Limits to arbitrage during the crisis: funding liquidity constraints and covered interest parity

Tommaso Mancini Griffoli & Angelo Ranaldo
Swiss National Bank

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Disclaimer

- The views expressed in this paper and presentation are those of the authors and do not necessarily reflect those of the Swiss National Bank.

Introduction

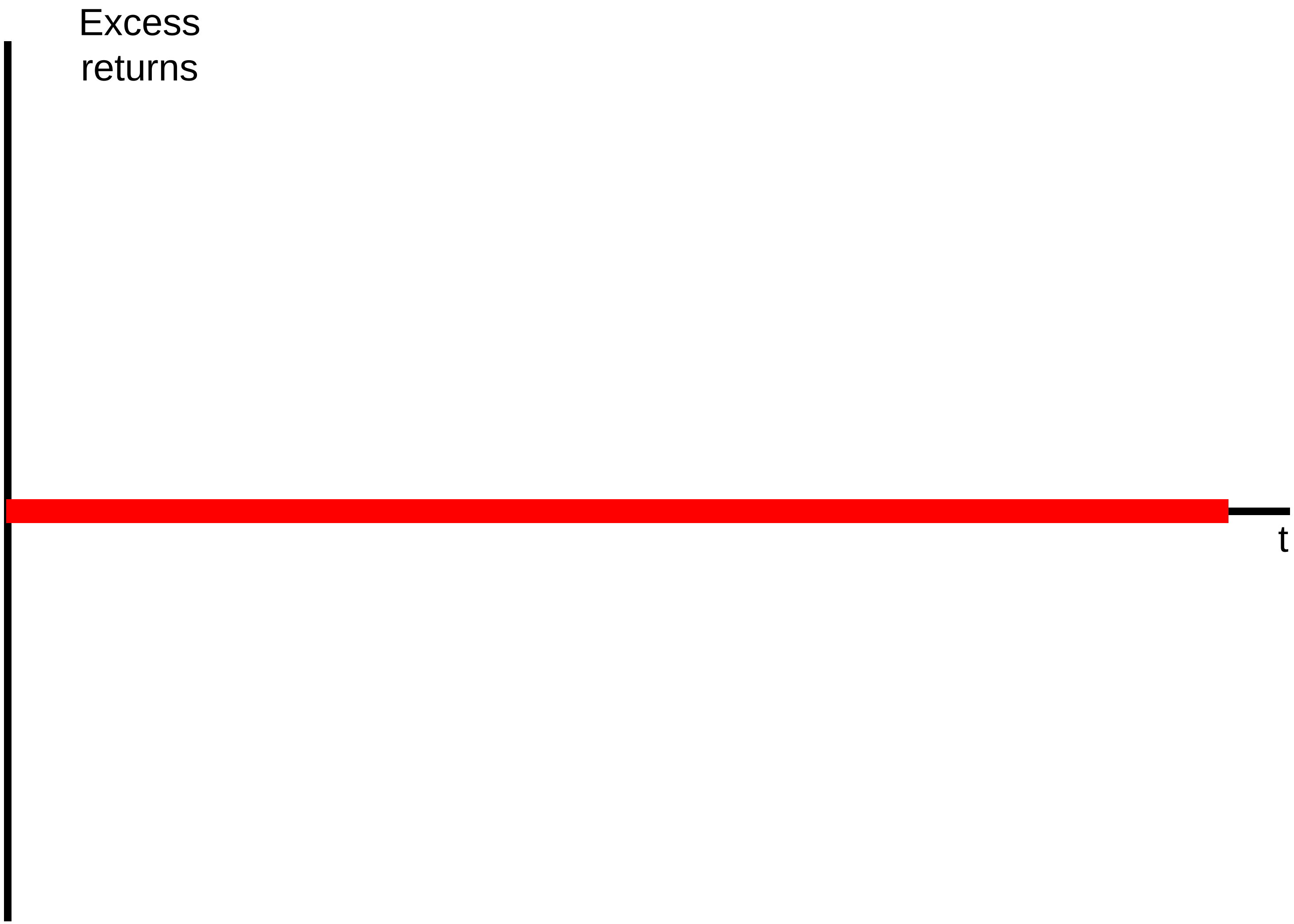
Introduction

- Keynes, J. M. (1923): A tract on monetary reform.
- "It must be remembered that the floating capital normally available, and ready to move from one centre to another for the purpose of taking advantage of arbitrage profits is by **no means unlimited in amount**" (p. 129)
- "The abnormal discount can only disappear when the high profit of arbitrage between spot and forward has drawn **fresh capital** into the arbitrage business" (p. 130)

Research aims

- To document deviations from the Covered Interest Rate Parity (CIP) during the crisis
- To explain them

CIP returns in the literature



CIP returns in the literature

- Frenkel and Levich (1975, 1977), Taylor (1989), Rhee and Chang (1992), Akram, Rime and Sarno (2008), Fong, Valente and Fung (2009, forthcoming), …

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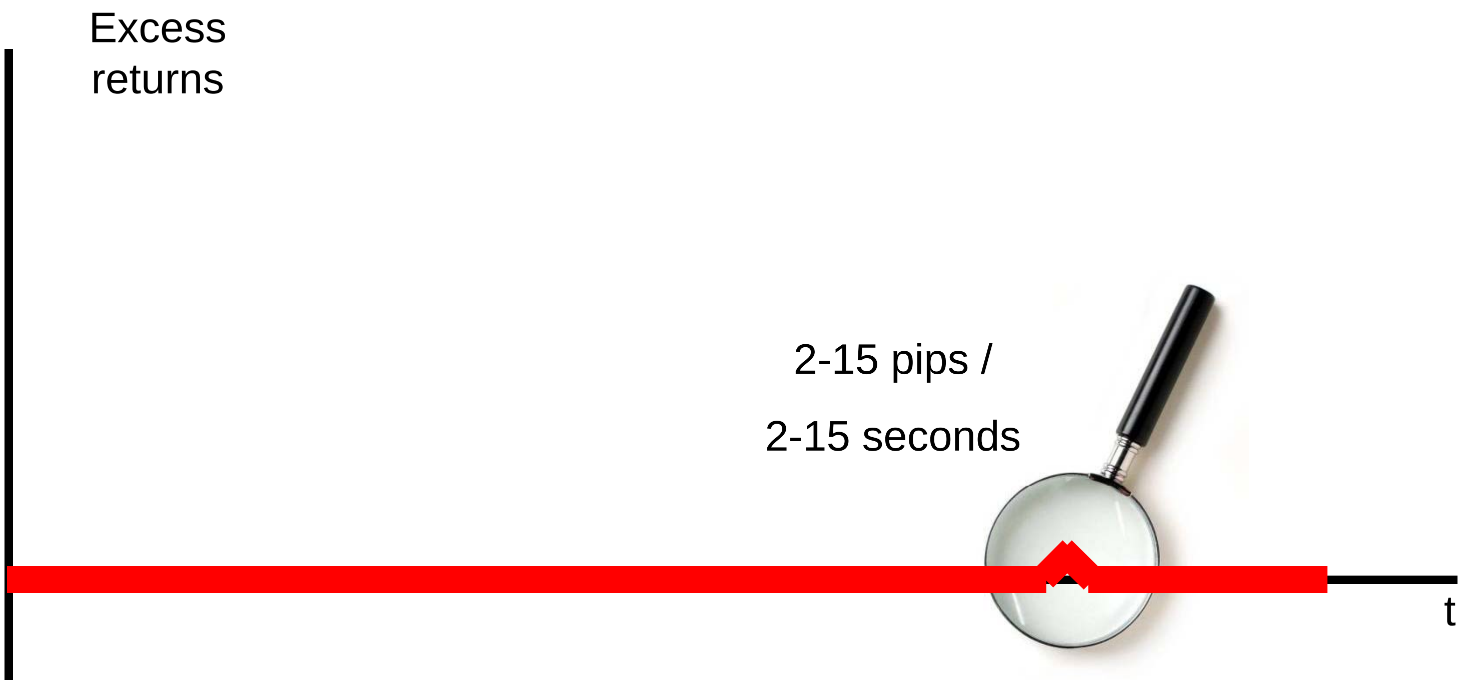

