Breakdown of covered interest parity: Mystery or myth?

Joint work with Alfred Wong

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*The views expressed here are solely the responsibility of the authors and should not be interpreted as reflecting the views of Hong Kong Monetary Authority.

Overview

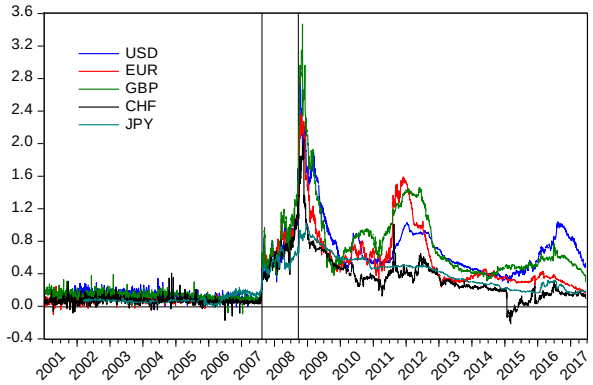
CIP deviation in FX swap and CCBS markets

- Until 2007, CIP was one of the most reliable parity conditions in international finance
- Since GFC, textbook arbitrage has emerged in the cross-currency market

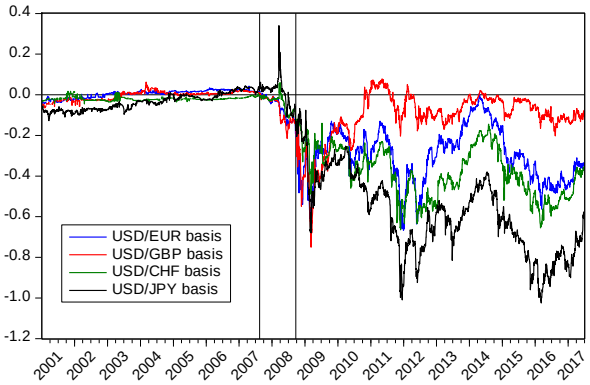
$$\frac{F_t}{S_0} \neq \left(\frac{1+r_{0,t}}{1+q_{0,t}}\right)^t$$

- Not a dollar-specific phenomenon

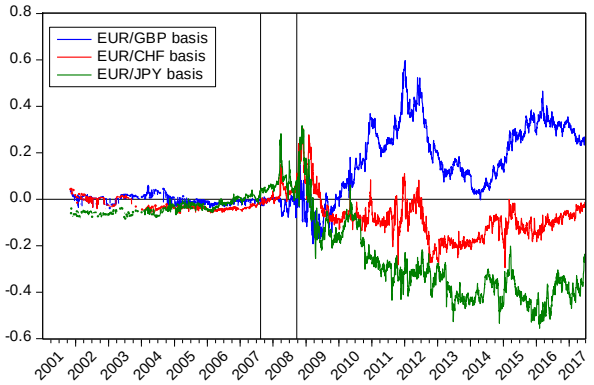
1-year CIP deviation



5-year CCBS basis against USD



5-year CCBS basis against EUR



Overview

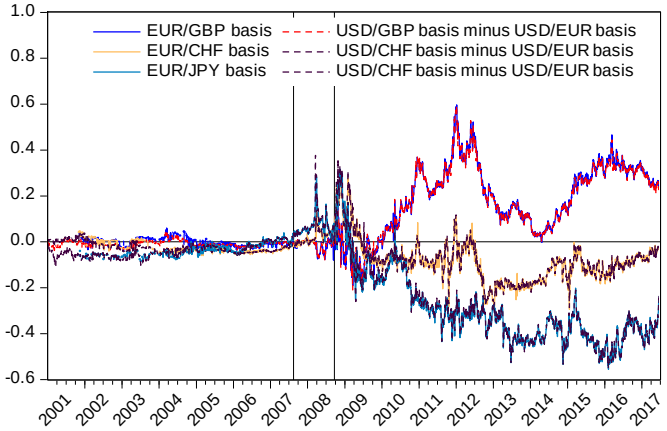
Literature and contribution

- Voluminous literature studying CIP deviation, attributing the phenomenon to
  - Credit risk and/or liquidity risk (Baba & Packer, 2009, Fukuda, 2016, Iida, Kimura & Sudo, 2015, Liao, 2016, Tuckman & Porfirio, 2003)
  - Regulatory/balance sheet constraints (Borio et al., 2016, Duffie, 2016)
  - Dollar shortage (Bottazzi et al., 2013, Du, Tepper & Verdelhan, 2017), dollar hedging demand (Sushko et al., 2017)
- Multi-curve modelling in finance literature shed light on the paradigm shift in pricing swaps since GFC
  - Interest rate swap valuation involves one risk-free rate curve for discounting and another risk-embedded curve for estimating future cash flows (Bianchetti, 2009, Grbac, 2015, Memouni, 2015, Mercurio, 2010)
- This paper contributes by studying major currency pairs, and found
  - There are no arbitrage opportunities
  - CIP adjusted by counterparty risks is still valid

