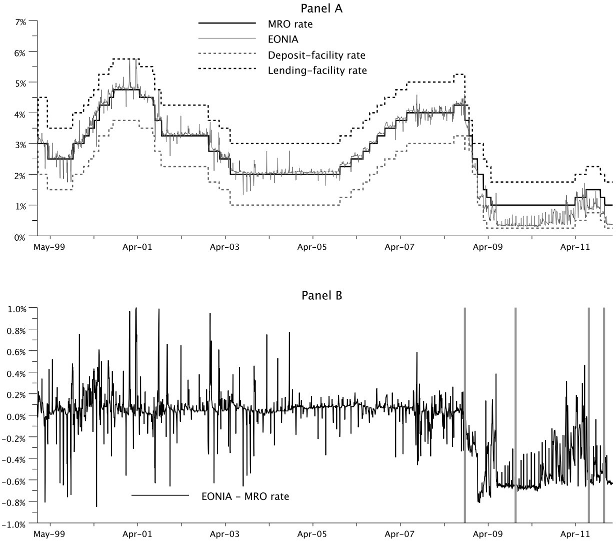
	This paper	Piazzesi (2005)	Fontaine (2009)	Feunou Fontaine (2010)	Andreasen Meldrum (2011)	Ang Piazzesi (2003)	Hamilton Wu (2010)	Balduzzi et al. (1997-98)
Consistent with ZLB	√			√	√		∼	
No-arbitrage term struct.	√	√	√	√	√	√	√	
Explicit model. of target	√	√	√	√				√
No need for approx.	√		√	√	√	√	√	√
Frequency	D	W	D	M	M	M	W	D
Area	Euro	US	US	US	US-UK	US	US	US
Longest maturity	4 yrs	5 yrs	12 mths	12 mths	10 yrs	10 yrs	10 yrs	3 mths
Includes crisis period	√			√	√		√	
yields	Swap	Swap	Fut	Treas	Treas	Treas	Treas	Bank

Introduction

EONIA and OIS

- Shortest-term rate: Overnight interbank rate (Euro Over-Night Index Average, EONIA)
- Medium-term rates: Overnight Index Swap (OIS) rates
  - More and more considered as "risk-free yields" (far less affected by credit-risk valuation than EURIBOR yields/swaps, Joyce et al. 2011),
  - Except in the U.S. (liquid Fed Funds future contract), OIS = main instrument for hedging central bank policy (Lang, 2010)
  - In the euro area, OIS = key rates used to gauge market expectations of monetary-policy rate's moves.

