The Price of Money:
The Reserves Convertibility Premium over the Term Structure

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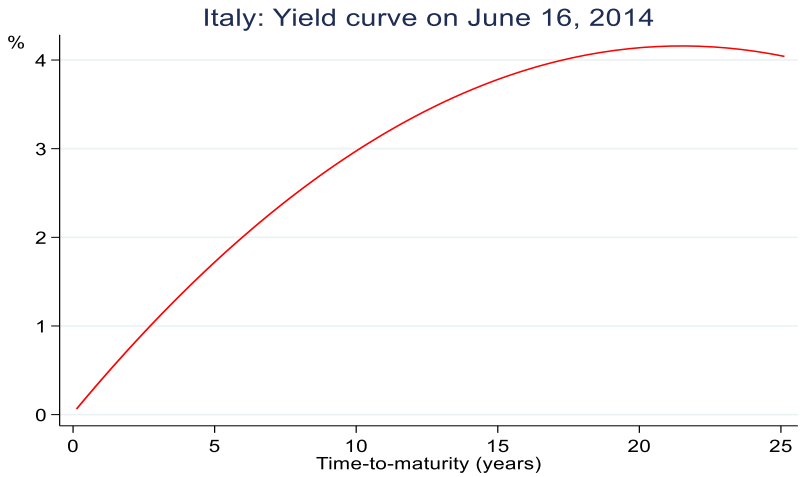


The rate of interest on these securities is a measure of their imperfection – of their imperfect `moneyness.' The nature of money and the nature of interest are therefore very nearly the same problem.

--Hicks (1939)

Introduction and motivation

- An immutable "law" of economics: money provides utility
  - Store of value, unit of account, medium of exchange

Reserves convertibility premium

- Two tier monetary system
- All transactions ultimately settle in central bank money (reserves)

1. No substitute => banks must have reserves
   - Banks can get reserves from other banks
     - Directly by borrowing. Indirectly by selling assets (Nyborg and Östberg, 2014)
   - But only the Central Bank can create new reserves

2. Central banks issue reserves against collateral
   - Terms of exchange set by central bank through its collateral policy

- Reserves convertibility premium: Value from convertibility into reserves

Liquidity premium

- Convertibility into money central in Hicks' original idea on liquidity premia

Hicks (1939)

- Interest rates on bills, notes, bonds are positively correlated with the cost of conversion into medium of exchange and vice versa (Amihud and Mendelson, 1986)
- Yields decrease in "moneyness:" degree of acceptability as medium of exchange
  - Safer (low duration, low credit risk) securities have higher "moneyness" (Krishnamurthy and Vissing-Jorgensen 2012, Greenwood, Hanson, and Stein 2015, Nagel 2016)

- Liquidity premium determined "on the margin" (Lagos, Rochetau, and Wright, 2017)

This paper: Reserves convertibility premium

- Moneyness captured by rate of convertibility into reserves as set by central bank (Chapman, Chiu, Molico, 2011)

Specific context: Term structure

Government-bond yield curve

- Used to price other assets, broad influence on asset prices, forecasting
- Often attempted controlled by central banks, e.g: Outright yield curve control: Fed, 1940's; Bank of Japan, since 2016. Operation Twist: Fed, 1961; 2011-2012)
- Enormous literature on term structure and fixed income pricing (see overviews by Dai and Singleton, 2003, Gürkaynak and Wright, 2012, Duffee, 2013).
- But little on the effect of direct convertibility into reserves, i.e., collateral policy.

Why this matters

- Cost of government debt
- Policy
- Pricing of securities
- Habitat effects in term structure due to institutional, monetary effects
- Liquidity premia – "moneyness" as convertibility into reserves, status with central bank

Eurosystem's collateral framework

- Before QE, reserves injected into the banking system through repos (collateralized loans) as part and parcel of conventional monetary-policy implementation

Collateral policy governs

1. Set of eligible collateral banks can use in repos with the central bank
   - 30,000 – 40,000 securities on public list of eligible collateral
   - Government bonds, covered bonds, corporate bonds, ABS's etc
2. Quantity of central bank money per eligible collateral (collateral value):

$$Collateral\ value_{it} = (1 - haircut_{it}) \times Price_{it}$$

   - Moneyness captured by degree of convertibility into reserves, that is, haircut
   - Haircuts are stale – updated every three to four years

Research questions:

1. Is there a reserves convertibility premium – do haircuts affect prices?
2. Differential effects across term structure?
   - Different maturities may be owned by different players
     i. Eligible counterparties: only banks
     ii. Banks hold relatively short-term paper (average duration around 3 years; Fecht et al, 2016; Koijen et al, 2021).

