Deviations from Covered Interest Rate Parity

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Federal Reserve Board, Columbia, MIT Sloan

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ESSAYS
IN
PERSUASION

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MONETARY
REFORM

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Background

- 1923, Keynes: A Tract on Monetary Reform, Chapter IV.

  - Covered Interest Rate Parity:
    - Borrow \$1 at the U.S. dollar risk-free rate $y_t^{\$}$;
    - Exchange that \$1 for S_t units of foreign currency;
    - Invest at foreign risk-free rate $y_t^{\star}$;
    - Convert the proceeds back at the pre-determined forward rate F_t;
    - No risk, no profits:
      $$1 + y_t^{\$} = (1 + y_t^{\star}) \, S_t / F_t$$

- Today:
  - In every undergraduate and graduate textbook...
  - Size of FX forward and swap markets:
    - Notional outstanding: \$61 trillion
    - Daily trading volume: \$3 trillion

This Paper

Currently, in one of the largest markets in the world, there are large, long-lasting, and systematic deviations from the covered interest rate parity,

1. leading to systematic **arbitrage opportunities**;

2. **caused notably by the cost of financial intermediation**. . .

3. and linked to **nominal interest rates**.

Related Literature

- ▶ **Tests of CIP**: Keynes (1923), ..., Stein (1962), Glahe (1967), Aliber (1973), Frenkel and Levich (1975, 1977, 1981), Deardorff (1979), Dooley and Isard (1980), Callier (1981), Bahmani-Oskooee and Das (1985), Clinton (1988), ...Akram, Rime, and Sarno (2008)

  - ▶ **CIP deviations during the crisis**: Baba and Packer (2009), Baba, Packer and Nagano (2008), Baba, McCauley and Ramaswamy (2009), Bottazzi et al. (2012), Coffey, Hrung and Sarkar (2009), McGuire and von Peter (2009), Goldberg, Kennedy and Miu (2011), Griffoli and Ranaldo (2011), Ivashina, Scharfstein and Stein (2015)

  - ▶ **CIP deviations post-crisis**: Buraschi, Menguturk, and Sener (2015), Du and Schreger (2016), Arai, Makabe, Okawara, and Nagano (2016), Borio, McCauley, McGuire, and Sushko (2016), Iida, Kimura, and Sudo (2016), Liao (2016), Wong, Leung, and Ng (2016), Ivashina, Stein, and Scharfstein (2016), Rime, Schrimpf, and Syrstad (2017), Avdjiev, Du, Koch and Shin (2017), Sushko, Borio, McCauley, and McGuire (2017), Cenedese, Della Corte, and Wang (2017), Duffee (2017), Andersen, Duffee and Song (2017)

- ▶ Potential frameworks:
  - ▶ **Global imbalances, costly intermediation**: Caballero, Farhi, and Gourinchas (2008, 2016), Gabaix and Maggiori (2015).
  - ▶ **Intermediary-based, liquidity-based, margin-based asset pricing, and preferred habitat investors**: Vayanos and Vila (2009), Garleanu and Pedersen (2011), He and Krishnamurthy (2012, 2013), Krishnamurthy and Vissing-Jorgensen (2012), Brunnermeier and Sannikov (2014), Greenwood and Vayanos (2014), Adrian, Etula, and Muir (2014), He, Kelly, and Manela (2015)
  - ▶ **Global liquidity and global banks**: Bruno and Shin (2015), Cetorelli and Goldberg (2011, 2012), Correa, Sapriza and Zlate (2012), Rose and Spiegel (2012), Shin (2012), Amador, Bianchi, Bocola, and Perri (2016).