Model
Decomposition of the overnight interest rate



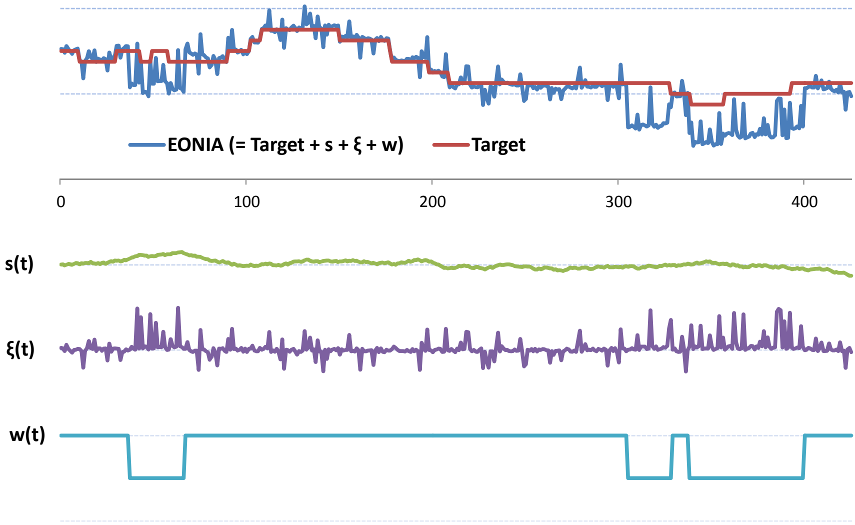
Model

Decomposition of the overnight interest rate

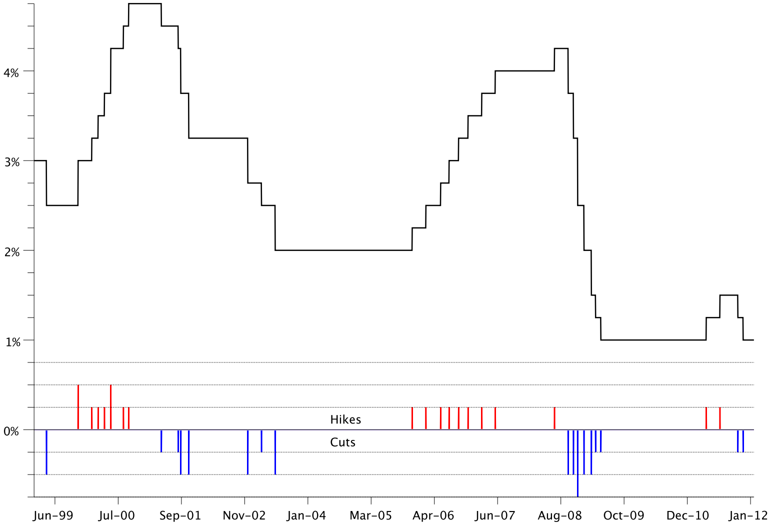
- The specification of the overnight interbank rate r_t is central.

$$r_t = \underbrace{\bar{r}_t}_{\text{Target}} + \underbrace{\xi_t + s_t + w_t}_{\text{EONIA spread}}$$

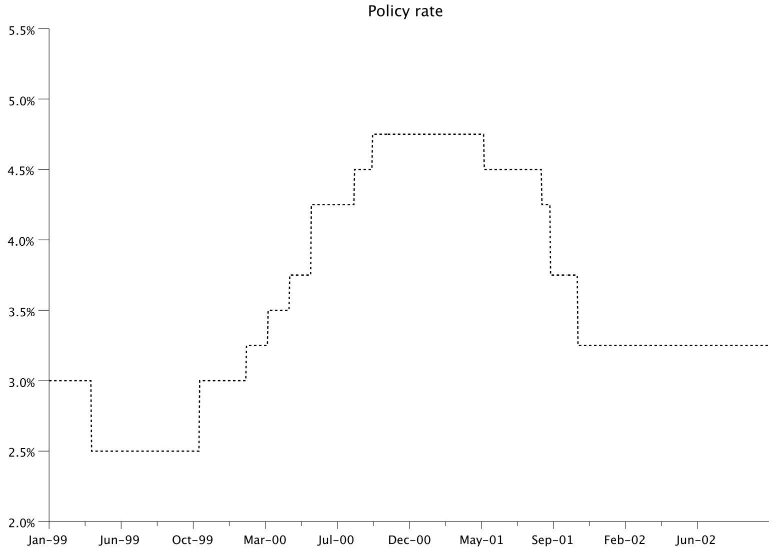
- Target rate $\bar{r}_t$ has a step-like path $\bar{r}_t = \Delta' z_{r,t}$, where
  - $\triangle = [\ 0 \quad 0.25 \quad 0.50 \quad \ldots \quad \bar{r}_{max}\ ]'$ and
  - $z_{r,t} = [\ 0 \quad \ldots \quad 0 \quad 1 \quad 0 \quad \ldots \quad 0\ ]'$
- EONIA spread:
  - ξ_t: highly volatile component that is uncorrelated to higher-maturity yields
  - w_t: change in the conditional mean of the EONIA spread, 2 states: (I) EONIA close to the MRO, (II) EONIA below the MRO
  - s_t: persistent and mean-reverting fluctuations