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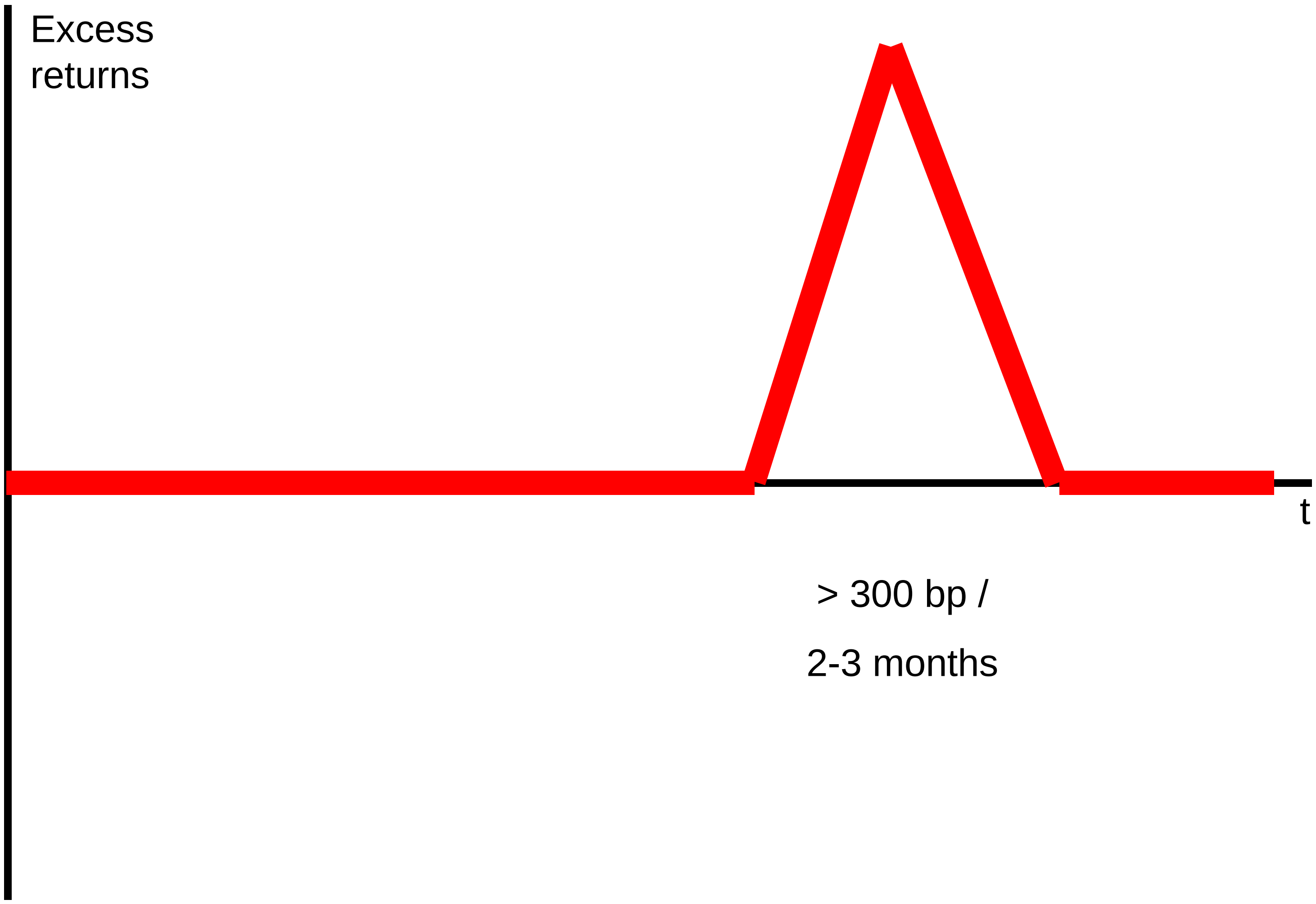
What we found



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Literature

- On the crisis:
  - Baba and Parker (2008, 2009)
  - Baba, Parker and Nagano (2008)
  - Genberg, Hui, Wong, and Chung (2009)
  - Coffey, Hrung, Nguyen, and Sarkar (2009)
  - Jones (2009)

- But using unrealistic settings
  - Libor rates: indicative “ask” possibly biased by strategic signaling and time-of-day effects (11:00 Ldn time)
  - Transaction costs
  - Non-synchronized data
  - Not short-term maturities
  - Uncollateralized money market rates: hard to disentangle the drivers

CIP arbitrage

CIP condition

- CIP arbitrage:

1. borrowing in currency *k* at the cost $r_{k,t}$
2. exchanging the sum in currency *j* at the spot rate S_t
3. lending the proceeds in currency *j* at a rate $r_{j,t}$
4. avoiding exchange rate risk by selling the currency *j* using a forward contract at rate $F_{t \ldots T}$.

$$z_t = \frac{F_{t \ldots T}}{S_t}\left(1 + r_{j,t}\right) - \left(1 + r_{k,t}\right)$$

- FX rates expressed as the price in currency *k* of one unit of currency *j*

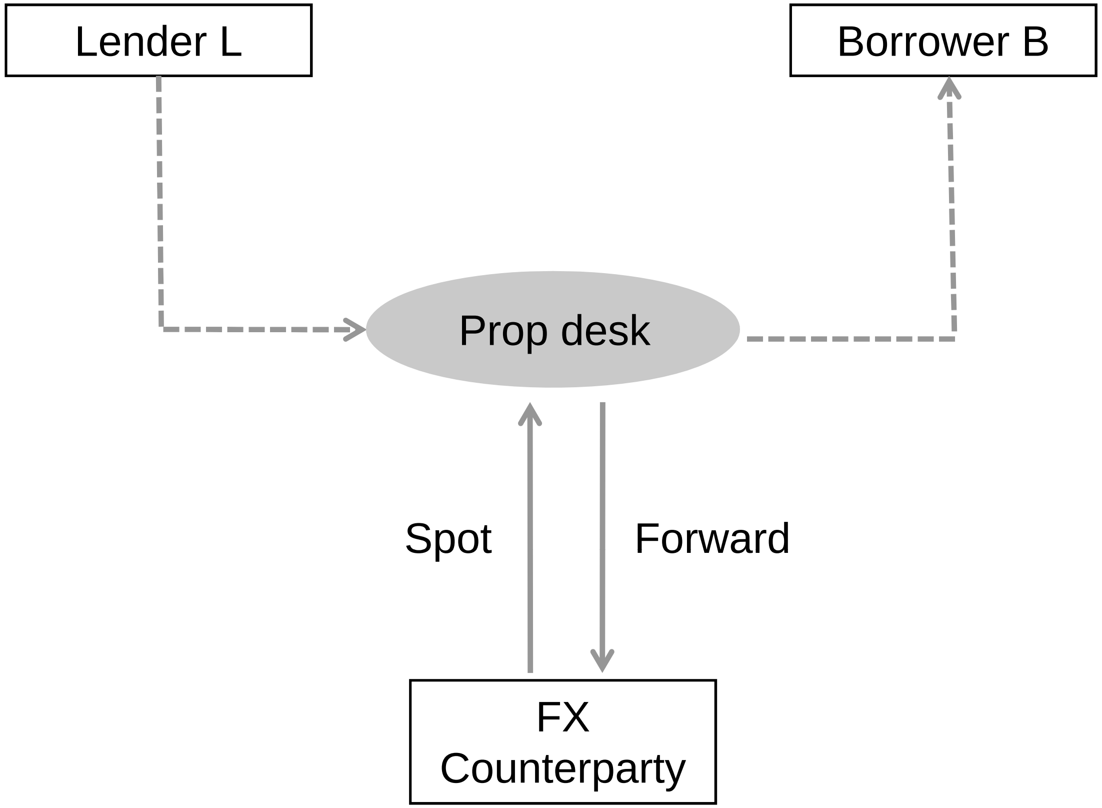
How to implement CIP arbitrage

- But how is CIP arbitrage actually implemented?
- What instruments are used to borrow / lend?
- What transaction costs are undertaken?
- Are there hidden cost or risk?
- What is the term over which CIP arbitrage should hold?

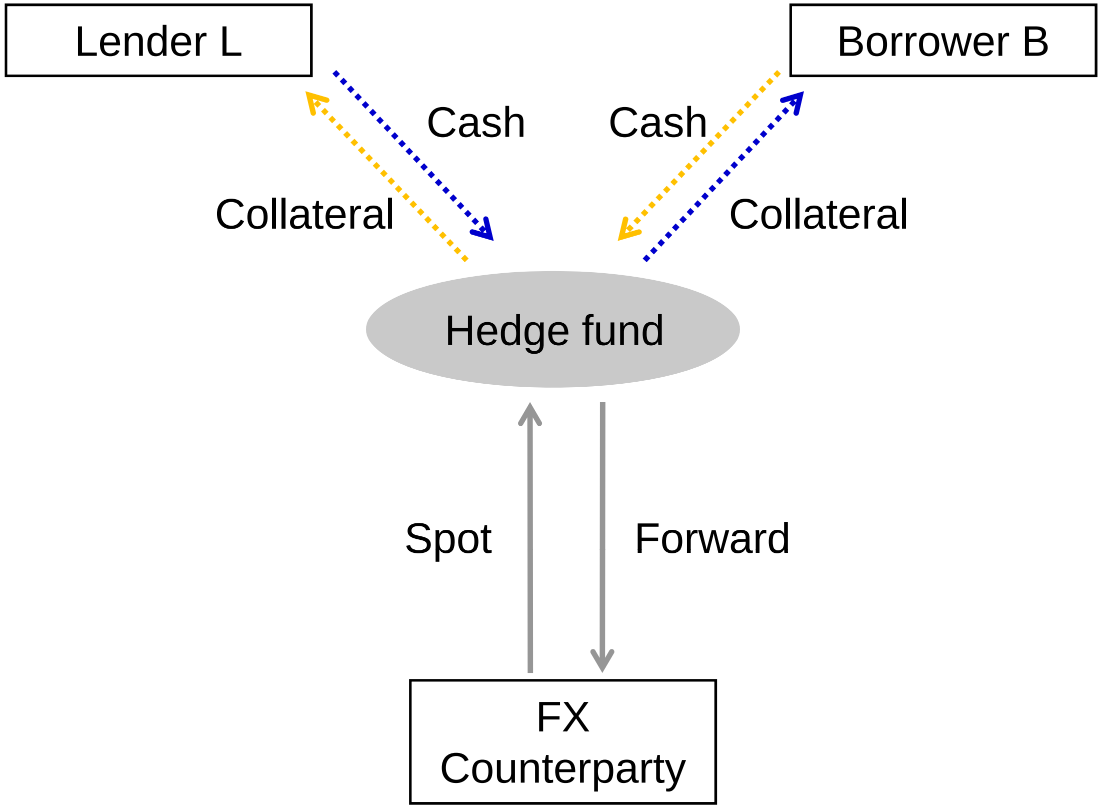
How to perform CIP arbitrage

1. Unsecured arbitrage
2. Secured arbitrage

CIP arbitrage: uncovered



CIP arbitrage: covered



Unsecured vs Secured arbitrage

	Unsecured	Secured
WHO	Prop desks	Hedge Funds
WHERE	Interbanking MM	REPO market
WHEN	RO ON ≥ 1 week	≤ 1 week
WHAT IF in crisis	Riskier	Safer