Outline

1. Arbitrage opportunities

   - Repo basis
   - KfW Basis

2. The causal role of banks' balance sheets:

   - the quarter ends' smoking gun
   - CIP deviations and a proxy for banks' balance sheet costs
   - CIP deviations and other spreads

3. The role of global imbalances: evidence from nominal interest rates

   - in the cross-section
   - in the time series

From the Covered Interest Parity' Deviations

to the Arbitrage Opportunities

Covered Interest Rate Parity

▶ Without transaction costs:

$$1 + y_t^\$ = (1 + y_t^\star)\, S_t/F_t$$

▶ With transaction costs:

$$1 + y_t^{\$,ask} \geq (1 + y_t^{\star,bid})S_t^{bid}/F_t^{ask} \text{ and } (1 + y_t^{\$,bid})F_t^{bid}/S_t^{ask} \leq 1 + y_t^{\star,ask}.$$
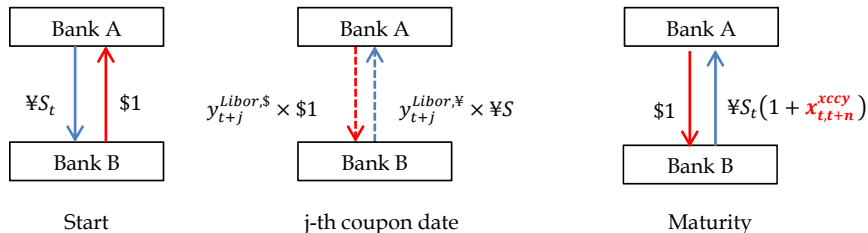
Deviation from Covered Interest Parity

- Cross-currency basis x_t:

$$\left(1 + y_t^{\$}\right) = (1 + y_t^{\star} + x_t)\frac{S_t}{F_t}.$$

In logs, for the intuition:

$$x_t \simeq \underbrace{y_t^{\$}}_{\text{Direct \$ rate}} - \underbrace{[y_t^{\star} - (f_t - s_t)]}_{\text{Synthetic \$ rate}}$$
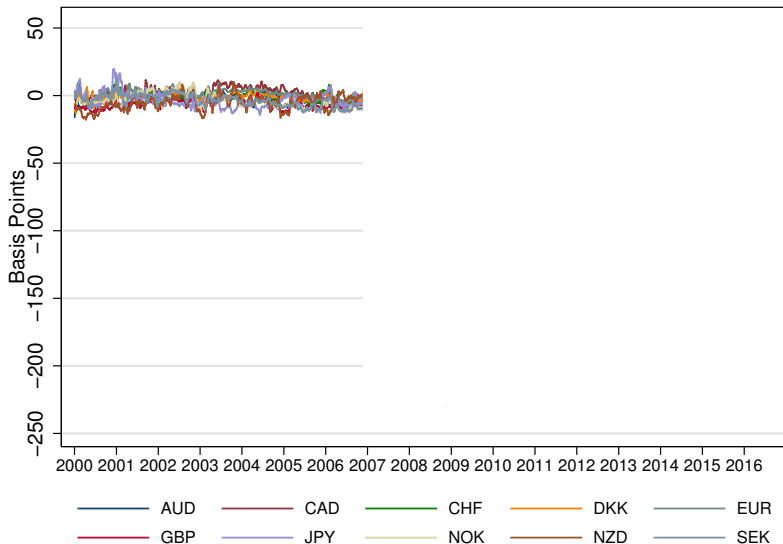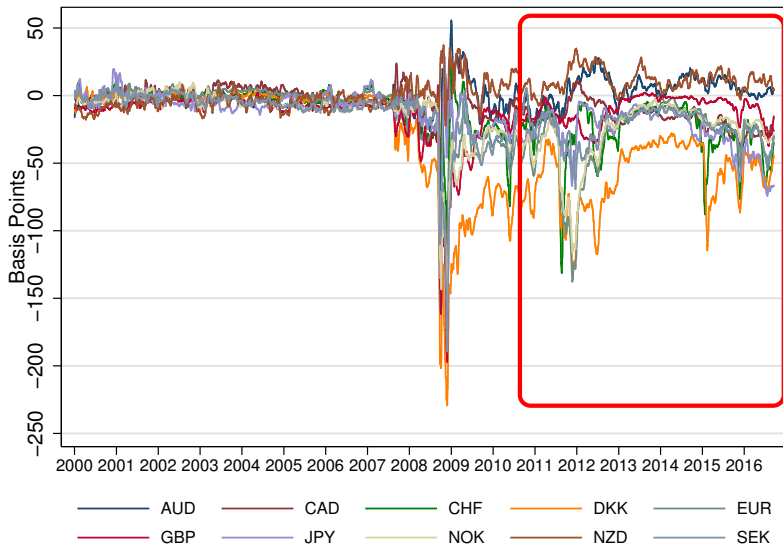
Yen/Dollar Cross-Currency Basis Swap