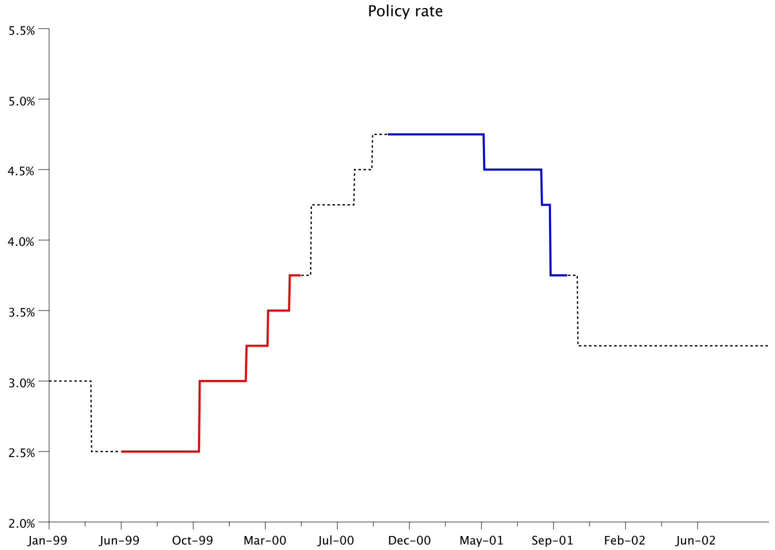

EONIA (= Target + s + ξ + w)
Target
0
100
200
300
400
s(t)
ξ(t)
w(t)

Policy rate

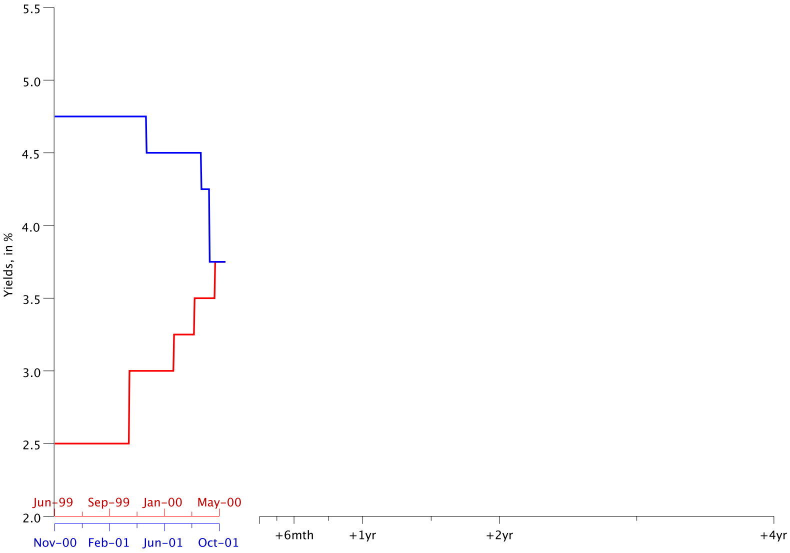


4%
3%
2%
1%
0%
Hikes
Cuts
Jun–99
Jul–00
Sep–01
Nov–02
Jan–04
Mar–05
Apr–06
Jun–07
Aug–08
Oct–09
Dec–10
Jan–12

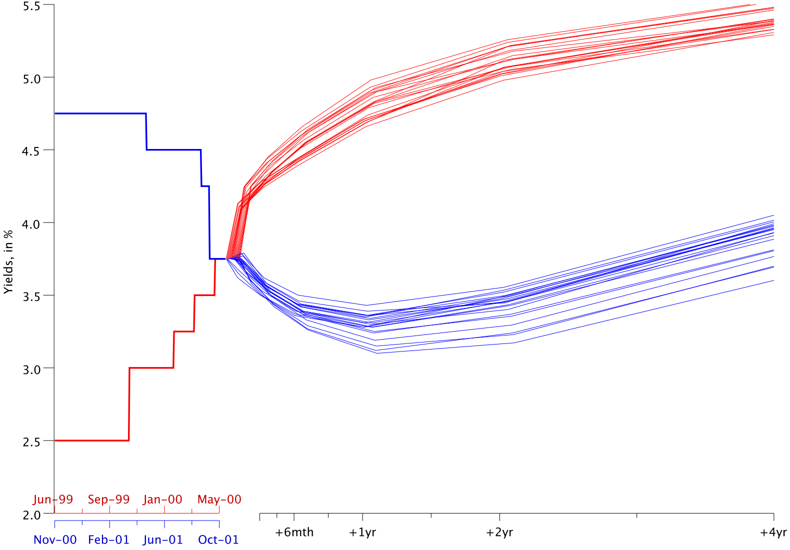

Policy rate
5.5%
5.0%
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
Jan−99
Jun−99
Oct−99
Mar−00
Jul−00
Dec−00
May−01
Sep−01
Feb−02
Jun−02