Find

- A higher rate of convertibility implies lower yield, ceteris paribus
- Convertibility premium tapers off, becoming insignificant at longer end
  - Consistent with banks owning mostly shorter-term assets
- For Italy: One pp increase in haircut increases 1-year spot rate by two bps

Contribution relative to extant literature

- Direct convertibility of an asset into central-bank money is priced
  - First paper to document effect of haircut changes in CB repos on already eligible assets
  - Novel methodology to estimate treatment effects over term structure

Related work

- Eligibility premium? Bindseil and Papadia (2006), Corradin and Rodriguez-Moreno (2016), Pelizzon et al (2023):
  - Broad cross-section of bonds with new eligibility status
  - Mixed findings, mixes haircut effect with eligibility effect, no term structure effect estimated

Overview of empirical approach

Institutional structure (Nyborg, 2017 and ECB documentation)

- Haircuts determined by ratings from four official rating agencies
  - Bond specific rating, issuer rating
  - Two rating categories: High and low haircuts (ceteris paribus)
  - Same-country government bonds. Different rating categories possible when rated by different agencies: haircut inconsistencies

Haircut inconsistencies and delta curves

- Use public list of eligible collateral to identify all haircut inconsistencies over time
  - April 8, 2010 to Jan 6, 2015
- Build separate spot curves of high- versus low-haircut same-country government bonds
  - Delta curve: high- minus low-haircut spot curves
  - Estimate delta curve over time (prices from Bloomberg)
- Identify four events where haircut differentials changed
  - Haircut harmonization: rule-change to eliminate haircut inconsistencies
- Difference-in-differences (change in delta curve)

Methodological contribution

- Dealing with differential treatment effects over the term structure in a DiD setting
  - Challenge: Standard DiD specification subject to false and mismeasured treatment effects (Nyborg, Woschitz 2023)

Table 3. Haircut and yield differentials: Examples

June 16, 2014

ISIN	Maturity	Haircut (in %)	Rating category	Yield (in %)	Rating agency	Issue rating	Country rating
Panel A: Example 1							
ES00000120C3	Jan. 31, 2015	0.5	1 (AAA to A–)	0.205	S&P	–	BBB
					Fitch	–	BBB+
					Moody's	–	Baa2
					DBRS	**AL**	AL
ES0000011892	Jan. 31, 2015	6.0	2 (BBB+ to BBB–)	0.284	S&P	–	BBB
					Fitch	**BBB+**	BBB+
					Moody's	–	Baa2
			1.4 bps per pp haircut		DBRS	–	AL
Panel B: Example 2							
ES00000123V7	Jan. 31, 2018	2.5	1 (AAA to A–)	1.108	S&P	–	BBB
					Fitch	–	BBB+
					Moody's	–	Baa2
					DBRS	–	**AL**
ES0000011926	Jan. 31, 2018	10.0	2 (BBB+ to BBB–)	1.283	S&P	–	BBB
					Fitch	**BBB+**	BBB+
					Moody's	–	Baa2
			2.3 bps per pp haircut		DBRS	–	AL

Identification strategy: Collateral framework implementation errors

- Reuters, November 4, 2012:

  "The European Central Bank (ECB) is checking whether it may have contravened its own strict rules by lending to Spanish banks on overly generous terms, an ECB spokeswoman said on Sunday."

- ECB press conference November 8, 2012, President Mario Draghi, said:

  ". . .we take this mistake very seriously. And so the Governing Council has mandated the Eurosystem Audit Committee . . . to assess the implementation of the collateral framework in the Eurosystem . . . "

- The implementation mistake was to ignore issue ratings in setting haircuts
  - Many countries involved, not just Spain
- Subsequent actions to, first, correct the mistakes and, second, change the rules provide identification
- Focus on Spain and Italy because of solid coverage of haircut inconsistencies across days and the maturity spectrum