Unsecured arbitrage

- The expected (ex-ante) payoff when rolling over ON unsecured money market

$$z_{2,t} = \frac{F_{t\dots T}^{B}}{S_t^{A}}\left(1+r_{j,t\dots T}^{C,B}\right)-\left(1+r_{k,t\dots T}^{C,A}\right)$$

- Cumulative interest rates to borrow (*Ask*) in ccy *k* and lend (*Bid*) in ccy *j* at time *t* with maturity *T*:

$$1+r_{k,t\dots T}^{C,A} = E_t\left[\prod_{s=t}^{T-1}\left(1+r_{k,s\dots s+1}^{A}\right)\right]$$

$$1+r_{j,t\dots T}^{C,B} = E_t\left[\prod_{s=t}^{T-1}\left(1+r_{j,s\dots s+1}^{B}\right)\right]$$

Implementing CIP arbitrage using OIS

- Avoid **interest risk** using Overnight Index Swaps (OIS)
- OIS is a fixed / floating interest rate swap with the floating leg tied to a overnight unsecured reference rate such as FF and Eonia
- No exchange of principal: reducing counterparty default risk

Unsecured arbitrage

- The OIS rate in currency k:

$$1+r^{O}_{k,t...T}=1+r^{C}_{k,t...T}=E_t\left[\prod_{s=t}^{T-1}\left(1+r_{k,s...s+1}\right)\right]$$

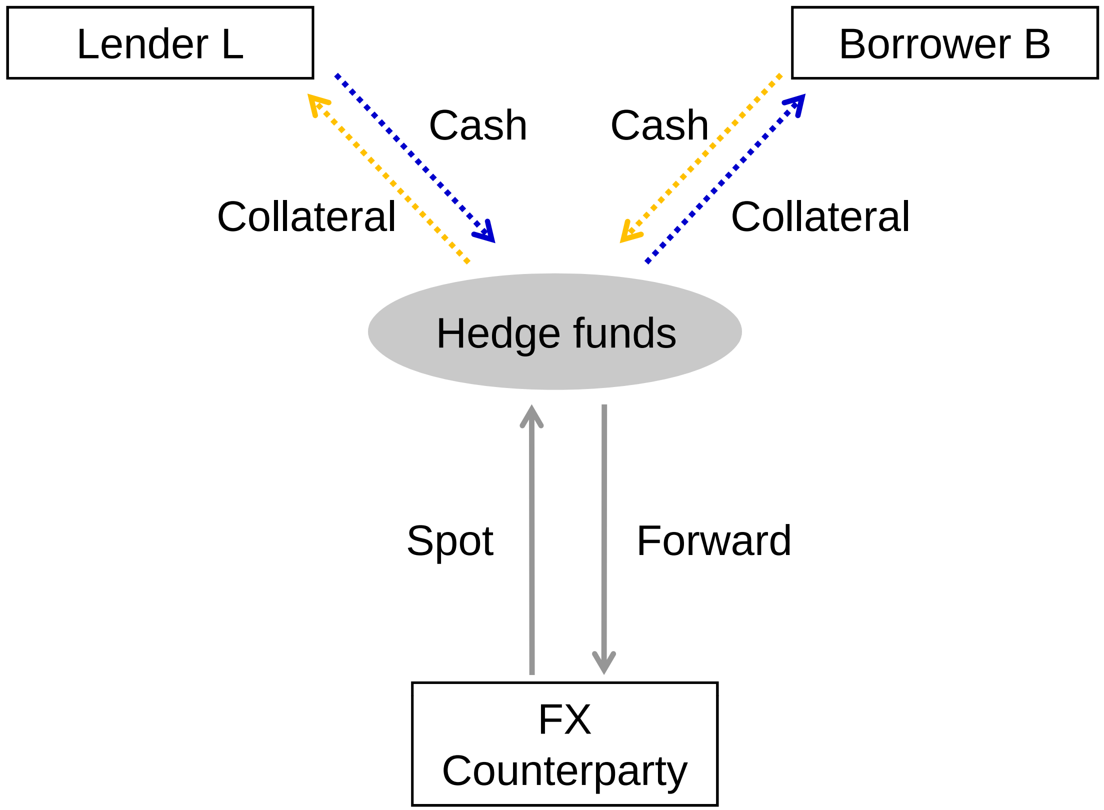
- The trader's expected payoff from CIP arbitrage:

$$z_{3,t}=\frac{F^{B}_{t...T}}{S^{A}_{t}}\left[\left(1+r^{C,B}_{j,t...T}\right)-\left(1+r^{C}_{j,t...T}\right)+\left(1+r^{O,B}_{j,t...T}\right)\right]+\left[\left(1+r^{C}_{k,t...T}\right)-\left(1+r^{C,A}_{k,t...T}\right)-\left(1+r^{O,A}_{k,t...T}\right)\right]$$

- Simplified payoff:

$$z^{'}_{3,t}=\frac{F^{B}_{t...T}}{S^{A}_{t}}\left(1+r^{O,B}_{j,t...T}\right)-\left(1+r^{O,A}_{k,t...T}\right)$$

Secured arbitrage



$$z_{4,t} = \frac{F_{t...T}^{B}}{S_{t}^{A}}\left(1 + r_{j,t...T}^{R,B}\right) - \left(1 + r_{k,t...T}^{R,A}\right)$$

Data

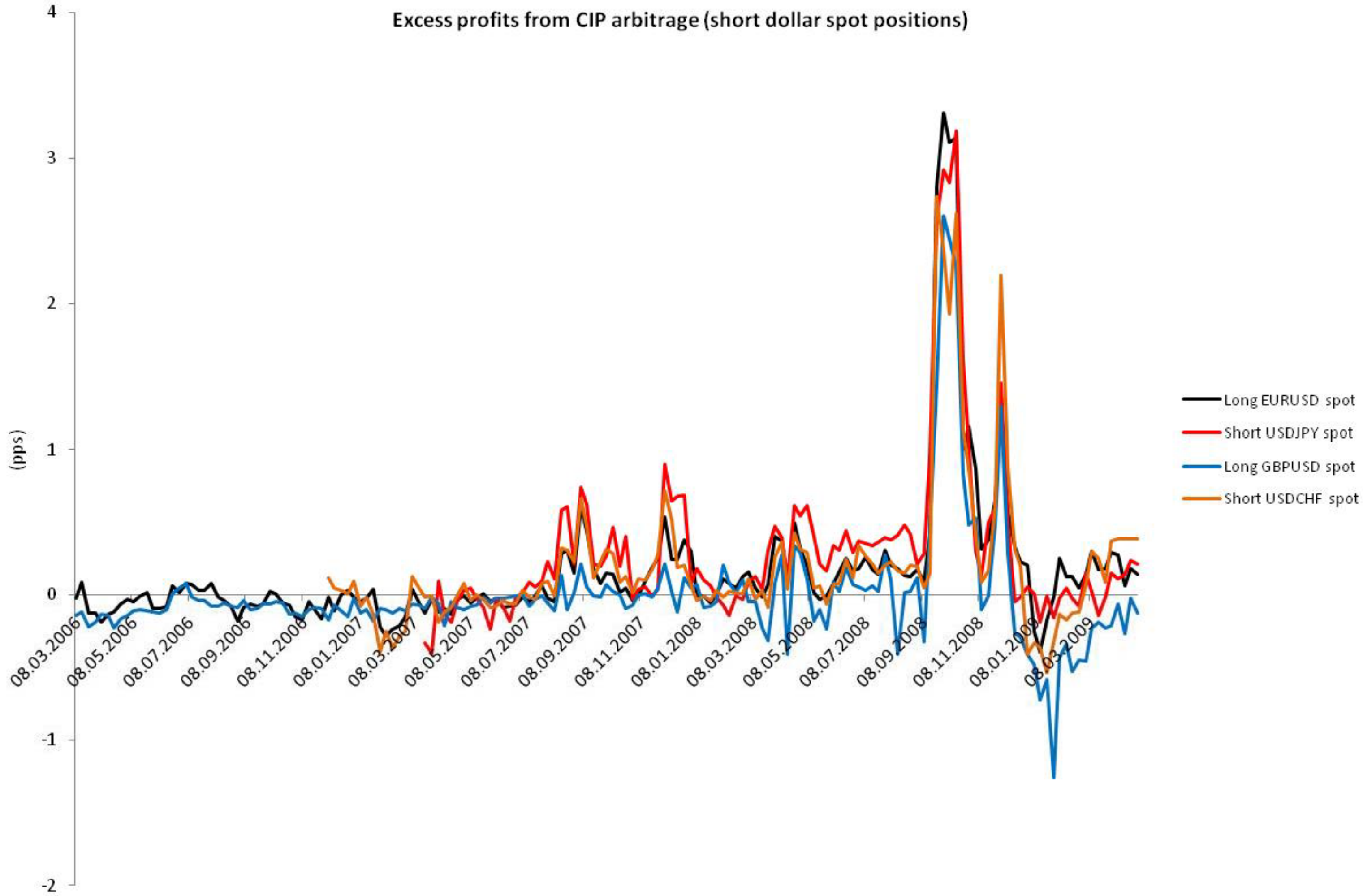
Data

Asset	Synch	Maturity	Bid / Ask	Source
FX spt	Snaps / All	spot	Yes	TP / EBS
FX fwd	Yes, snaps	ON-2Y	Yes	TP
OIS	Yes, snaps	1W-2Y	Yes	TP
REPO USD	Snaps	ON-3M	Price	ICAP
REPO EUR	All trades	ON-1Y	Yes	EUREX
REPO CHF	All trades	ON-3M	Yes	EUREX