Policy rate
5.5%
5.0%
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
Jan–99
Jun–99
Oct–99
Mar–00
Jul–00
Dec–00
May–01
Sep–01
Feb–02
Jun–02

Model



5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Yields, in %
Jun−99
Sep−99
Jan−00
May−00
Nov−00
Feb−01
Jun−01
Oct−01
+6mth
+1yr
+2yr
+4yr



5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Yields, in %
Jun-99
Sep-99
Jan-00
May-00
Nov-00
Feb-01
Jun-01
Oct-01
+6mth
+1yr
+2yr
+4yr

The dynamics of the target

L. B. Smaghi: "Three questions on monetary policy easing"

"At that time [October 2006], central banks worldwide were raising interest rates, so I thought it would be useful to consider the key challenges that monetary policy faced in a tightening phase [...]:
When to start tightening monetary policy? At what speed to tighten? And when to stop tightening?

Circumstances have changed. Now, central banks worldwide are lowering interest rates. So we could ask the same questions, but just change one word:
When to start easing monetary policy? At what speed? And when to stop easing?"

University of Ancona, Ancona, 6 March 2009

The dynamics of the target

L. B. Smaghi: "Three questions on monetary policy easing"

"At that time [October 2006], central banks worldwide were raising interest rates, so I thought it would be useful to consider the key challenges that monetary policy faced in a tightening phase [...]:
When to start tightening monetary policy? At what speed to tighten? And when to stop tightening?

Circumstances have changed. Now, central banks worldwide are lowering interest rates.
So we could ask the same questions, but just change one word:
When to start easing monetary policy? At what speed? And when to stop easing?"

University of Ancona, Ancona, 6 March 2009

Monetary-policy regimes (or phases):

- Easing ($z_{m,t} = [\ 1 \quad 0 \quad 0\ ]$),
- Status Quo ($z_{m,t} = [\ 0 \quad 1 \quad 0\ ]$),
- Tightening ($z_{m,t} = [\ 0 \quad 0 \quad 1\ ]$).

The dynamics of the target

- $z_{r,t} \otimes z_{m,t}$: dynamics defined by 15.006 switching probabilities! However...
- ... the vast majority of these are 0
- The remaining ones depend on the monetary-policy regime and on the policy rate (parametric form)
- Eventually, the matrix depends on 16 parameters

Accounting for the drop in the EONIA spread $(w_t + \xi_t)$

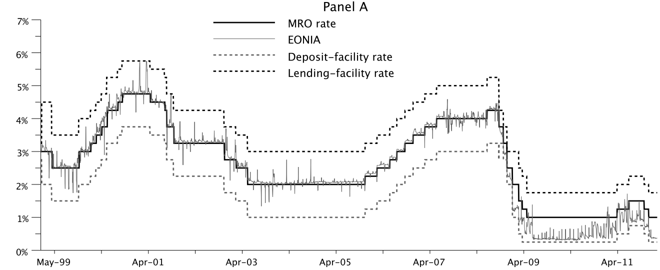
$$r_t = \underbrace{\bar{r}_t}_{\text{Target}} + \underbrace{s_t + w_t + \xi_t}_{\text{EONIA spread}}$$

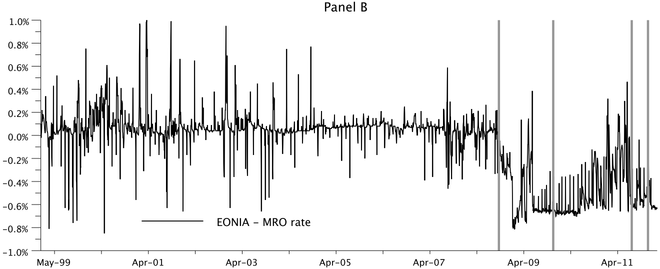
- In October 2008, adoption of a fixed-rate full allotment (FRFA) tender procedure: the ECB accommodates any demand for liquidity its bank counterparties might express (at the policy rate, against eligible collateral).

- FRFA contributed to generate a steady excess of liquidity balances in the overnight market.