Table 1: Mapping from bond characteristics to haircuts

Fixed and zero-coupon central-government bonds

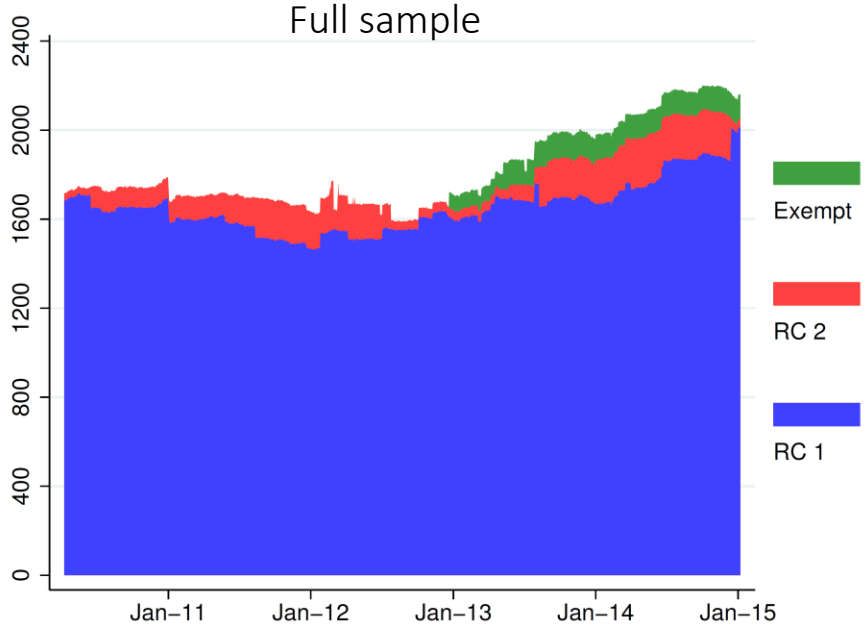
	Coupon type	Residual maturity (years) 0-1	1-3	3-5	5-7	7-10	>10	Residual maturity (years) 0-1	1-3	3-5	5-7	7-10	>10
Panel A: Regular haircuts													
Rating		**Apr. 8, 2010 – Sep. 30, 2013**						**Oct. 1, 2013 – May 25, 2017**					
AAA to A–	Fixed	0.5	1.5	2.5	3.0	4.0	5.5	0.5	1.0	1.5	2.0	3.0	5.0
(Category 1)	Zero	0.5	1.5	3.0	3.5	4.5	8.5	0.5	2.0	2.5	3.0	4.0	7.0
BBB+ to BBB–	Fixed	5.5	6.5	7.5	8.0	9.0	10.5	6.0	7.0	9.0	10.0	11.5	13.0
(Category 2)	Zero	5.5	6.5	8.0	8.5	9.5	13.5	6.0	8.0	10.0	11.5	13.0	16.0
Panel B: Extraordinary haircuts applied to securities exempt from minimum rating rule requirements													
Exempted country		**Dec. 21, 2012 – Dec. 14, 2014[1]** **Jun. 29, 2016 – May 25, 2017[1]**						**Dec. 15, 2014 – Feb. 10, 2015[1]**					
Greece	Fixed	15.0	33.0	45.0	54.0	56.0	57.0	6.5	11.0	16.5	23.0	34.0	40.0
	Zero	15.0	35.5	48.5	58.5	62.0	71.0	6.5	12.0	18.0	26.0	39.5	52.5
		May 9, 2013 – Mar. 31, 2016[1]											
Cyprus	Fixed	14.5	27.5	37.5	41.0	47.5	57.0						
	Zero	14.5	29.5	40.0	45.0	52.5	71.0						
Panel C: Additional haircuts applied to assets denominated in foreign currency													
		Apr. 8, 2010 – Dec. 31, 2010[2]						**Nov. 9, 2012 – May 25, 2017**					
Currency		Add additional haircut to regular (or extraordinary) haircut						Apply additional haircut as valuation markdown before regular (or extra-ordinary) haircut					
GBP and USD		8.0						16.0					
JPY		8.0						26.0					

Figures 1a and 1b.
Distribution of government bonds across rating categories

1. Public lists of eligible collateral, valid for: April 9, 2010 to January 7, 2015 (1,232 lists)
2. 5,704 zero and fixed coupon central-government bonds (2,246,390 security-day observations)
3. Use haircut and other information on public lists to back out Eurosystem rating categories of each bond each day

a. Feed the 5,704 securities into Bloomberg
b. Lose 830 securities that are not in Bloomberg, 1,456 that have no price data and 605 that have theoretical prices only
c. Exclude 359 ISINs that are consols or the coupons are linked to inflation (according to Bloomberg), security specific information on the public list and Bloomberg do not match or changes over time, or data is not good in some other way. Exclude common European holidays.
d. Left with 2,454 securities and 1,202,586 obs

Full sample



Sample with market prices

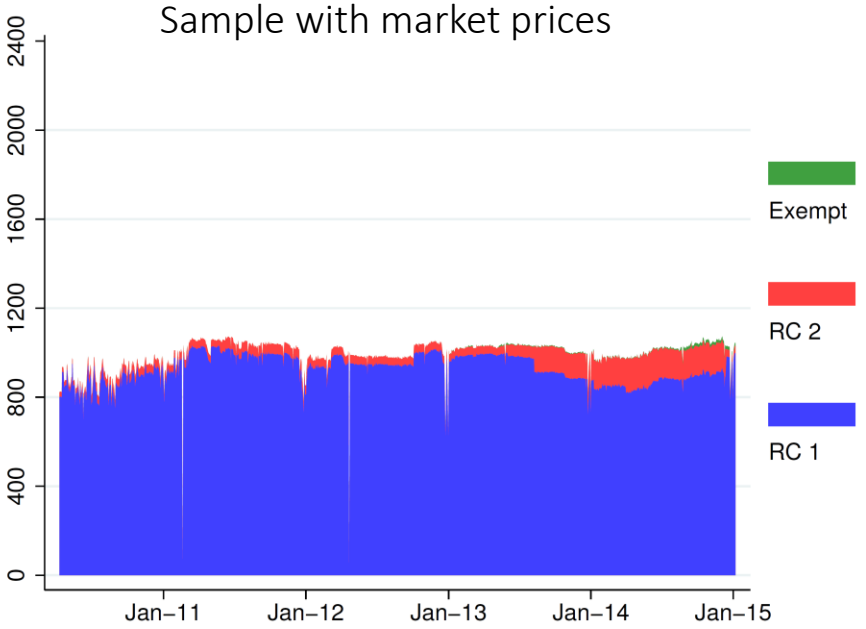


Table 4. Incidence of haircut inconsistencies across countries
Panel B: Sub-sample with market prices