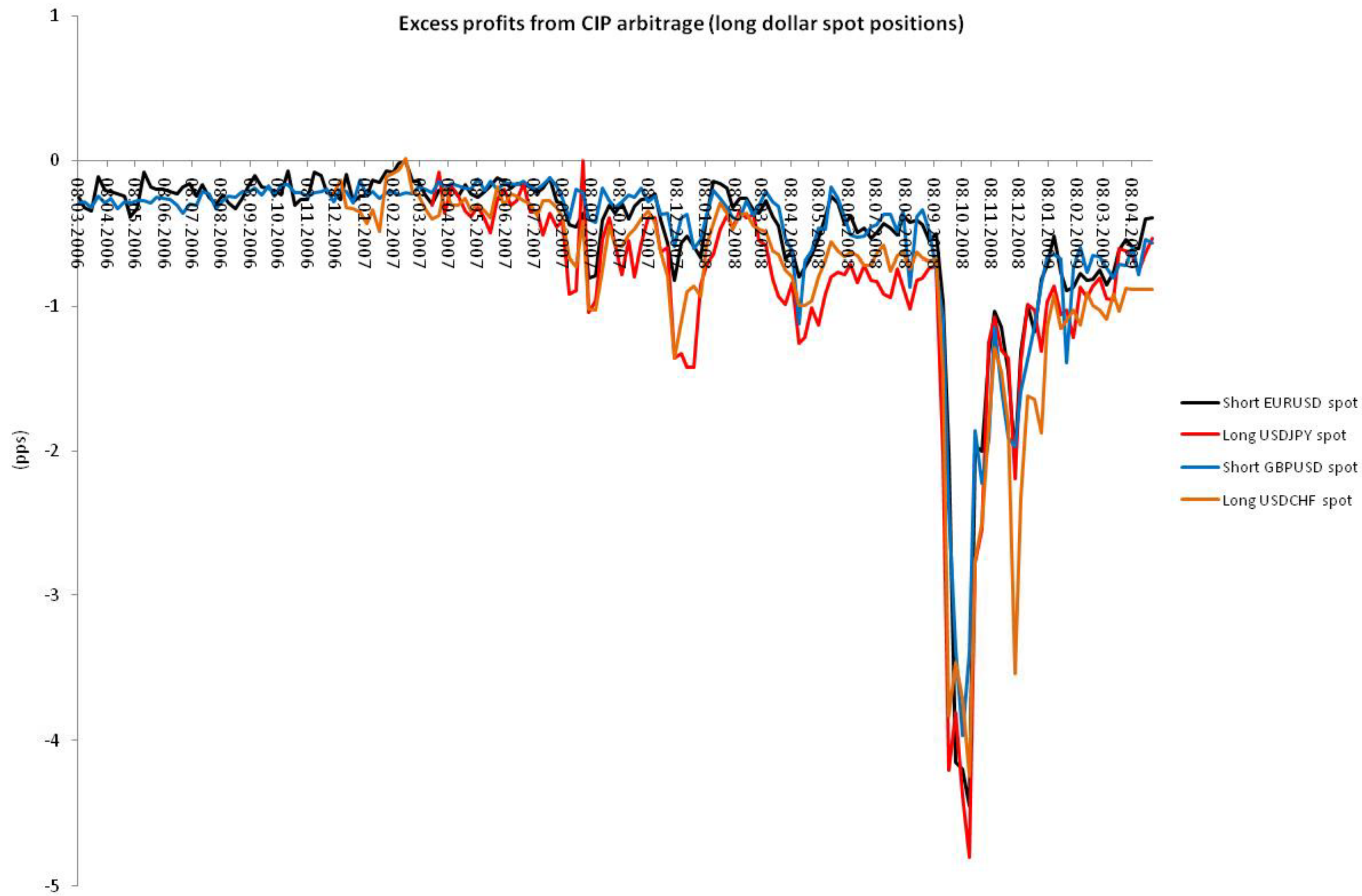
– EURUSD, USDJPY, GBPUSD, USDCHF, EURCHF
– 2006-2009

Documenting CIP deviations

CIP deviations: short USD 1M



CIP deviations: long USD 1M



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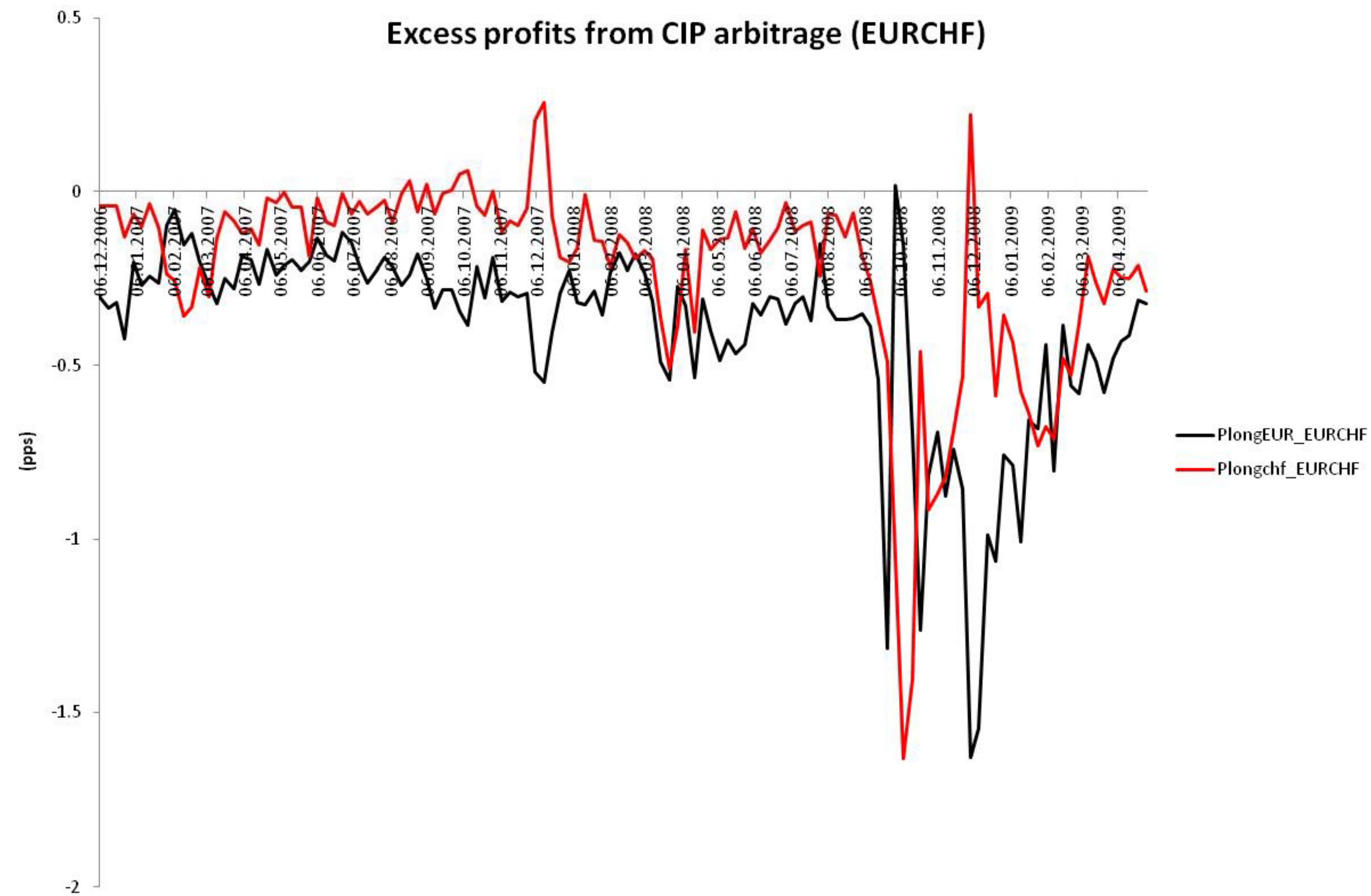
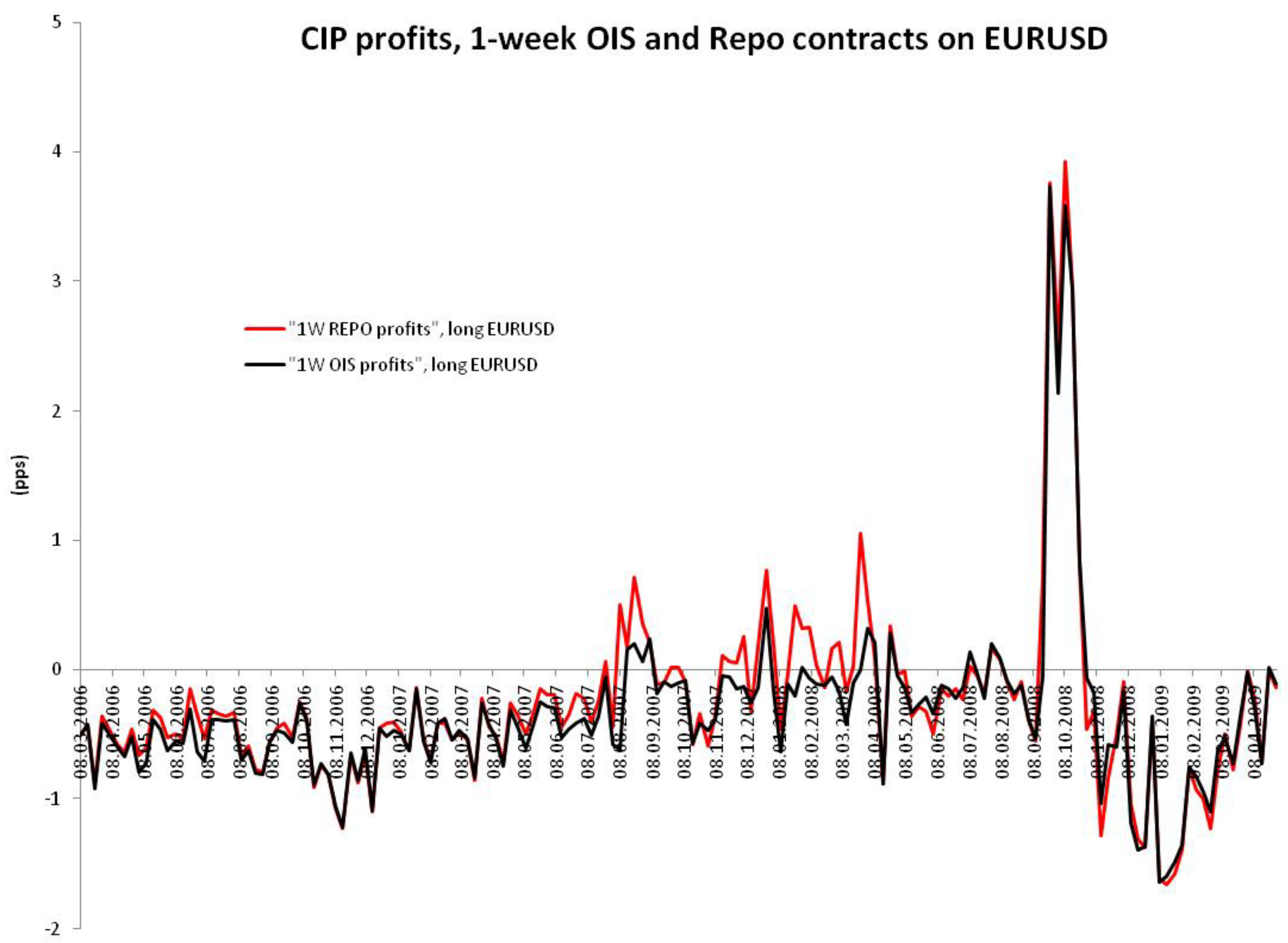
EURCHF 1M: only when USD involved