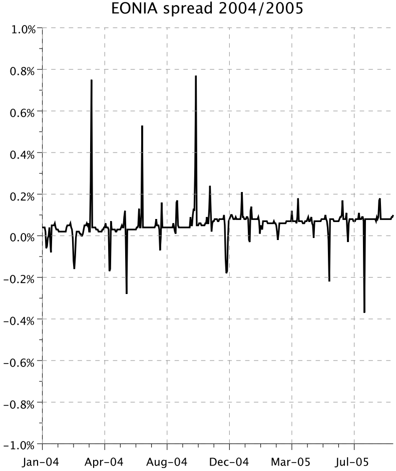
  ⇒ Downward pressure on the overnight interest rate, which drifted toward the lower limit of the monetary policy corridor (Beirne, 2012, Fahr et al., 2010).

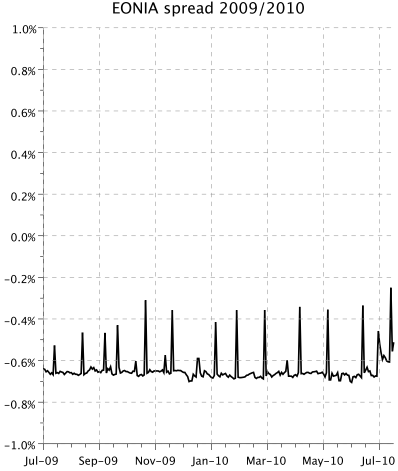
Accounting for the drop in the EONIA spread $(w_t + \xi_t)$





Accounting for the drop in the EONIA spread $(w_t + \xi_t)$





Accounting for the drop in the EONIA spread ($w_t + \xi_t$)

- The distribution of the volatile component depends on the liquidity-surplus regime:

$$w_t + \xi_t = \left[\begin{array}{cc} (w_{norm} + \xi_{norm,t}) & (w_{exc} + \xi_{exc,t}) \end{array} \right] z_{exc,t}$$

- The dynamics of the Markov chain $z_{exc,t}$ is described by a 2×2 matrix of transition probabilities.
- The $\xi_{i,t}$'s (fat tails, skewed) are drawn from Beta-based distributions; the distributions depend on the excess-liquidity regime.

Pricing

- Under the risk-neutral (pricing) measure: factors follow the same kind of processes (same specifications), different parameterizations (Π_t^* and Φ^* under $\mathbb{Q}$ vs. Π_t and Φ under $\mathbb{P}$) ▸ s.d.f.
- h-period yield:

$$y_{t,h} = -\frac{1}{h}\ln P_{t,h} \quad \text{where} \quad P(t,h) = E^{\mathbb{Q}}\left\{\exp\left(-r_t - \ldots - r_{t+h-1}\right)\right\}$$

- Using the independence assumption of the pricing factors:

$$\begin{aligned} P(t,h) &= E_t^{\mathbb{Q}}\left(e^{-\sum_{i=0}^{h-1}\bar{r}_{t+i}}\right) E_t^{\mathbb{Q}}\left(e^{-\sum_{i=0}^{h-1}(w_{t+i}+\xi_{t+i})}\right) E_t^{\mathbb{Q}}\left(e^{-\sum_{i=0}^{h-1}s_{t+i}}\right) \\ &= P_1(t,h) \times P_2(t,h) \times P_3(t,h) \end{aligned}$$

- Affine term-structure model:

$$y(t,h) = -\frac{1}{h}\ln\left(P_{t,h}\right) = -\frac{1}{h}\left[G(t,h)z_t + A_h + B_h s_t\right]$$

where $z_t = z_{r,t} \otimes z_{m,t} \otimes z_{exc,t}$ (the dimension of z_t is 246×1).

Pricing

- Under the risk-neutral (pricing) measure: factors follow the same kind of processes (same specifications), different parameterizations (Π_t^* and Φ^* under $\mathbb{Q}$ vs. Π_t and Φ under $\mathbb{P}$) s.d.f.
- h-period yield:

$$y_{t,h} = -\frac{1}{h}\ln P_{t,h} \quad \text{where} \quad P(t,h) = E^{\mathbb{Q}}\{\exp(-r_t - \ldots - r_{t+h-1})\}$$