The cross-currency basis swap rates must be such that:

$$\left(1 + y_{t,t+n}^{\$,IRS}\right)^n = \left(1 + y_{t,t+n}^{\star,IRS} + x_{t,t+n}^{xccy}\right)^n \frac{S_t}{F_{t,t+n}}.$$
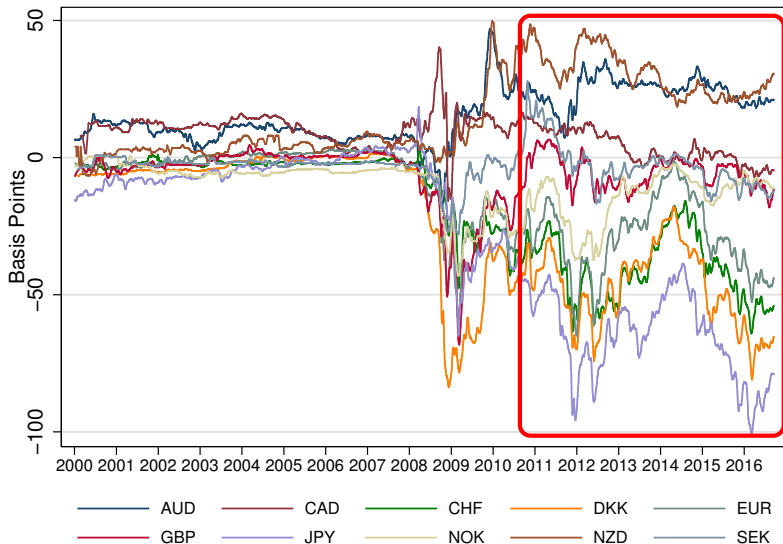
Three-Month Libor Cross-Currency Basis: G10 Currencies

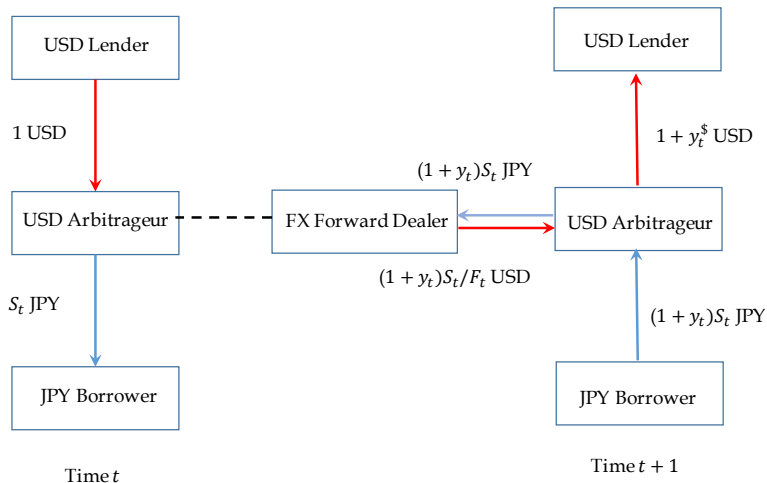# Three-Month Libor Cross-Currency Basis: G10 Currencies