Secured vs Unsecured arbitrage (1W)



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Takeaways

- **Using OIS:**

1. Excess profits are **currency-specific**: only when the USD is involved
2. Excess profits are **directional**: only when the USD is shorted on the spot market

- **Using Repos:**

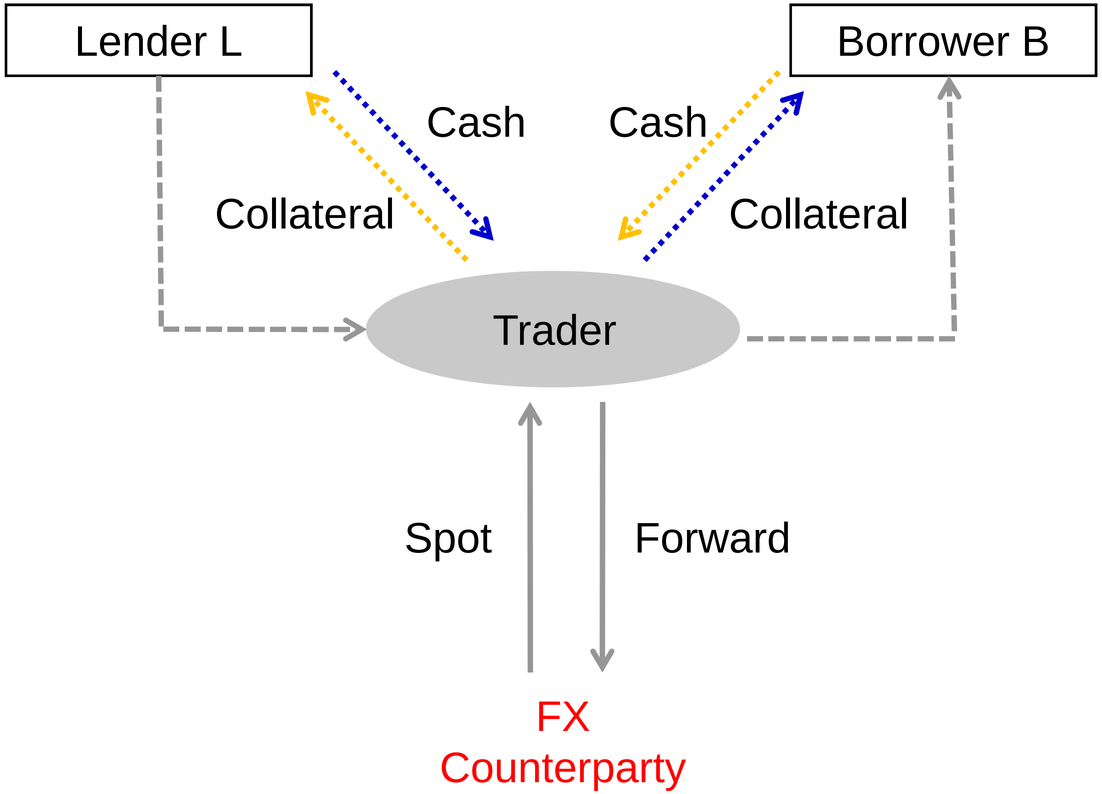
3. Same picture

Explanations

Why?

