Crypto Covered Interest Parity Deviations

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Outline

Motivation

- Evolution of financial markets in crypto space (futures, options, credit, ...)
- CIP as "closest thing to a physical law in int. finance" (Borio et al., 2016)
- (Absolute) CIP deviations of up to 15% until Q1/2018, i.e. much smaller than in conventional currency markets ◂ CIP in fiat world
- Structural break: entry of sophisticated arbitrageurs (Jane Street)

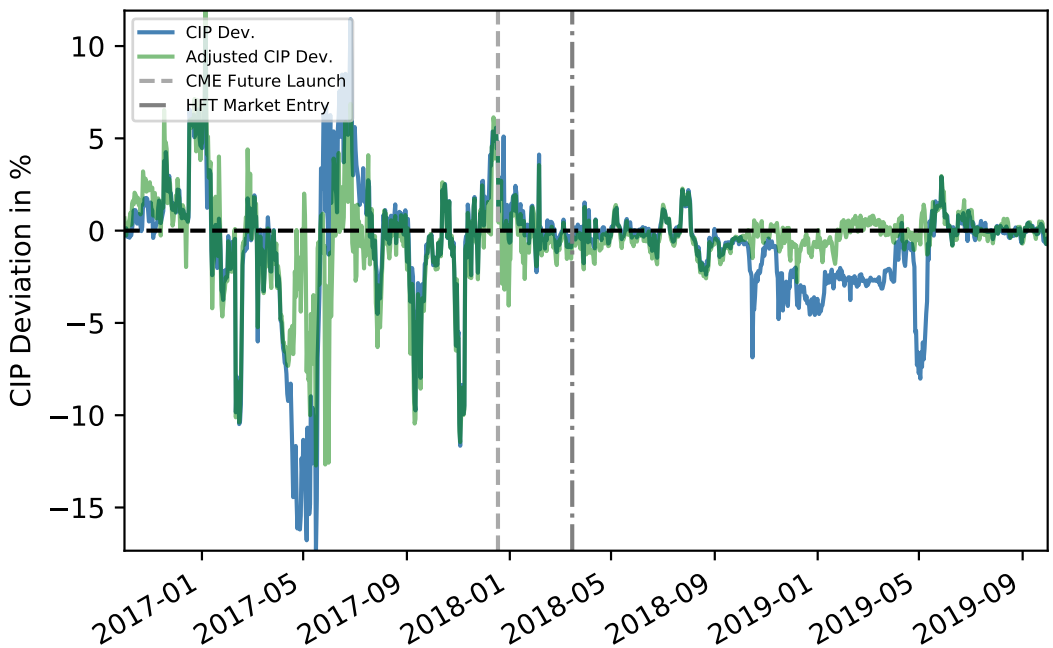


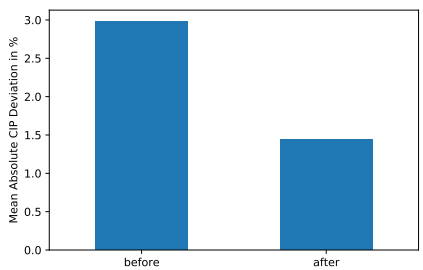
Figure 1: CIP Deviations over Time

Contribution

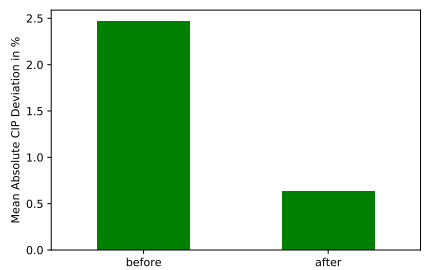
1. Analysis of CIP in crypto space (does not hold until 03/2018)
2. Identification of structural break (not CME future but HFT arbitrageurs)
3. Impact of HFT arbitrageurs in untapped market (stronger for less liquid market)

We ...

- ... shed light on potential drivers of CIP deviations (before and after 03/2018)
- ... test for the effect of a BTC future launch on a traditional exchange
- ... relate remaining deviations to counterparty risk ("*Bitfinex Premium*")



(I) Mean of abs. CIP Deviations



(II) Mean of abs. adjusted CIP Deviation

Figure 2: CIP deviations before and after Jane Street entry

Literature Review

- Covered Interest Parity (CIP)
  - ... due to funding constraints: Rime et al. (2017)
  - ... due to regulatory constraints: Du et al. (2018)
- Crypto market and financial instruments:
  - BTC price jumps and CME future: Hale et al. (2018)
  - large cross-exchange arbitrage profits until end of sample period (03/2018): Makarov and Schoar (2019)
- High-frequency Trading (HFT) firms:
  - market efficiency increases: Hendershott et al. (2011), Menkveld (2013), Brogaard et al. (2014), and Brogaard et al. (2018)

Theoretical Background

- CIP as fundamental law, any deviation allows for profits through arbitrage
- CIP states that the basis of the future or forward must be equal to the interest rate differential (see 1).

$$\underbrace{f_t - s_t}_{\text{basis}} \approx \underbrace{i_t - i_t^*}_{\text{rate differential}} \tag{1}$$

- To visualize violations of CIP, we calculate the BTC/USD cross-currency basis by rearranging Equation 1 to Equation 2 whereby a deviation from zero resembles a violation of the CIP.

$$\underbrace{(i_t^{*T} - i_t^T) + f_t^T - s_t}_{\text{cross-currency basis}} \approx \text{CIP Deviation} \tag{2}$$