Five-Year Cross-Currency Basis: G10 Currencies

From the Covered Interest Parity' Deviations

to the Arbitrage Opportunities

CIP Arbitrage with a Negative Basis ($x_t < 0$)

USD Lender	USD Lender
$\downarrow$ 1 USD	$\uparrow$ $1 + y_t^\$$ USD
USD Arbitrageur	$(1 + y_t)S_t$ JPY ... FX Forward Dealer ... $(1 + y_t)S_t/F_t$ USD ... USD Arbitrageur
S_t JPY	$(1 + y_t)S_t$ JPY
JPY Borrower	JPY Borrower
Time t	Time $t + 1$

Net Cash Flow   0 USD $-(1 + y_t^\$) + (1 + y_t)S_t/F_t \approx -x_t > 0$ USD

What Can Go Wrong?

- Transaction costs?
    - Libor rates are indicative: manipulation?

- The arbitrage entails lending money: credit risk?

- The arbitrage entails signing a forward contract: counterparty risk?

Counterparty Risk on FX Derivatives

- Highly collateralized
  - Defined in the Credit Support Annex of the International Swap and Derivative Association (ISDA)
  - Initial margins + variation margins in cash with the amount equal to the mark-to-market value of the swap.

- Evidence from the CDS market:
  - Arora, Gandhi, and Longstaff (2011): a 645 basis point increase in the seller's CDS spreads translates only to a one basis point reduction in the quoted CDS premium using actionable quote data.
  - Using real CDS transaction data, Du, Gadgil, Gordy, and Vega (2016) obtain estimates of similar magnitude.

Risk-Free Arbitrage Opportunities

- Short-term CIP arbitrage:
    - General Collateral (GC) repo CIP arbitrage
    - Size: $1.5 trillion in U.S., $1.8 trillion in Europe, $0.5 trillion in Japan.

- Long-term CIP arbitrage:
    - KfW bonds denominated in different currencies
    - KfW liabilities are fully backed by the German government
    - Size: Annual issuance about $70 billion. Outstanding: $370 billion ($170 billion EUR and $130 billion USD).
    - Other AAA supranational issuers: EIB, World Bank, etc.

Short-Term Arbitrage: Repo Contracts

▶ When the repo basis is negative:

1. Borrow at USD repo for one week,
2. Invest in EUR/CHF/DKK/JPY repo for one week,
3. Perfectly hedge FX risk using FX forwards.

	CHF	DKK	EUR	JPY
Mean basis	-21.4	-41.3	-19.8	-22.3
Std dev of basis	(28.6)	(22.7)	(16.6)	(28.7)
Fractions of sample with negative basis	99%	96%	96%	100%
Mean arb. profits	16.3	19.3	11.5	17.8
Std dev of profits	(27.4)	(23.7)	(13.7)	(22.8)
Fractions of sample with positive profits	84%	67%	81%	93%

Note: All moments in basis points. Arbitrage profits take into account transaction costs of forwards and spots, but miss half repo bid-ask spreads for CHF, EUR and JPY. The sample is 1/1/2009–12/31/2016.

Long-Term Arbitrage: KfW Bonds

- When the KfW basis is negative (EUR/CHF/JPY), the arbitrage strategy for the dollar investor is:
    1. Short KfW bond issued in USD (shorting fee)
    2. Long KfW bond issued in EUR/CHF/JPY,
    3. Hedge EUR/CHF/JPY FX risk using cross-currency swaps,

	AUD	CHF	EUR	JPY
Mean basis	0.1	-23.5	-13.6	-30.2
Std. dev. of basis	(11.5)	(15.7)	(9.7)	(15.2)
Fractions of sample with negative basis	57%	97%	94%	98%
Mean arb. profit	5.8	15.2	8.7	20.2
Std. dev. of profit	(3.4)	(8.9)	(5.4)	(11.3)
Fractions of sample with negative basis	2%	33%	23%	63%

Notes: All moments in basis points. Arbitrage profits take into account transaction costs of bonds, swaps and median shorting fees. The sample is

1/1/2009–8/30/2016.