Country	Days	Securities	Distribution of securites over haircut-inconsistency days								
			Rating categories 1 and 2			Rating category 1			Rating category 2		
			Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Panel B: Sub-sample with market prices											
Cyprus	33	5	4.1	3	5	1.5	1	4	2.6	1	4
Greece	1	13	13.0	13	13	1.0	1	1	12.0	12	12
Hungary	97	13	12.0	9	13	1.0	1	1	11.0	8	12
Ireland	194	24	11.7	10	13	10.0	9	10	1.7	1	3
Italy	345	250	172.0	159	192	103.3	91	116	68.8	53	78
Latvia	16	25	21.8	7	25	6.7	3	7	15.1	1	19
Portugal	1	24	24.0	24	24	15.0	15	15	9.0	9	9
Slovenia	14	19	14.4	12	17	12.4	10	15	2.0	2	2
Spain	441	220	142.5	58	154	126.4	49	149	16.1	1	25
TOTAL	1,142	593									

- Nine countries with haircut inconsistencies
- Coverage
  - Amazing in Italy
  - Good also in Spain
- Focus on Spain and Italy because of solid coverage of haircut inconsistencies across days and the maturity spectrum

Events for DiD analysis

Events that widen haircut differentials

1. Mass correction of implementation errors (Divergence)
   - Several bonds moved to high-haircut rating category due to rating below A-
   - Spain: June 3, 2013. Italy: August 9, 2013.
2. ECB haircut update: October 1, 2013. Widens haircut differential between government bonds in rating categories 1 and 2

Expect: Delta curve should increase

Events that shrink haircut differentials

3. Announcement of haircut harmonization: September 1, 2014.
   - Only country ratings will matter for government bonds
4. Implementation of haircut harmonization: December 15, 2014.
   - Italian and Spanish government bonds: rating category 1 due to AL rating by DBRS

Expect: Delta curve should decrease

Treated and control bonds

Sample period: May 13, 2013 to January 7, 2015

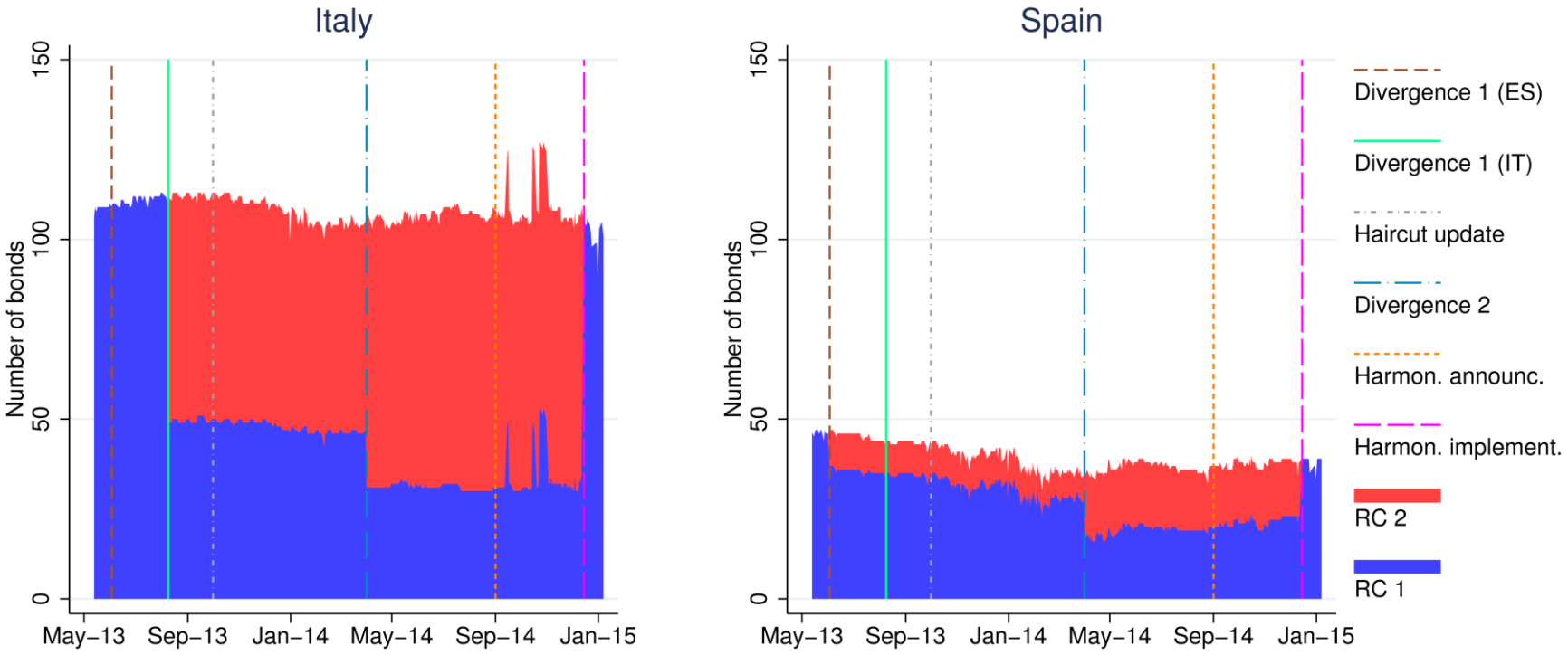
1. 15 business days before Spanish divergence date to 15 days after harmonization
2. Subset of bonds with market prices