No arbitrage opportunities

CCBS basis matrix

- CCBS basis matrix $A_n = (\alpha_{i,j})_{i,j=1}^{n}$ satisfies: $\alpha_{i,j} + \alpha_{j,k} = \alpha_{i,k}$
  - *Property 1:* $\alpha_{i,i} = 0$ for $i = 1,2,\dots,n$
  - *Property 2:* $\alpha_{i,j} + \alpha_{j,i} = 0$ *for* $i, j = 1,2,\dots,n$
  - *Property 3:* The basis matrix can be entirely determined by its ith row, where $i = 1,2,\dots,n$.



CCBS roundtrip arbitrage

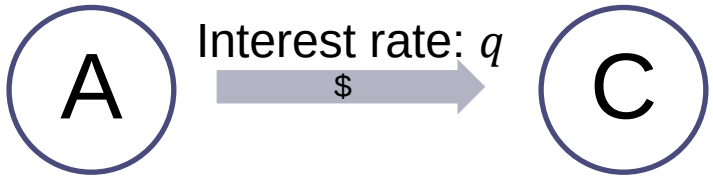
	Currency i	Currency j	Currency k
		Gross cash flows of three contracts	
$t = 0$	1	$-S_j$	
$t = 1$	$-r_i$	$S_j(r_j + \alpha_{i,j})$	
$t = 1$	-1	S_j	
$t = 0$		S_j	$-S_k$
$t = 1$		$-S_j r_j$	$S_k(r_k + \alpha_{j,k})$
$t = 1$		$-S_j$	S_k
$t = 0$	-1		S_k
$t = 1$	$r_i + \alpha_{k,i}$		$-S_k r_k$
$t = 1$	1		$-S_k$
		Net cash flows	
$t = 0$	0	0	0
$t = 1$	$\alpha_{k,i}$	$S_j \alpha_{i,j}$	$S_k \alpha_{j,k}$

	USD	EUR	GBP	CHF	JPY
USD	0	−33.1	−7.4	−35.5	−57.8
EUR	33.1	0	25.8	−1.9	−24.7
GBP	7.4	−25.8	0	−27.6	−50.4
CHF	35.0	1.9	27.6	0	−22.8
JPY	57.8	24.7	50.4	22.8	0

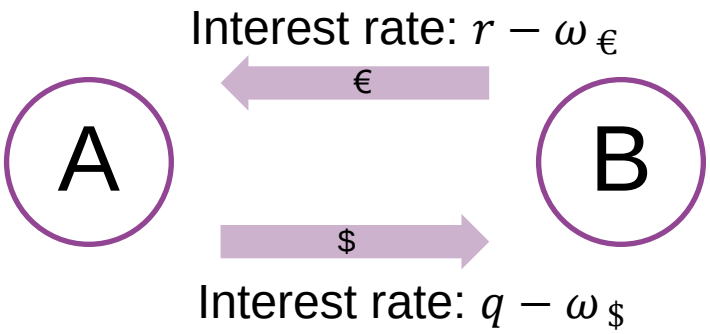
	USD	EUR	GBP	CHF	JPY
USD	0	−33.1	−6.9	−35.6	−58.5
EUR	33.1	0	26.3	−2.5	−25.4
GBP	6.9	−26.3	0	−28.8	−51.6
CHF	35.6	2.5	28.8	0	−22.9
JPY	58.8	25.4	51.6	22.9	0