- Rationing of funds
  - Risk
  - Liquidity

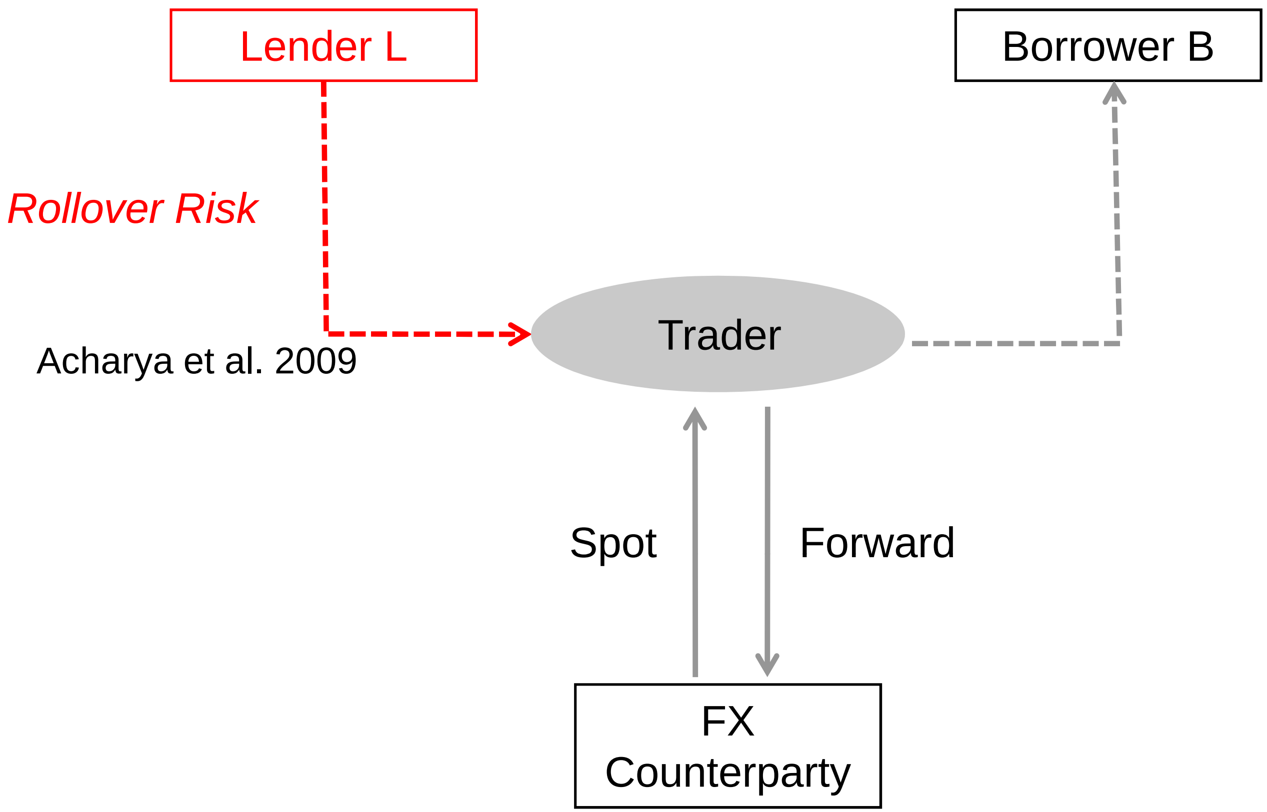
Risk: (1) FX fwd contract risk



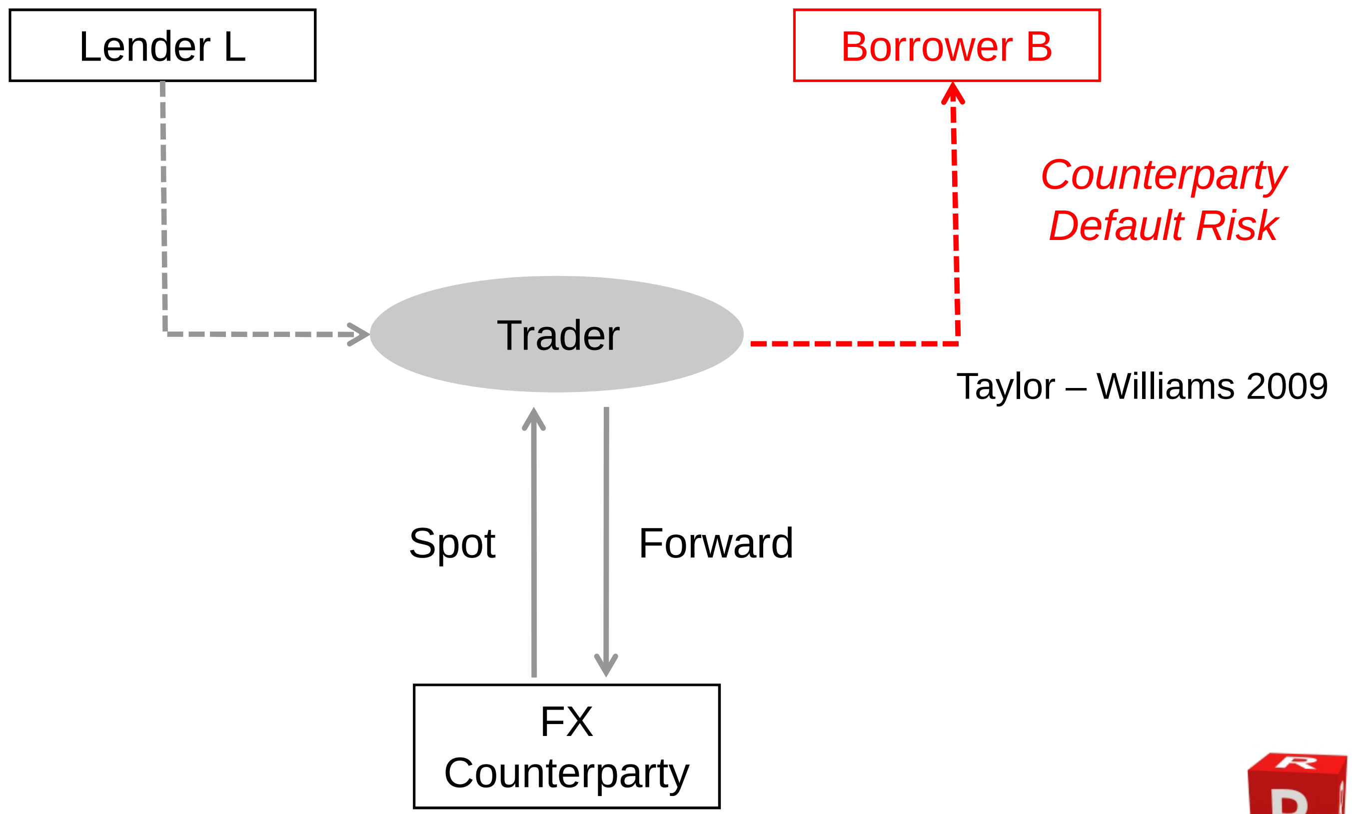
Duffie – Huang 1996
Melvin – Taylor 2009

Contract Risk

Risk: (2) Roll-Over Risk



Risk: (3) Counterparty Risk



Liquidity

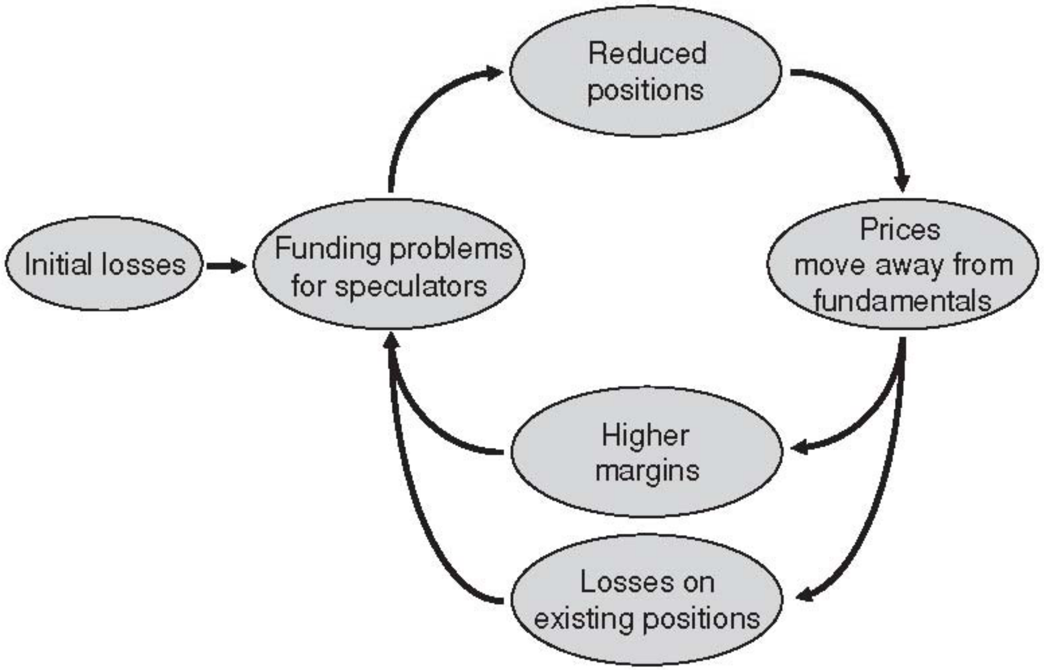


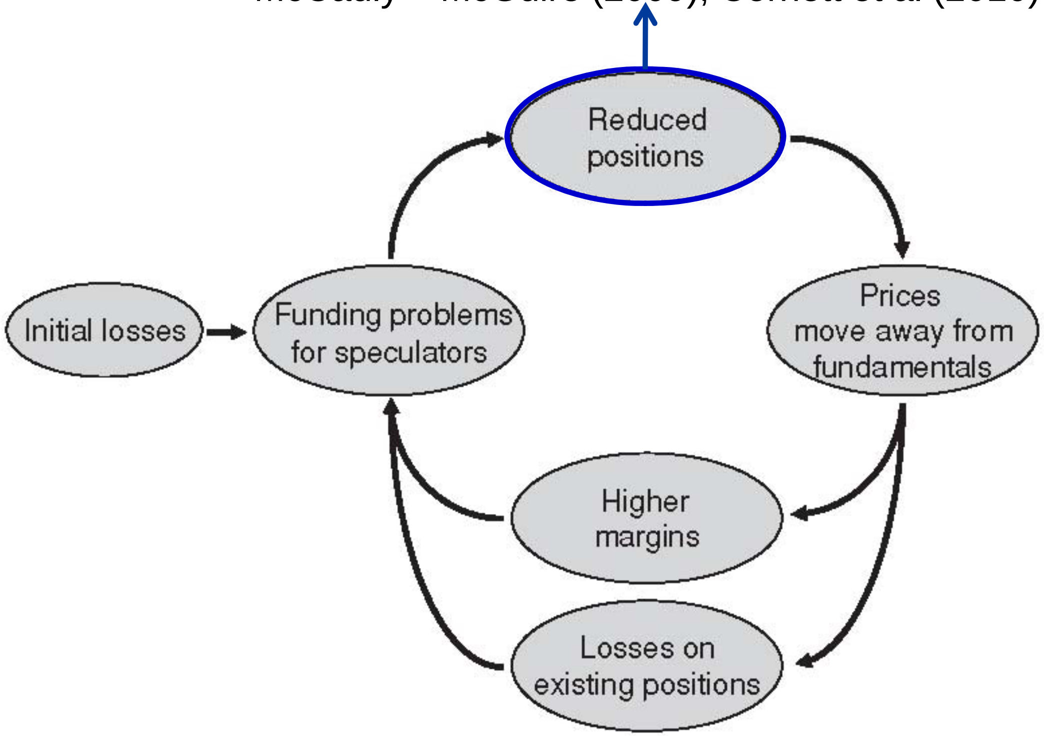
Figure 2
Liquidity spirals

Brunnermeier and Pedersen RFS 2009

Liquidity: (1) deleveraging

Massive deleveraging

- Garleanu – Pedersen (2009), Adrian – Shin (2008b), McCauly – McGuire (2009), Cornett et al (2010)