Treated and control bonds

Event	Period	Treated bonds	Control bonds
1. Divergence	Pre event	Rating category 1	Rating category 1
(mass correction)	Post event	Rating category 2	Rating category 1
2. Haircut update	Pre event	Rating category 2	Rating category 1
	Post event	Rating category 2	Rating category 1
3. Harmonization	Pre event	Rating category 2	Rating category 1
announcement	Post event	Rating category 2	Rating category 1
4. Harmonization	Pre event	Rating category 2	Rating category 1
implementation	Post event	Rating category 1	Rating category 1

- Italy: All bonds in rating category 2 are zero-coupon
- Spain: Some fixed-coupon in category 2, but over very few days. Drop these.
- Since all treated bonds are zeros, also use zeros as controls

Figures 1e and 1f. Distributions Italian and Spanish bonds across rating categories in the final sample (zeros with market prices)



Vertical lines ("event" dates):

- Divergence (mass correction of implementation mistakes)
  - Italy: August 9, 2013 (mint-green solid). 63 securities
  - Spain: June 3, 2013 (brown dashed). 15 securities
  - [April 1, 2014 (blue longdash-dotted). Italy: 16 securities, Spain: 10 securities]
- Haircut update: October 1, 2013 (grey dash-dotted)
- Announcement, haircut harmonization: September 1, 2014 (orange shortdashed)
- Implementation, haircut harmonization: December 15, 2014 (magenta-colored longdashed)

DiD regression: Differential treatment effects
Fully flexible cubic spot curves

- Different spot curves: pre, post; treated, controls

1. DiD model under cubic yield-curve specification:

$$yield_{it} = \boldsymbol{\Gamma}_1' \mathbf{Mat}_{it} + \boldsymbol{\Gamma}_2' \mathbf{Mat}_{it} 1_{Treated,i} + \boldsymbol{\Gamma}_3' \mathbf{Mat}_{it} 1_{Post,t} + \boldsymbol{\Gamma}_4' \mathbf{Mat}_{it} 1_{Treated,i} \times 1_{Post,t} + \varepsilon_{it}$$

   where

   a. $\mathbf{Mat}_{it}' = \begin{bmatrix} 1 & x_{it} & x_{it}^2 & x_{it}^3 \end{bmatrix}$, where x is residual time-to-maturity

   b. $\boldsymbol{\Gamma}_j'$ is vector of coefficients, with individual elements $\gamma_{k,j}, k = 0,\ldots,3$

2. Estimated spot curve for control bonds pre-event:

$$s(x) = \hat{\gamma}_{0,1} + \hat{\gamma}_{1,1} x + \hat{\gamma}_{2,1} x^2 + \hat{\gamma}_{3,1} x^3$$

3. Estimated treatment delta curve:

$$\Delta_4(x) = \hat{\gamma}_{0,4} + \hat{\gamma}_{1,4} x + \hat{\gamma}_{2,4} x^2 + \hat{\gamma}_{3,4} x^3$$

- Estimated with OLS over ten- and twenty-day event windows
- Standard errors clustered on the bond level and calculated using delta method

Table 9, Italy: Treatment effects at selected maturities under flexible model
Cubic spot curves. Ten-day event window. Effects in bps.