CIP adjusted by counterparty risks

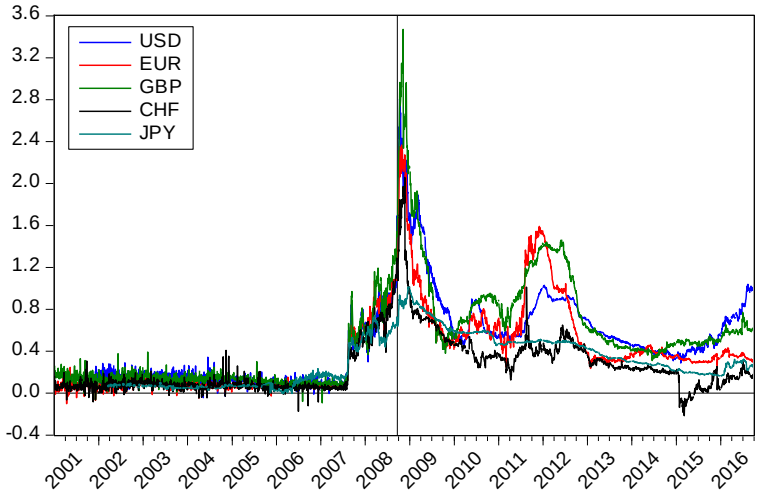
Interbank loan: uncollateralized



FX swap and CCBS: collateralized



Libor-OIS spread increases since 8 Aug 2007



Why no bases before the GFC?

$$\omega_{€} = \omega_{\$} = 0$$

CIP adjusted by counterparty risks

- Aware of the counterparty risks embedded in Libors, it is fair for market participants to adjust for the risks when valuing a product of different risk profile

$$\frac{F}{S} = \frac{1 + r - \omega_r}{1 + q - \omega_q}$$

$$= \frac{1 + r - \beta\,(r - r_f)}{1 + q - \gamma\,(q - q_f)}$$

Exclude counterparty risks from the interbank rate

- However, FX swaps or CCBS are not totally risk-free

$$\frac{F}{S} = \frac{1 + r_f + (1 - \beta)(r - r_f)}{1 + q_f + (1 - \gamma)(q - q_f)}$$

Include funding liquidity risks to the risk-free rate

Estimation

Rearranging the previous equation,

$$\frac{F}{S} = \frac{1 + \beta r_f + (1-\beta)r}{1 + \gamma q_f + (1-\gamma)q}$$

Log transformation

$$lnF - lnS \approx \beta r_f - \gamma q_f + (1-\beta)r - (1-\gamma)q$$

Estimating equation

$$\boldsymbol{\Delta Fp_t = C_0 + C_1 \Delta OIS_t^{FC} + C_2 \Delta OIS_t^{DC} + C_3 \Delta IRS_t^{FC} + C_4 \Delta IRS_t^{DC} + \varepsilon_t}$$

Hypothesis

- Hypothesis 1: $C_0 = 0$
- Hypothesis 2a: $C_1 + C_3 = 1$
- Hypothesis 2b: $C_2 + C_4 = -1$

Data

- 5-year CCBS of 7 currency pairs involving 5 major currencies
  - EUR, GBP, CHF and JPY vis-à-vis USD
  - GBP, CHF, and JPY vis-à-vis EUR
- Sample period covers Sep 22, 2009 to Jun 30, 2017
- All data collected from Bloomberg with daily frequency

Metadata

	USD	EUR	GBP	CHF	JPY
			IRS rates		
Reference rate	3M Libor	3M Euribor	3M Libor	3M Libor	6M Libor
Payment frequency	Quarterly	Annually	Quarterly	Annually	Semi-annually
			OIS rates		
Reference rate	Effective Fed funds rate	Euro overnight index average	Sterling overnight index average	Tom/next indexed swap in CHF fixing	Tokyo overnight average rate
Description	A weighted average of rates on trades arranged by major brokers	A weighted average of overnight unsecured lending rates in the interbank market, initiated within the Euro area by contributing banks	A weighted average rate of unsecured sterling overnight cash transactions brokered in London by WMBA member firms	Based on quotations from approximately 30 reference banks for its Tom/next unsecured lending rate to prime banks, supplied to Cosmorex AG	Based on uncollateralized overnight average call rates for lending among financial institutions, published by Bank of Japan
Published by	Federal Reserve Bank New York	European Central Bank	Wholesale Markets Brokers' Association	Cosmorex AG	Bank of Japan

Descriptive statistics

	USD	EUR	GBP	CHF	JPY
5-year forward premium (annualized, %) vis-à-vis USD					
Mean		-0.93	-0.15	-1.77	-2.01
Median		-0.75	-0.04	-1.51	-2.06
Maximum		0.69	0.62	-0.57	-1.10
Minimum		-2.58	-1.59	-3.19	-2.93
Std. Dev.		0.82	0.47	0.66	0.40
Obs.		2,029	2,029	2,029	2,029
5-year forward premium (annualized, %) vis-à-vis EUR					
Mean			0.78	-0.84	-1.08
Median			0.65	-0.80	-0.94
Maximum			2.02	-0.26	0.01
Minimum			-0.36	-1.57	-3.11
Std. Dev.			0.51	0.28	0.69
Obs.			2,029	2,029	2,029
5-year IRS rate (%)					
Mean	1.60	1.01	1.55	0.27	0.26
Median	1.60	0.83	1.45	0.25	0.25
Maximum	2.94	3.10	3.34	1.73	0.78
Minimum	0.72	-0.34	0.30	-1.00	-0.24
Std. Dev.	0.50	0.93	0.69	0.72	0.19
Obs.	2,012	2,029	1,978	2,015	2,029