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Liquidity spirals

Liquidity: (2) prudential hoarding

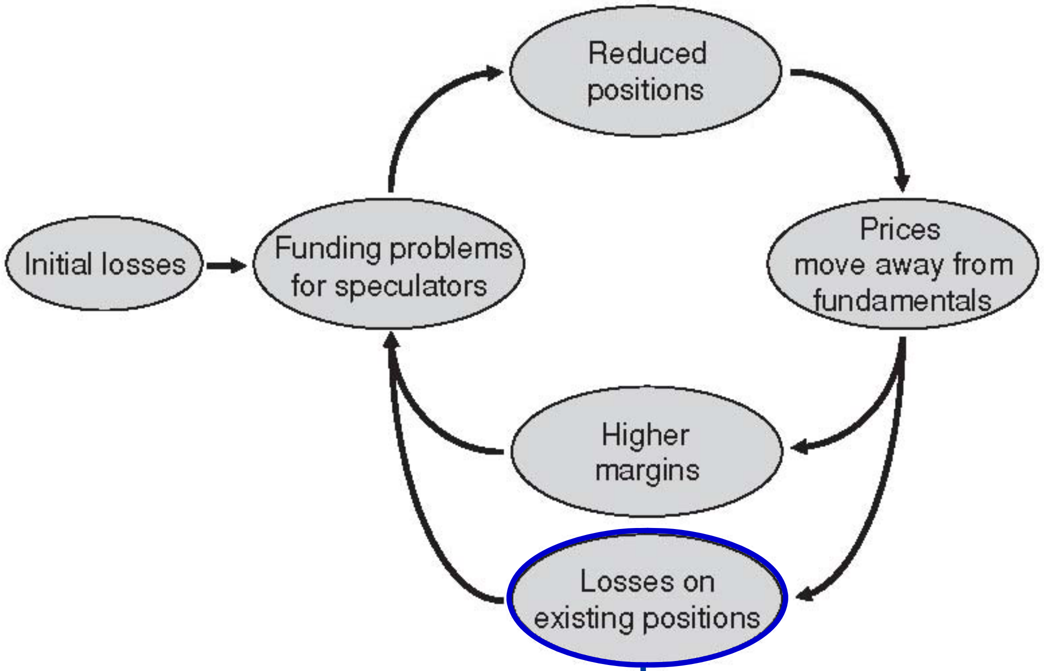
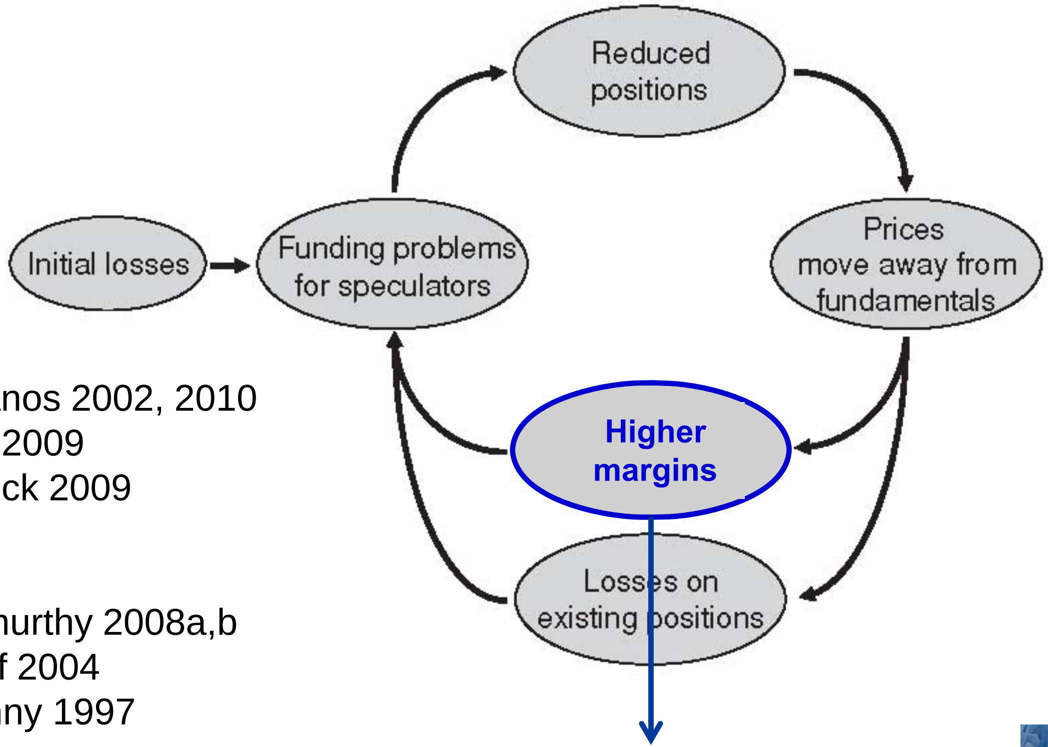


Figure 2
Liquidity spirals

Prudential hoarding

- ➢ USD liquidity funding strains, MM 09
- ➢ Signaling
- ➢ Vicious circles
- ➢ BP 09, AS 08b, Gromb – Vayanos 09

Liquidity: (3) haircuts



Gromb – Vayanos 2002, 2010
Acharya et al. 2009
Gorton – Metrick 2009
BP 2009
Kondor 2009
He – Krishnamurthy 2008a,b
Liu – Longstaff 2004
Shleifer – Vishny 1997

Insufficient capital

- Secured arbitrage requires capital to cover margins / haircuts.
- Hedge funds facing increasing redemptions and falling prices.
- Raising new equities is not an option

Explaining CIP deviations

Estimation

$$\Delta z_t = \alpha + \rho' \Delta z_{t-1} + \beta' B_t + \chi' X_t + \delta' \Phi_t + \varepsilon_t$$

Market liquidity

Funding liquidity

Risk factors

- For EURUSD time series
- For all USD pairs in panel
- Weekly

Variables

MKT LIQ.	FACTOR	UNSECURED	SECURED
	Trading cost	Bid-Ask spread (LL)	Bid-Ask spr. (LL)

FUNDING LIQ.TY	FACTOR	UNSECURED	SECURED
	Deleverage	Balance sheet	Balance sheet
	Hoarding	CB deposit	CB deposit
	Limited capital	-	Repo spread
	Policy measure	CB swaps, Reserve credits	CB swaps, Reserve credits
	General	Libor-OIS, TED	Libor-OIS, TED

RISKS	FACTOR	UNSECURED	SECURED
	Contract	Implied volat.	Implied volat.
	Rollover	Interest differen.	-
	Counterparty	CDS	-
	Controls	VIX, CDS	VIX, CDS

Results on long EURUSD / shorting USD

		1	2	3	4	5	6	7
Factors	**Market Liquidity**							
Transaction cost	FX liquidity	-0.021	**-0.039**	**-0.039**	-0.032	-0.026	-0.040	**-0.041**
		-0.906	-1.671	-1.747	-1.331	-1.153	-1.573	-2.171
Transaction cost	OIS liquidity	**0.302**	**0.321**	**0.374**	0.089	0.129	**0.330**	**0.237**
		2.661	2.741	3.150	0.740	1.139	2.666	2.924
Factors	**Funding Liquidity**							
Policy tool	CB swap		**-6.704**		**-4.618**	**-4.721**	**-6.743**	**-7.537**
			-4.498		-3.303	-3.468	-4.120	-8.198
Policy tool	Reserve credits			**-4.289**				
				-3.300				
General	TED Spread				**0.655**			
					4.032			
General	Libor-OIS					**0.765**		
						4.426		
Deleverage	Adrian-Shin CPG						1.433	
							0.661	
Hoarding	Deposit							**1.009**
								10.649
Factors	**Risks**							
Contract	IV		**1.697**	**1.581**	**0.967**	**1.397**	**1.853**	**1.074**
			3.104	2.920	1.796	2.763	3.050	2.802
Rollover	Interest Diff.		-0.246	-0.293	-0.205	-0.154	-0.291	-0.124
			-1.219	-1.415	-1.102	-0.840	-1.317	-0.939
Counterparty	CDS		-0.305	-0.270	-0.477	-0.243	-0.335	0.118
			-0.808	-0.704	-1.329	-0.695	-0.776	0.475
Control	VIX		0.446	0.257	0.179	0.075	0.358	-0.191
			0.968	0.564	0.393	0.166	0.701	-0.565
	Adj. R2	0.040	0.237	0.185	0.345	0.380	0.223	0.637

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Transaction cost	OIS liquidity	**0.302**	**0.321**	**0.374**	0.089	0.129	**0.330**	**0.237**
		2.661	2.741	3.150	0.740	1.139	2.666	2.924
Factors	**Funding Liquidity**							
Policy tool	CB swap		**-6.704**		**-4.618**	**-4.721**	**-6.743**	**-7.537**
			-4.498		-3.303	-3.468	-4.120	-8.198
Policy tool	Reserve credits			**-4.289**				
				-3.300				
General	TED Spread				**0.655**			
					4.032			
General	Libor-OIS					**0.765**		
						4.426		
Deleverage	Adrian-Shin CPG						1.433	
							0.661	
Hoarding	Deposit							**1.009**
								10.649
Factors	**Risks**							
Contract	IV		**1.697**	**1.581**	**0.967**	**1.397**	**1.853**	**1.074**
			3.104	2.920	1.796	2.763	3.050	2.802
Rollover	Interest Diff.		-0.246	-0.293	-0.205	-0.154	-0.291	-0.124
			-1.219	-1.415	-1.102	-0.840	-1.317	-0.939
Counterparty	CDS		-0.305	-0.270	-0.477	-0.243	-0.335	0.118
			-0.808	-0.704	-1.329	-0.695	-0.776	0.475
Control	VIX		0.446	0.257	0.179	0.075	0.358	-0.191
			0.968	0.564	0.393	0.166	0.701	-0.565
	Adj. R2	0.040	0.237	0.185	0.345	0.380	0.223	0.637

Results on long EURUSD / shorting USD

		1	2	3	4	5	6	7
Factors	**Market Liquidity**							
Transaction cost	FX liquidity	-0.021	**-0.039**	**-0.039**	-0.032	-0.026	-0.040	**-0.041**
		-0.906	-1.671	-1.747	-1.331	-1.153	-1.573	-2.171
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Results on long EURUSD / shorting USD

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			0.968	0.564	0.393	0.166	0.701	-0.565
	Adj. R2	0.040	0.237	0.185	0.345	0.380	0.223	0.637

Results on long EURUSD / shorting USD

		1	2	3	4	5	6	7
Factors	**Market Liquidity**							
Transaction cost	FX liquidity	-0.021	**-0.039**	**-0.039**	-0.032	-0.026	-0.040	**-0.041**
		-0.906	-1.671	-1.747	-1.331	-1.153	-1.573	-2.171
Transaction cost	OIS liquidity	**0.302**	**0.321**	**0.374**	0.089	0.129	**0.330**	**0.237**
		2.661	2.741	3.150	0.740	1.139	2.666	2.924
Factors	**Funding Liquidity**							
Policy tool	CB swap		**-6.704**		**-4.618**	**-4.721**	**-6.743**	**-7.537**
			-4.498		-3.303	-3.468	-4.120	-8.198
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					4.032			
General	Libor-OIS					**0.765**		
						4.426		
Deleverage	Adrian-Shin CPG						1.433	
							0.661	
Hoarding	Deposit							**1.009**
								10.649
Factors	**Risks**							
Contract	IV		**1.697**	**1.581**	**0.967**	**1.397**	**1.853**	**1.074**
			3.104	2.920	1.796	2.763	3.050	2.802
Rollover	Interest Diff.		-0.246	-0.293	-0.205	-0.154	-0.291	-0.124
			-1.219	-1.415	-1.102	-0.840	-1.317	-0.939
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			0.968	0.564	0.393	0.166	0.701	-0.565
	Adj. R2	0.040	0.237	0.185	0.345	0.380	0.223	0.637

Secured arbitrage on EURUSD (1W)