- Using the independence assumption of the pricing factors:

$$\begin{aligned} P(t,h) &= E_t^{\mathbb{Q}}\left(e^{-\sum_{i=0}^{h-1}\bar{r}_{t+i}}\right) E_t^{\mathbb{Q}}\left(e^{-\sum_{i=0}^{h-1}(w_{t+i}+\xi_{t+i})}\right) E_t^{\mathbb{Q}}\left(e^{-\sum_{i=0}^{h-1}s_{t+i}}\right) \\ &= P_1(t,h) \times P_2(t,h) \times P_3(t,h) \end{aligned}$$

- Affine term-structure model:

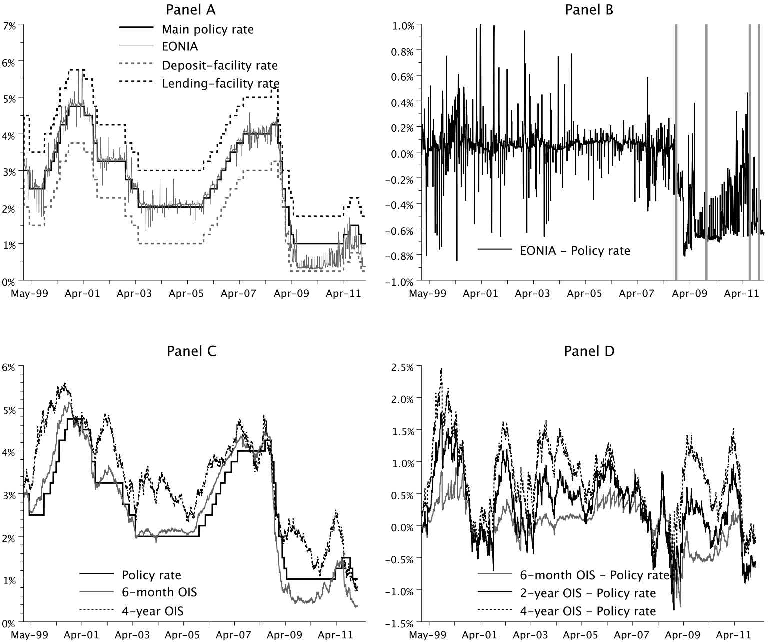
$$y(t,h) = -\frac{1}{h}\ln(P_{t,h}) = -\frac{1}{h}[G(t,h)z_t + A_h + B_h s_t]$$

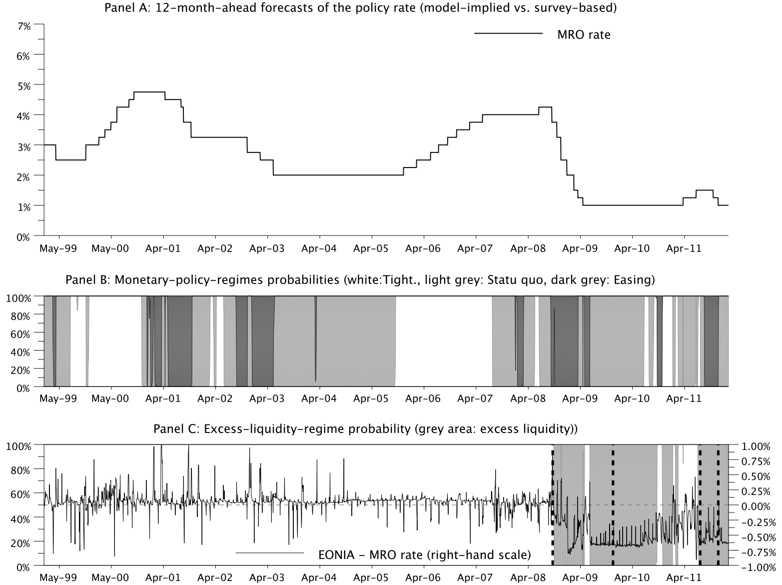
where $z_t = z_{r,t} \otimes z_{m,t} \otimes z_{exc,t}$ (the dimension of z_t is 246×1).