- Small roll-over risk on shorting fees

Summary So Far

- Deviations from CIP offer arbitrage opportunities

    - After controlling for transaction costs and credit risk

- Why should we care? A benign view:

    - Small deviations and FX derivatives are a zero-sum game

    - Higher FX hedging costs because safer banks (thanks to the regulation), and thus more reliable hedging products, and we're safe

    - A measure of the monopolistic rent of having access to USD?

Should We Care?

- A less benign view:

  - One of the largest and most liquid markets; not clear why arbitrage opportunities should only exist there

  - Deadweight cost of hedging tax on firms

  - Banks' balance sheet costs are high, banks perhaps can't absorb shocks in the future, and we're not safe

- Academic view:

  - CIP is a clean laboratory to test our theories; no asset pricing model needed... **The academic dream!**

The Cost of Financial Intermediation

Increased Costs of Financial Intermediation

1. Risk-weighted capital (Basel II.5 and Basel III): Long-term CIP trade

2. Non-risk-weighted capital (LR and SLR): Short-term CIP trade

Change in Capital Requirements for U.S. G-SIBs

	Pre-Crisis	Post-Crisis
Tier 1 Capital	4% RWA	9.5%–13% RWA*
Total Capital	8% RWA	11.5%-15% RWA*
Leverage Ratio	3% Average Assets	6% (Total Assets +off B/S)

3. Other requirements:
    - Volcker Rule
    - Over-the-counter derivative market reform
    - FDIC broader assessment base for deposit insurance fees

Capital Charges Against a Five-Year Libor CIP Trade

Year	VaR (annualized)	SVaR (annualized)	Capital Ratio	Capital Charges (% of notional)
2000	4.87%		8%	0.56%
2001	3.34%		8%	0.39%
2002	3.65%		8%	0.42%
2003	3.64%		8%	0.42%
2004	3.12%		8%	0.36%
2005	2.07%		8%	0.24%
2006	1.92%		8%	0.22%
2007	3.26%		8%	0.38%
2008	19.21%		8%	2.22%
2009	20.28%		8%	2.34%
2010	12.03%		8%	1.39%
2011	12.78%		8%	1.47%
2012	14.39%		8%	1.66%
2013	8.94%	20.28%	8%	3.37%
2014	6.43%	20.28%	11.50%	4.44%
2015	9.20%	20.28%	11.50%	4.88%

Banks' Balance Sheet Costs

- Risk-weighted capital rules:
  - Capital charges for a 5-year Libor CIP trade increased from around 0.5% in 2000 to close to 4.5% in 2015
  - Implicit leverage is reduced from 200 to 20.
  - Caveat: Focus here on one CIP arbitrage trade, not on the whole bank portfolio.

- Non-risk-weighted capital rules:
  - Assume that banks need to hold 6% of their capital against the CIP trades, and that their overall objective in terms of rates of return on capital is 10%, then banks need at least a $6\% \times 10\% = 60$ basis point cross-currency basis to engage in the trade.
  - Many CIP deviations are not attractive enough.

Limits Facing Other Arbitrageurs/Intermediaries

- **Multi-currency issuers:**
  - Can do funding cost arb., but not long-short arb.
  - Focus on arbitraging issuer-specific bases, not necessarily in line with the Libor basis

- **Hedge funds:**
  - Face higher costs of leverage because they need to borrow from prime brokers, who are regulated entities

- **U.S. money market funds:**
  - Have dollars, but law forbids investment in foreign-currency assets.
  - Recent prime to government-only fund conversion reduces U.S. MMFs' holdings of CPs and CDs issued by foreign banks

- **Central bank FX reserve managers:**
  - Have dollar reserves, can do secured arb. by lending out dollars, but face size and regulatory constraints

Quarter-End Anomalies

- Banks face tighter balance sheet constraints at the quarter end due to regulatory filings (based on quarter-end snapshots for European banks, quarter average + snapshots for U.S. banks) and investors' attention.