	1	2	3	4	5	6	7	8
Market Liquidity								
FX liquidity	-0.062	-0.065	-0.067	**-0.080**	**-0.068**	-0.053	**-0.086**	**-0.092**
	-1.539	-1.626	-1.609	-2.072	-1.714	-1.222	-2.639	-2.433
OIS liquidity	**0.746**	**0.776**	**0.854**	**0.491**	**0.658**	**0.765**	**0.738**	**0.483**
	4.166	4.568	4.536	2.899	3.857	4.369	5.673	2.976
Funding Liquidity								
CB swap		**-10.413**		**-8.128**	**-9.371**	**-9.860**	**-12.529**	**-7.637**
		-5.448		-4.440	-4.949	-4.846	-8.586	-4.352
Reserve credits			**-4.374**					
			-2.968					
TED Spread				**0.819**				
				4.055				
Libor-OIS					**0.529**			
					2.348			
Adrian-Shin CPG						2.713		
						1.060		
Deposit							**1.109**	
							7.643	
Repo spread								**0.612**
								2.685
Risks								
IV		**1.521**	0.803	1.013	**1.515**	**1.611**	**1.379**	0.887
		1.983	0.977	1.419	2.043	1.909	2.372	1.291
CDS		0.099	0.264	-0.003	0.166	0.239	0.284	-0.114
		0.205	0.494	-0.007	0.357	0.438	0.778	-0.191
VIX		0.379	0.011	-0.167	-0.022	0.087	-0.300	-0.138
		0.579	0.015	-0.268	-0.033	0.123	-0.581	-0.325
Adj. R2	0.159	0.267	0.156	0.357	0.298	0.260	0.528	0.396

Robustness

Robustness tests

- Time of day
- Maturity
- Sub-samples
- CB swaps vs Credits
- Euro CDS
- Levels
- Single regression
- Other measures of liquidity (PS)
- Estimation methods
- EBS data

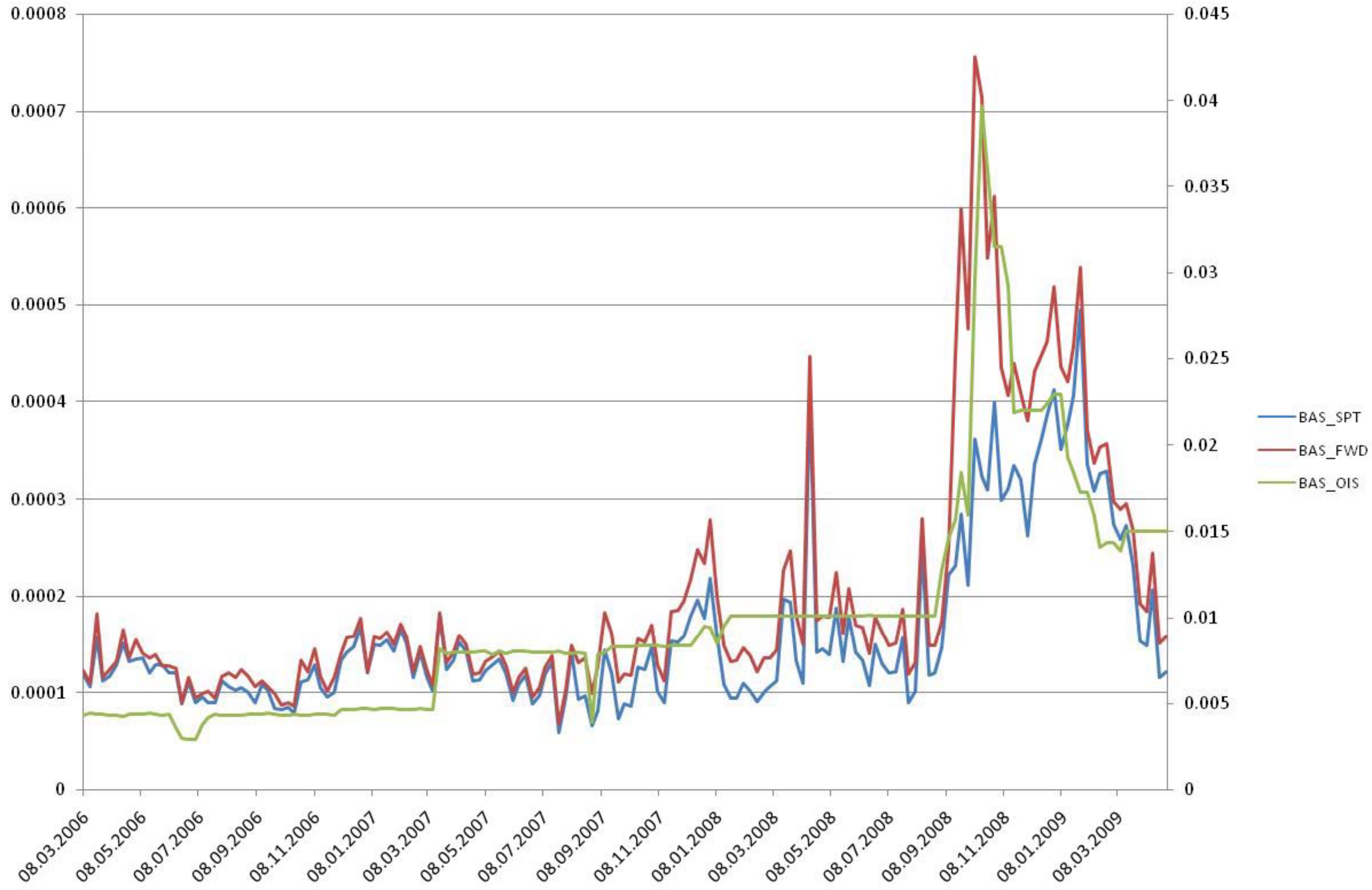
Conclusion

Summary

- Limits to arbitrage
  - Documentation, Measurement
  - Explanation
- Central role of liquidity constraints
- Role for policy

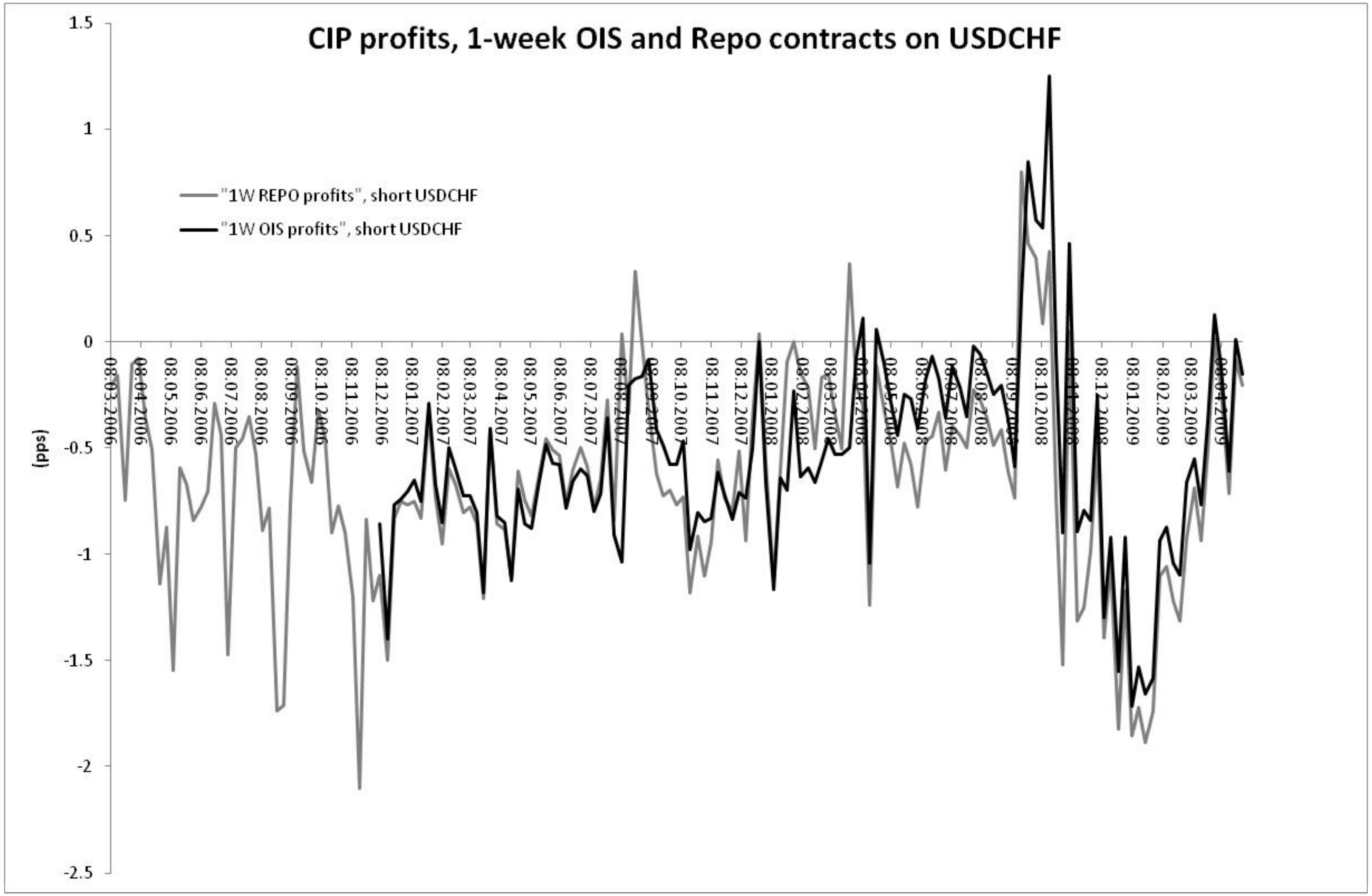
Appendix

Documenting CIP deviations



- Transaction costs and liquidity patterns

Secured vs Unsecured arbitrage (1W)



Angelo Ranaldo
Swiss National Bank