$\Rightarrow$ **Thanks to quasi-explicit formulas, exact pricing extremely quick.**

Overview

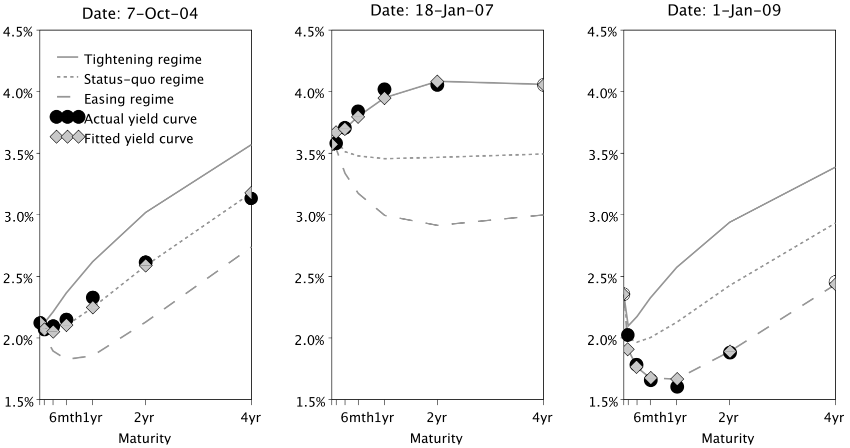
- Sample: Jan-1999 – Feb-2012, daily (3.416 days)
- 7 maturities: 1 day, 1 month, 3 months, 6 months, 1 year, 2 years, 4 years
- Use of survey forecasts (12-months-ahead forecasts of short-term rates, source: *Consensus forecasts*)
- Maximum likelihood estimation
- 52 parameters to estimate, but substantial number of observations ($\sim$25.000 observations)
- Computation of the log-L is based on Monfort and Renne (2011): mixture of Kitagawa-Hamilton filtering + inversion techniques
  - Two sources of latency: regimes ($z_{m,t} \otimes z_{exc,t}$) + shocks ε_t
  - Kim's (1994) filter could be implemented but very slow in the current case (6 unobserved regimes, 3.416 periods)


Panel A
Main policy rate
EONIA
Deposit-facility rate
Lending-facility rate
7%
6%
5%
4%
3%
2%
1%
0%
May-99
Apr-01
Apr-03
Apr-05
Apr-07
Apr-09
Apr-11
Panel B
EONIA - Policy rate
1.0%
0.8%
0.6%
0.4%
0.2%
0.0%
-0.2%
-0.4%
-0.6%
-0.8%
-1.0%
Panel C
Policy rate
6-month OIS
4-year OIS
Panel D
6-month OIS - Policy rate
2-year OIS - Policy rate
4-year OIS - Policy rate
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
-0.5%
-1.0%
-1.5%

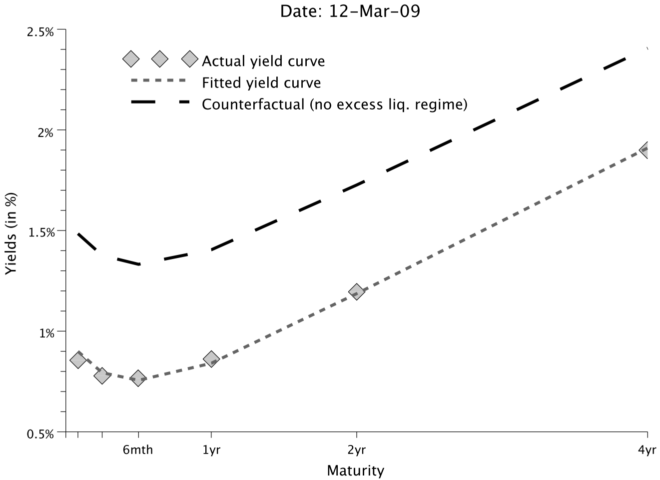


Panel A: 12-month-ahead forecasts of the policy rate (model-implied vs. survey-based)
MRO rate
7%
6%
5%
4%
3%
2%
1%
0%
May-99
May-00
Apr-01
Apr-02
Apr-03
Apr-04
Apr-05
Apr-06
Apr-07
Apr-08
Apr-09
Apr-10
Apr-11
Panel B: Monetary-policy-regimes probabilities (white:Tight., light grey: Statu quo, dark grey: Easing)
100%
80%
60%
40%
20%
0%
May-99
May-00
Apr-01
Apr-02
Apr-03
Apr-04
Apr-05
Apr-06
Apr-07
Apr-08
Apr-09
Apr-10
Apr-11
Panel C: Excess-liquidity-regime probability (grey area: excess liquidity))
100%
80%
60%
40%
20%
0%
1.00%
0.75%
0.50%
0.25%
0.00%
-0.25%
-0.50%
-0.75%
-1.00%
EONIA - MRO rate (right-hand scale)
May-99
May-00
Apr-01
Apr-02
Apr-03
Apr-04
Apr-05
Apr-06
Apr-07
Apr-08
Apr-09
Apr-10
Apr-11