	USD	EUR	GBP	CHF	JPY
5-year OIS rate (%)					
Mean	1.34	0.78	1.30	0.14	0.14
Median	1.37	0.63	1.18	0.13	0.15
Maximum	2.79	2.82	3.11	1.60	0.57
Minimum	0.47	-0.47	0.13	-0.95	-0.37
Std. Dev.	0.53	0.85	0.68	0.61	0.17
Obs.	2,029	2,029	2,029	1,899	2,029
5-year IRS-OIS spread (bps)					
Mean	26.3	22.7	25.6	5.2	11.2
Median	25.1	19.6	22.7	9.2	10.5
Maximum	55.7	57.6	66.4	32.3	21.6
Minimum	13.0	7.3	12.1	-18.1	2.6
Std. Dev.	7.1	9.6	8.4	9.3	4.0
Obs.	2,012	2,029	1,978	1,887	2,029

Results

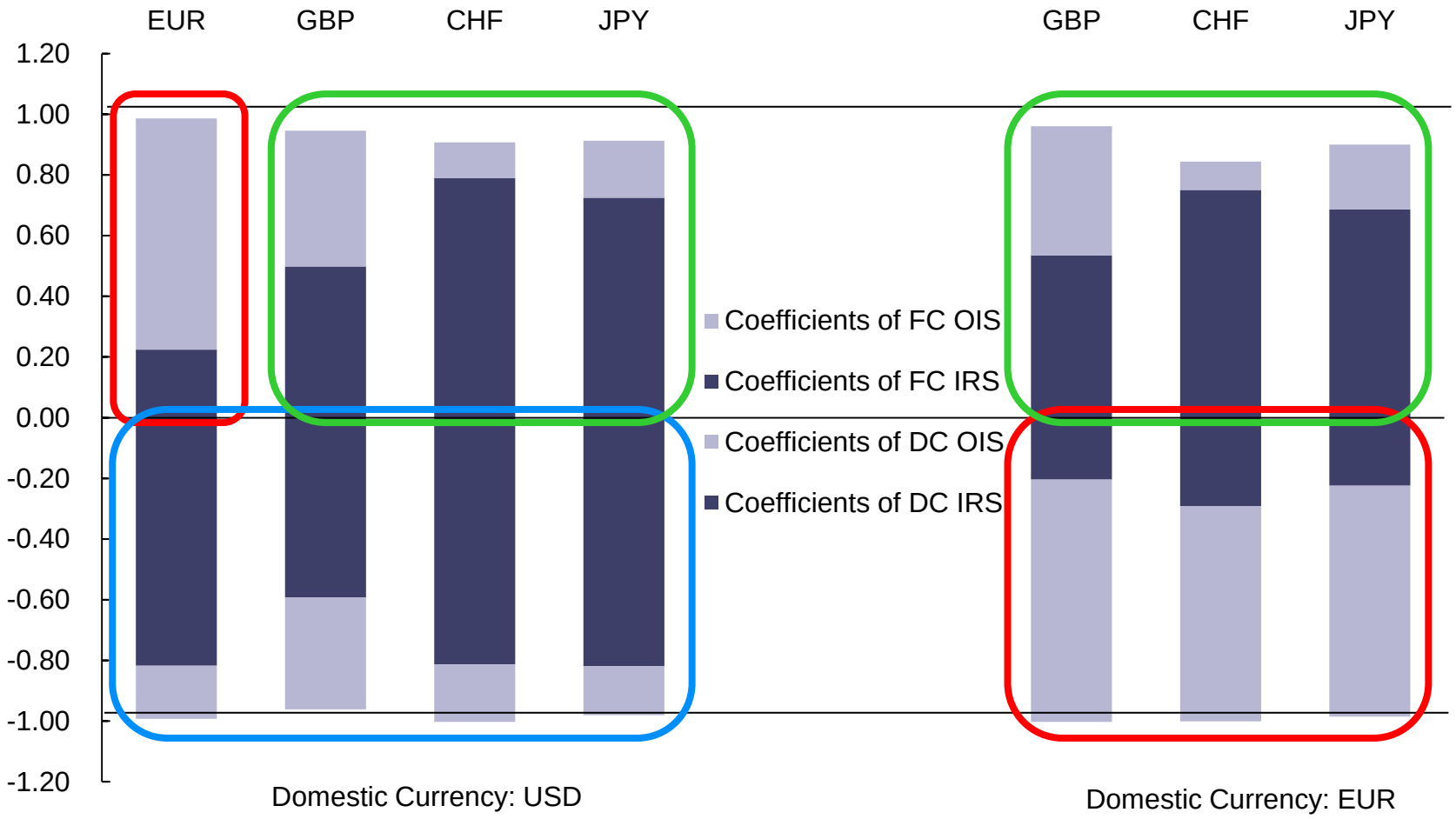
Unrestricted model

$$\Delta Fp_t = C_0 + C_1 \Delta OIS_t{}^{FC} + C_2 \Delta OIS_t{}^{DC} + C_3 \Delta IRS_t{}^{FC} + C_4 \Delta IRS_t{}^{DC} + \varepsilon_t$$

Foreign currency	EUR	GBP	CHF	JPY	GBP	CHF	JPY
				Unrestricted model			
		USD as domestic currency			EUR as domestic currency		
Constant	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
C1 (FC OIS)	0.7616***	0.4480***	0.1175***	0.1882***	0.4262***	0.0936**	0.2143***
	(0.0382)	(0.0446)	(0.0346)	(0.0643)	(0.0505)	(0.0365)	(0.0694)
C2 (DC OIS)	-0.1747***	-0.3682***	-0.1893***	-0.1606***	-0.7986***	-0.7096***	-0.7609***
	(0.0333)	(0.0386)	(0.0556)	(0.0495)	(0.0486)	(0.0723)	(0.0629)
C3 (FC IRS)	0.2246***	0.4979***	0.7899***	0.7243***	0.5343***	0.7506***	0.6860***
	(0.0368)	(0.0445)	(0.0453)	(0.0703)	(0.0514)	(0.0483)	(0.0742)
C4 (DC IRS)	-0.8176***	-0.5927***	-0.8128***	-0.8196***	-0.2042***	-0.2913***	-0.2239***
	(0.0329)	(0.0376)	(0.0548)	(0.0495)	(0.0468)	(0.0699)	(0.0616)