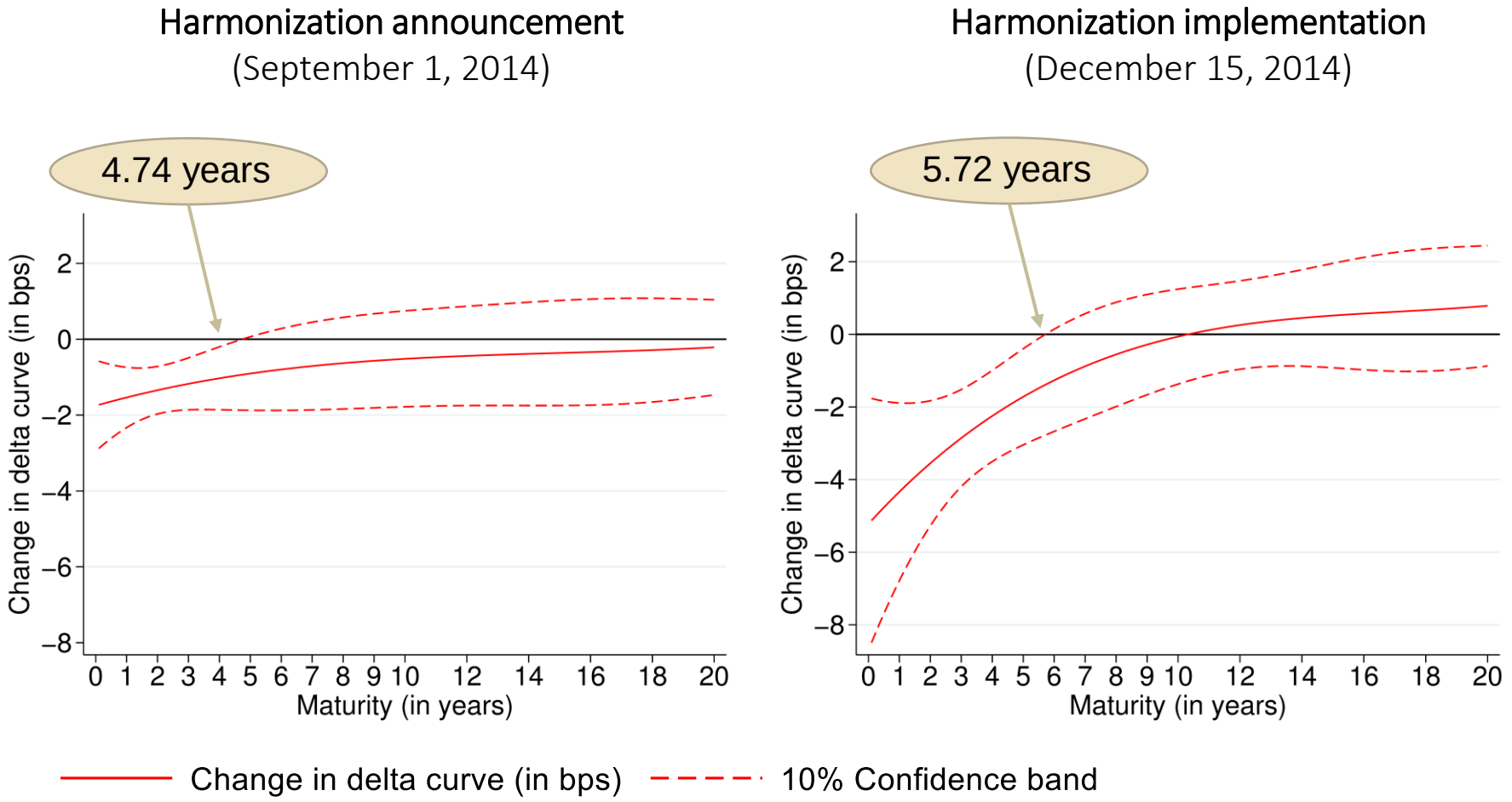
	Haircut differential widens				**Haircut differential shrinks**			
	Mass correction		Haircut update		Harmon. announc.		Harmon. impl.	
Maturity (in years)	Change delta	Change haircut	Change delta	Change haircut	Change delta	Change haircut	Change delta	Change haircut
0.5	**0.020**^{b}	5.0	**0.074**^{a}	0.5	**-0.016**^{a}	0.0	**-0.048**^{a}	-5.5
1	**0.019**^{b}	5.0	**0.062**^{a}	0.5	**-0.015**^{a}	0.0	**-0.043**^{a}	-5.5
2	**0.017**^{b}	5.0	**0.041**^{a}	1.0	**-0.013**^{a}	0.0	**-0.036**^{a}	-6.0
3	**0.016**^{b}	5.0	**0.024**^{b}	1.0	**-0.012**^{a}	0.0	**-0.029**^{a}	-6.0
5	0.013	5.0	-0.001	2.5	-0.009	0.0	**-0.017**^{b}	-7.5
8	0.007	5.0	-0.016	4.0	-0.006	0.0	-0.006	-9.0
12	-0.000	5.0	-0.009	4.0	-0.004	0.0	0.003	-9.0
16	-0.008	5.0	0.013	4.0	-0.003	0.0	0.006	-9.0
20	-0.016	5.0	**0.029**^{b}	4.0	-0.002	0.0	0.008	-9.0
Adj. R^2	0.9962	–	0.9962	–	0.9933	–	0.9960	–

a, b, c denote significance (two-sided) at 1%, 5%, 10%, respectively.
Significance based on z-statistics using the delta method (with SEs clustered on bonds).

- Higher rate of convertibility (lower haircut) implies lower yield
- Significant haircut effect out to around five years
- Harmonization: implementation effect larger than announcement effect

Figure 4. Harmonization: Changes in delta curves for Italy

Cubic spot curves. Significant implementation effect. Consistent with monetary perspective.



- 1 year. Announcement through implementation: -10.1 bps. Or, -1.8 bps per pps haircut

DiD regressions: Differential treatment effects

Fully flexible model with Diebold-Li (2006) spot curves

1. DiD model under the Diebold-Li (2006) spot-curve specification is

$$yield_{it} = \mathbf{B}_1^{'}\mathbf{L}_{it} + \mathbf{B}_2^{'}\mathbf{L}_{it}1_{Treated,i} + \mathbf{B}_3^{'}\mathbf{L}_{it}1_{Post,t} + \mathbf{B}_4^{'}\mathbf{L}_{it}1_{Treated,i}\times 1_{Post,t} + \varepsilon_{it}$$

   where

   a. $\mathbf{L}_{it}$ is a three-dimensional vector of regressors: 1, $l_{1,t}(x;\lambda_t)$, and $l_{2,t}(x;\lambda_t)$

   b. $\mathbf{B}_j^{'}$ is vector of coefficients, with individual elements $\beta_{k,j}, k = 0,1,2$