Influence of the monetary-policy regimes



Influence of the excess-liquidity regime



Different applications

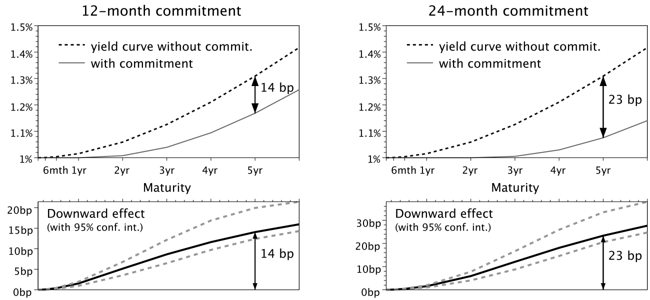
1. Risk premia associated with changes in the policy rate
   1. the estimation suggests that the sdf is related to the different regimes
   2. this implies that there are policy-rate-related risk premia ($E^{\mathbb{P}}(\bar{r}_{t+h}) \neq E^{\mathbb{Q}}(\bar{r}_{t+h})$)
   3. Risk premia turn out to be statistically significant, even for short-term maturities
   4. the (expectation-hypothesis-based) practice that consists in backing out market-expected paths by computing forward OIS rate is biased

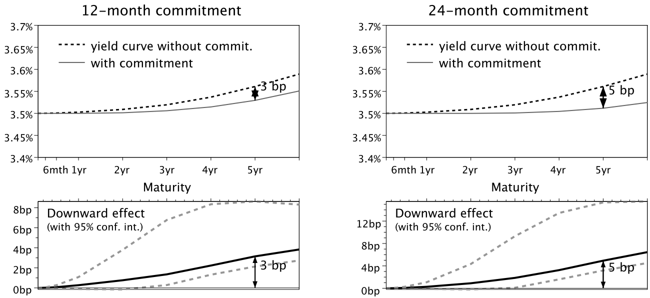
      charts
2. Assessment of a (virtual) forward-guidance measure

Application example: Assessing a non-standard monetary-policy measure

- In the model, the central bank behavior is defined through target-move probabilities
- Straightforward to assess the implications of credible announcements regarding future changes in the policy rate:
  - Deterministic paths over a given future period
  - Probabilistic indications
  - Examples: Canada April 2009, U.S. Fed January 2012 ▸ Press releases

$\Rightarrow$ Simple modifications in the appropriate probabilities of transitions (ex: set target-move proba. to zero for $t \in [M_1, M_2]$, the commitment period).


12–month commitment
24–month commitment
yield curve without commit.
with commitment
14 bp
23 bp
1.5%
1.4%
1.3%
1.2%
1.1%
1%
6mth 1yr
2yr
3yr
4yr
5yr
Maturity
Downward effect
(with 95% conf. int.)
20bp
15bp
10bp
5bp
0bp
30bp
20bp
10bp
0bp


12–month commitment
24–month commitment
yield curve without commit.
with commitment
3 bp
5 bp
3.7%
3.65%
3.6%
3.55%
3.5%
3.45%
3.4%
6mth 1yr
2yr
3yr
4yr
5yr
Maturity
Downward effect
(with 95% conf. int.)
8bp
6bp
4bp
2bp
0bp
12bp
8bp
4bp
0bp

Concluding remarks

- Novel (general) term-structure model
  - Intensive use of regime-switching features.
  - Explicit modeling of the monetary-policy rate and of an excess-liquidity regime
- Flexibility and tractability of the model illustrated by estimating it on high-frequency euro-area data including the crisis period
- Results:
  - Importance of "conventional" monetary-policy regimes and of the excess-liquidty regime (over the last four years) to account for fluctuations in the yield curve
  - Importance of using yield-curve information to identify monetary-policy regimes/phases (consistently with Bikbov and Chernov, 2008)

Thank you for your attention.