- Difference-in-differences (in differences):
  - Quarter-end days vs. the rest of the quarters
  - Before vs. after the crisis (or the new 1/2015 regulation)
  - 3M deviations (unaffected) vs. 1M and 1W deviations (affected)

- Null hypothesis:
  - Level: CIP deviations increase at quarter ends, more so post the crisis.
  - Term structure:
    - 3M-1M declines 1M before quarter ends;
    - 1M-1W increases 1M before quarter ends; and then declines 1W before quarter ends.

Level of CIP Deviations at Quarter Ends: $|x^{Yen}|$

Legend: 1w deviation (red), 1m deviation (green), 3m deviation (orange)

Larger Deviations for Contracts Reported at Quarter Ends

	3M-1M		1M-1W	
	Libor	OIS	Libor	OIS
$QendM_t$	0.565	0.573		
	(0.421)	(0.643)		
$QendM_t \times Post_t$	-4.023***	-4.808***		
	(0.552)	(0.770)		
$\mathbb{I}(QendM_t = 1, QendW_t = 0)$			-0.625	0.547
			(0.591)	(1.338)
$\mathbb{I}(QendM_t = 1, QendW_t = 0) \times Post_t$			6.517***	4.714***
			(0.760)	(1.461)
$QendW_t$			-3.217***	-3.780**
			(0.829)	(1.777)
$QendW_t \times Post_t$			-6.567***	-10.34***
			(1.073)	(1.951)
$Post_t$	5.464***	5.395***	0.920	-0.240
	(0.540)	(0.576)	(0.636)	(1.091)

Sample period: January 2000 - September 2016

Larger Deviations for Contracts Reported at Quarter Ends

especially after 1/2015

	3M-1M			1M-1W		
	Libor	OIS	Repo	Libor	OIS	Repo
$QendM_t$	0.565	0.565	0.565			
	(0.414)	(0.414)	(0.414)			
$QendM_t \times Post07_t$	-2.390***	-2.390***	-2.390***			
	(0.567)	(0.567)	(0.567)			
$QendM_t \times Post15_t$	-9.476***	-9.476***	-9.476***			
	(0.934)	(0.934)	(0.934)			
$\mathbb{I}_{QendM_t=1,QendW_t=0}$				-0.625	0.543	0.827
				(0.577)	(1.315)	(1.020)
$\mathbb{I}_{QendM_t=1,QendW_t=0} \times Post07_t$				4.242***	2.392	8.270***
				(0.773)	(1.466)	(1.505)
$\mathbb{I}_{QendM_t=1,QendW_t=0} \times Post15_t$				12.76***	11.05***	19.84***
				(1.226)	(1.426)	(3.635)
$QendW_t$				-3.217***	-3.782**	-5.618***
				(0.809)	(1.743)	(1.525)
$QendW_t \times Post07_t$				-1.404	-5.725***	-8.307***
				(1.085)	(1.950)	(2.353)
$QendW_t \times Post15_t$				-33.39***	-25.22***	-77.10***
				(1.849)	(2.057)	(6.177)
$Post07_t$	5.925***	5.925***	5.925***	0.843	-0.524	1.087
	(0.553)	(0.553)	(0.553)	(0.657)	(1.097)	(0.912)
$Post15_t$	-2.591***	-2.591***	-2.591***	0.444	1.594	5.516**
	(0.890)	(0.890)	(0.890)	(1.022)	(1.030)	(2.160)