2. Estimated spot curve for control bonds pre-event:

$$s^{dl}(x;\lambda) = \hat{\beta}_{0,1} + \hat{\beta}_{1,1}\, l_1(x;\lambda) + \hat{\beta}_{2,1}\, l_2(x;\lambda)$$

3. Estimated treatment delta curve:

$$\Delta_4^{dl}(x;\lambda) = \hat{\beta}_{0,4} + \hat{\beta}_{1,4}\, l_1(x;\lambda) + \hat{\beta}_{2,4}\, l_2(x;\lambda)$$

- Estimated over ten- and twenty-day event windows using NLS
- Standard errors clustered on the bond level and calculated using delta method

Table 10, Italy: Treatment effects at selected maturities under flexible model Diebold-Li (2006) spot curves. Ten-day event windows. In-sample I

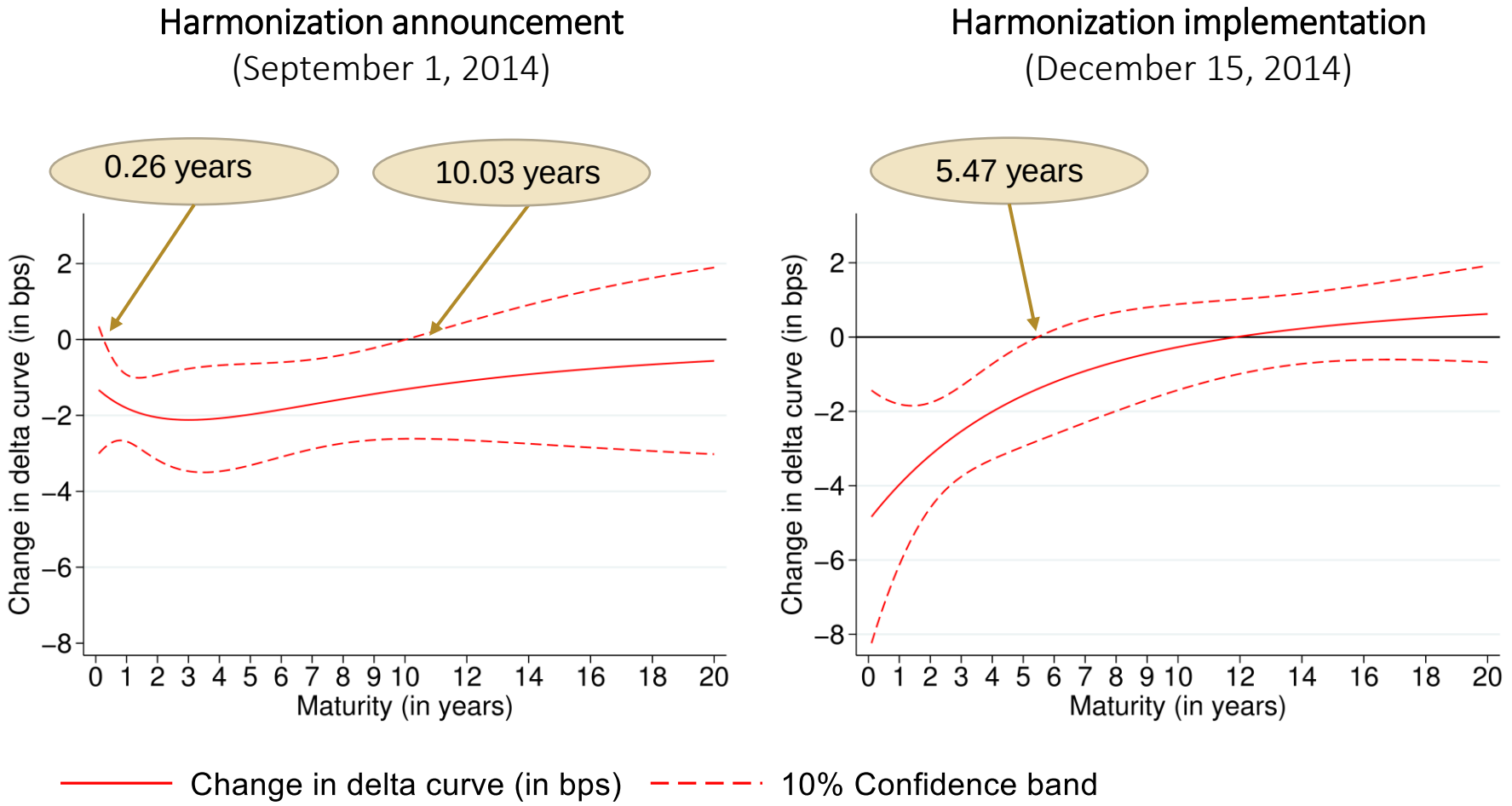
	Haircut differential widens				**Haircut differential shrinks**			
	Mass correction		Haircut update		Harmon. announc.		Harmon. impl.	
Maturity (in years)	Change delta	Change haircut	Change delta	Change haircut	Change delta	Change haircut	Change delta	Change haircut
0.5	0.008	5.0	**0.067**^{a}	0.5	**-0.016**^{b}	0.0	**-0.044**^{a}	-5.5
1	**0.012**^{b}	5.0	**0.043**^{a}	0.5	**-0.018**^{a}	0.0	**-0.040**^{a}	-5.5
2	**0.014**^{b}	5.0	0.014	1.0	**-0.021**^{a}	0.0	**-0.032**^{a}	-6.0
3	0.013	5.0	0.002	1.0	**-0.021**^{a}	0.0	**-0.025**^{a}	-6.0
5	0.007	5.0	-0.004	2.5	**-0.020**^{b}	0.0	**-0.016**^{c}	-7.5
8	-0.002	5.0	0.001	4.0	**-0.016**^{b}	0.0	-0.007	-9.0
12	-0.008	5.0	0.007	4.0	-0.011	0.0	0.000	-9.0
16	-0.012	5.0	0.011	4.0	-0.008	0.0	0.004	-9.0
20	-0.015	5.0	0.014	4.0	-0.006	0.0	0.006	-9.0
Adj. R^2	0.9941	–	0.9940	–	0.9964	–	0.9962	–
$\widehat{\lambda}$	0.5804	–	0.5932	–	0.3929	–	0.2655	–