R-squared	0.7986	0.7104	0.6278	0.6873	0.6398	0.3742	0.5183
Adj. R-squared	0.7982	0.7098	0.6270	0.6866	0.6390	0.3729	0.5173
DW Statistics	2.3565	2.7895	2.5773	2.5067	2.5514	2.6928	2.6482
Log Likelihood	14317	13587	12275	13400	13477	12328	13460

Results

Sum of shares of counterparty and liquidity risks



Results

Restricted model

$$\Delta Fp_t = C_0 + C_1 \Delta OIS_t^{FC} + C_2 \Delta OIS_t^{DC} + (1 - C_1)\Delta IRS_t^{FC} + (-1 - C_2)\Delta IRS_t^{DC} + \varepsilon_t$$

Foreign currency	EUR	GBP	CHF	JPY	GBP	CHF	JPY
				Restricted model			
		USD as domestic currency			EUR as domestic currency		
Constant	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
C1	0.7717***	0.4763***	0.1295***	0.2129***	0.4425***	0.1175***	0.2499***
	(0.0365)	(0.0440)	(0.0345)	(0.0607)	(0.0503)	(0.0364)	(0.0655)
C2	-0.1796***	-0.3998***	-0.1997***	-0.1703***	-0.7993***	-0.7238***	-0.7738***
	(0.0326)	(0.0373)	(0.0544)	(0.0490)	(0.0465)	(0.0698)	(0.0612)
R-squared	0.7985	0.7086	0.6254	0.6868	0.6377	0.3643	0.5175
Adj. R-squared	0.7983	0.7083	0.6250	0.6864	0.6374	0.3636	0.5170
DW Statistics	2.3618	2.8025	2.5797	2.5117	2.5587	2.6781	2.6547
Log Likelihood	14317	13581	12269	13398	13471	12313	13458

Conclusion

- Breakdown of CIP or the emergence of CCBS basis is no mystery, but reflects the currency-specific risk adjustment when pricing swaps
  - Excluding counterparty risk from Libor, or equivalently,
  - Including liquidity risk to OIS
- CCBS market is well-arbitraged regardless of regulatory changes