Taking Stock

▶ Banks' balance sheets at the end of the quarter locally cause CIP deviations

  1. Role of recent banking regulation on asset prices and arbitrage opportunities

  2. Self-regulating behavior of banks? New focus of investors?
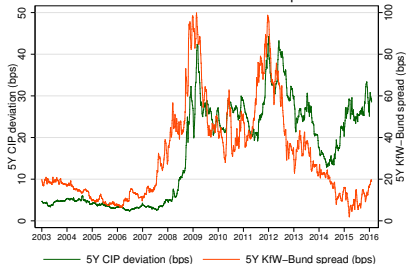
A Proxy for the Banks' Balance Sheet Costs:

Excess reserves of depository institutions around $2 trillion in fall 2016

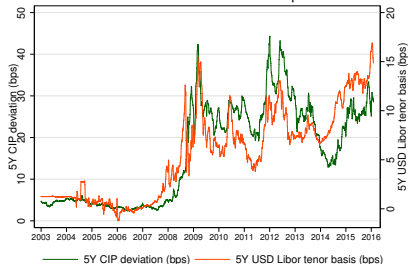# One-Week IOER-Based CIP Deviations (2009-2016)

Currency	Libor basis	IOER-Libor	OIS basis	IOER-OIS	Repo basis	IOER-Repo	IOER basis
CHF	-21.4	-15.5	-36.8	-24.8	-25.2	-16.5	-13.2
	(28.6)	(29.5)	(36.9)	(37.4)	(32.0)	(34.0)	(30.3)
DKK	-41.3	-35.4	-29.1	-16.1	-33.8	-24.4	-12.0
	(22.7)	(25.6)	(23.6)	(24.4)	(25.2)	(26.2)	(25.7)
EUR	-19.8	-13.9	-22.9	-11.1	-15.5	-7.1	8.8
	(16.6)	(19.1)	(15.8)	(17.2)	(14.7)	(17.3)	(23.6)
JPY	-22.3	-16.4	-26.5	-14.3	-26.6	-18.2	-15.6
	(28.7)	(29.1)	(30.7)	(30.9)	(29.1)	(30.9)	(29.4)
Total	-26.1	-20.2	-28.3	-16.1	-24.7	-16.0	-7.9
	(26.2)	(27.6)	(27.8)	(28.4)	(26.7)	(28.4)	(29.1)

Correlation with Other Fixed-Income Spreads

The Link with Interest Rates

CIP Deviations and Interest Rates: Across Countries

5Y Libor (corr.=89%)

- ▶ Other correlations:
  - ▶ Corr(KfW basis, KfW yield)=95%
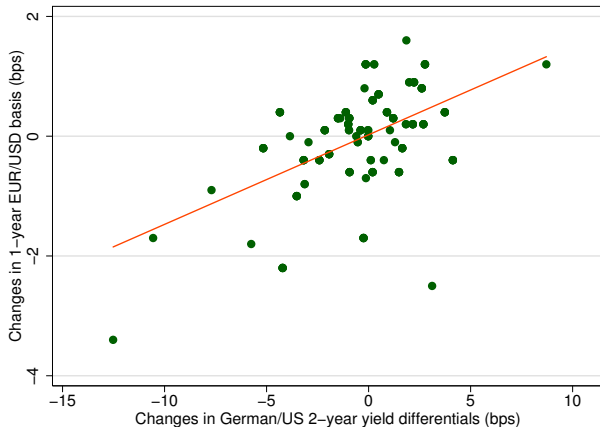 - ▶ Corr(OIS basis, OIS)=83%
  - ▶ Corr(Tres basis, Tres yields)=86%.

Funding Cost Arbitrage: KfW+SSA Relative Issuance

CIP Deviations and Nominal Interest Rates: Time Series

- Announcement effects of ECB monetary policy decisions on the cross-currency basis.

  - Event window: 5 minutes before the statement release to end of the press conference for each ECB monthly monetary policy meeting since 2010.

  - Measure monetary policy asymmetry: changes in 2-year German bund and U.S. Treasury yield differentials.

  - Intraday 1-year Libor cross-currency basis directly quoted by a major European bank.