a, b, c denote significance (two-sided) at 1%, 5%, 10%, respectively.
Significance based on z-statistics using the delta method (with SEs clustered on bonds).

- Similar to results under cubic specification

Figure 6. Harmonization: Changes in delta curves for Italy

Diebold-Li (2006) spot curves



- 1 year. Announcement through implementation: -9.4 bps. Or, -1.7 bps per pps haircut

Total haircut harmonization effect: One-year spot rate

Treatment effect at one-year maturity (in basis points)

	Spot curve specification			
	Cubic		Diebold-Li/Nelson-Siegel	
	Change	Per -1 pps in haircut	Change	Per -1 pps in haircut
Announcement	-1.5		-1.8	
Interim period	-4.3		-3.6	
Implementation	-4.3		-4.0	
Total	-10.1	**-1.8**	-9.4	**-1.7**

Note: 10-day event windows. Interim period: [announcement + 5, implementation − 6]

Table 9, Spain: Treatment effects at selected maturities under flexible model Cubic spot curves

Ten-day event windows

	Haircut differential widens				**Haircut differential shrinks**			
	Mass correction		Haircut update		Harmon. announc.		Harmon. impl.	
Maturity (in years)	Change delta	Change haircut	Change delta	Change haircut	Change delta	Change haircut	Change delta	Change haircut
0.5	**0.025**^{a}	5.0	-0.005	0.5	**-0.013**^{b}	0.0	0.002	-5.5
1	**0.039**^{a}	5.0	0.007	0.5	-0.002	0.0	0.010	-5.5
2	**0.026**^{a}	5.0	**0.014**^{b}	1.0	-0.004	0.0	**-0.020**^{b}	-6.0
3	0.010	5.0	0.009	1.0	-0.008	0.0	**-0.010**^{c}	-6.0
Adj. R^2	0.9897	–	0.9844	–	0.9257	–	0.9146	–

a, b, c denote significance (two-sided) at 1%, 5%, 10%, respectively.
Significance based on z-statistics using the delta method (with SEs clustered on bonds).

Concluding remarks

1. There is a reserves convertibility premium for government bonds
   - Yields rise in haircuts in central bank repos
   - One year spot rate: 2 bps per haircut percentage point
2. Changes to haircuts affect yields even when anticipated months in advance
   - Harmonization implementation effect stronger than harmonization announcement
3. Differential treatment effect over term structure, tapering off at the long end
   - Interpretation: Banks are counterparties in Eurosystem repos
     - Haircuts of given securities matter to the extent that banks hold the securities
4. Findings support the idea that the utility of CB money is embedded in asset prices
   - Securities that can be exchanged for more reserves are priced richer, ceteris paribus.
5. Relevance wrt our understanding of liquidity premia, formation of asset prices
6. Methodological contributions
   - Clean identification of changes in convertibility rates based on "haircut inconsistencies"
   - Combine DiD regressions with flexible yield-curve modeling, solution to sample-induced bias in standard DiD setup in fixed-income setting (Nyborg, Woschitz 2023)

Policy implications

1. Collateral policy can be used by central bank to move and shape the yield curve
   a. Does not interfere with market processes. Does not by itself affect CB balance sheet or composition of money in the system.
   b. Habitat effect suggests that effectiveness at longer maturities may require encouraging banks to hold longer-term bonds or expanding the set of counterparties in CB repos
      - Further research required to assess costs and benefits of such policies

2. Policy discussion on incentivizing green investments by favoring green collateral in the collateral framework. Idea is that this will lower the relative cost of green investments.
   - But…habitat effects
   - But effectiveness of policy may depend on extent to which counterparties in central bank repos hold the targeted bonds (green, brown)