ECB Monetary Policy and Euro/Dollar Basis

$$\Delta x_i = \underset{(0.056)}{0.024} + \underset{(0.025)}{0.150^{***}} \; (\Delta y_i^{GE} - \Delta y_i^{US}).$$
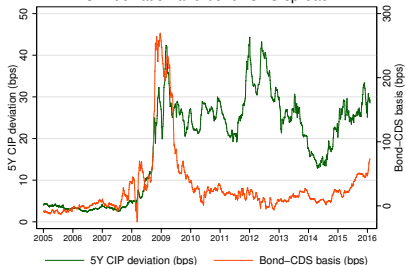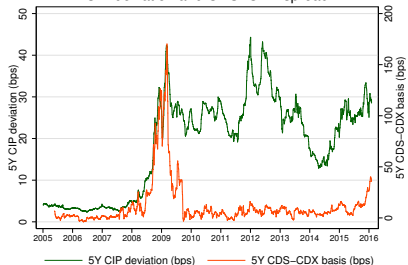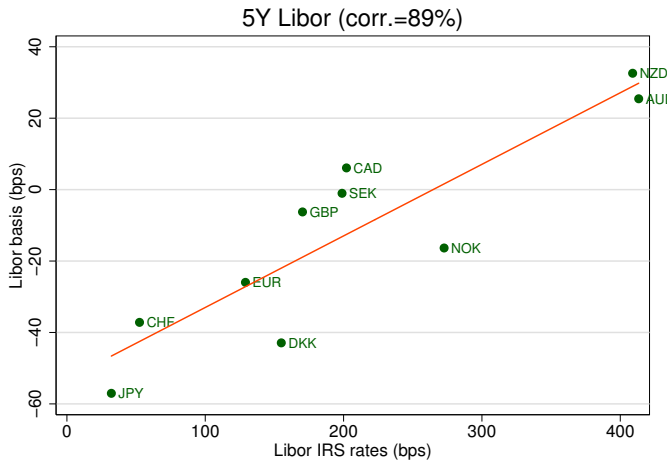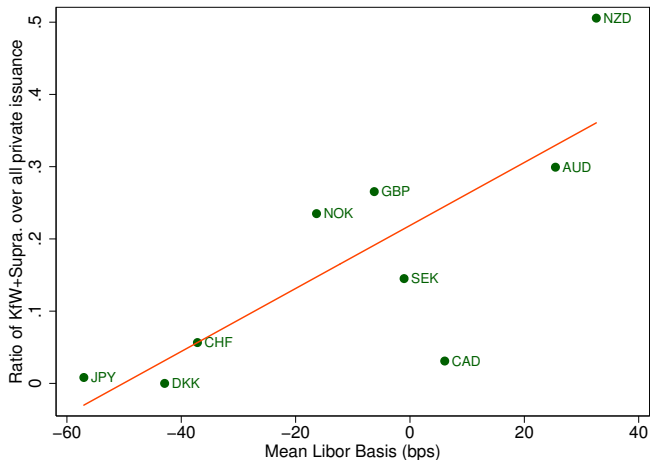
Conclusion
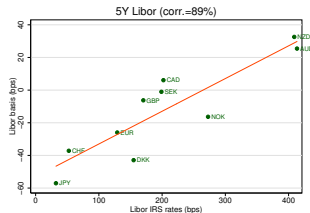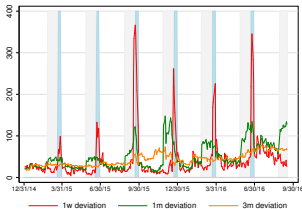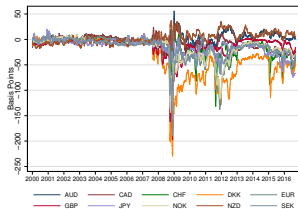
1. Persistent **arbitrage opportunities** in currency markets post-crisis.

2. Partly **due to banks' balance sheet costs**

3. Strongly **correlated with nominal interest rates**