Data

Name	Used Frequency	Source	From	To
		Baseline Data		
Weekly BTC/USD Future	Daily	OKEx	10/2016	10/2019
BTC/USD Spot	Daily	Bitfinex	10/2016	10/2019
BTC Interest Rate	Daily	Bitfinex	10/2016	10/2019
USD Interest Rate	Daily	Bitfinex	10/2016	10/2019
		Additional Data: Diff-and-Diff		
Weekly LTC/USD Future	Daily	OKEx	04/2017	10/2019
LTC Interest Rate	Daily	Bitfinex	04/2017	10/2019
LTC/USD Spot	Daily	Bitfinex	04/2017	10/2019
LTC/USD Aggregated Spot Volume	Daily	CryptoCompare	04/2017	10/2019
		Additional Data: Counterparty Risk		
BTC/USD Spot Index	Daily	CryptoCompare	10/2018	10/2019
BTC/USD Aggregated Spot Volume	Daily	CryptoCompare	10/2016	10/2019
VIX Index	Daily	Eikon	12/2017	10/2019
TED Spread	Daily	Eikon	12/2017	10/2019
USDT/USD Spot Index	Daily	CryptoCompare	12/2017	10/2019

Table 1: Data Sources

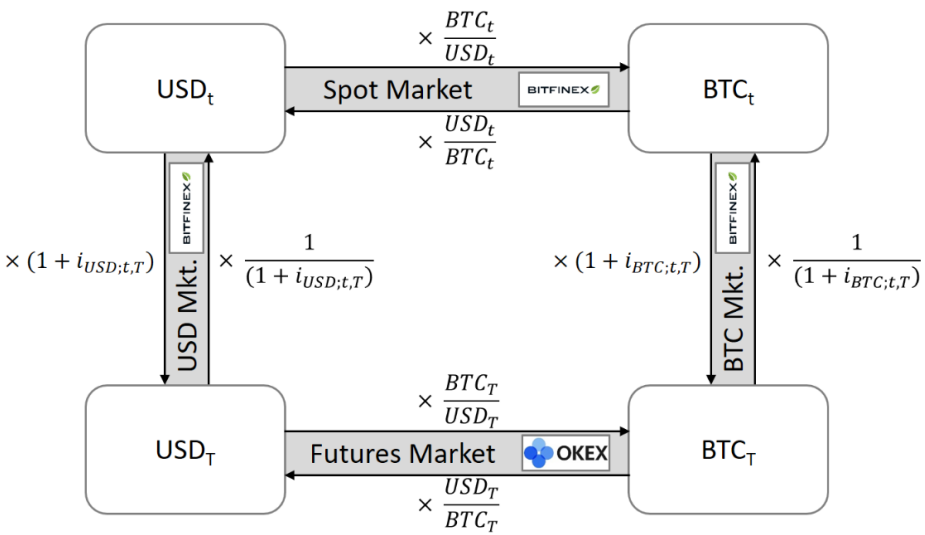
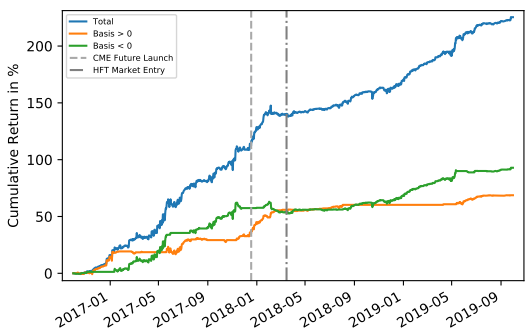


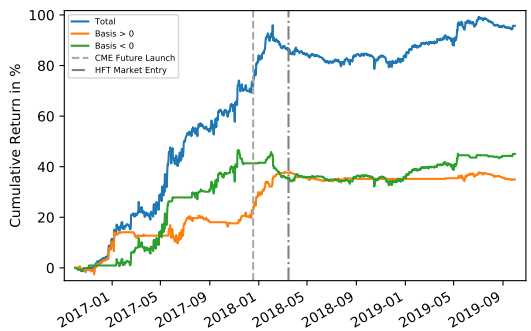
Figure 3: Mechanics of Trading Strategy

Trading Strategy

- Strategy below trades on every CIP deviation irrespective of its size
- Sharpe Ratio improves once smaller deviations are neglected as fees may exceed the gain from trading on small deviations
- Net Profit accounts for fees on OKEx (3bp) and Bitfinex (5bp) as well as additional loan charges of 15% on Bitfinex
- As we see below, most of the arbitrage profits made when the basis was negative, i.e. when the arbitrageur needs to sell the BTC in the spot market.



(I) Trading Strategy Profits Gross



(II) Trading Strategy Profits Net

Figure 4: Trading Strategy

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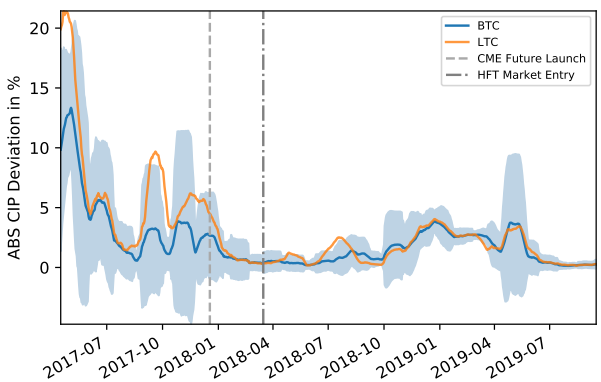
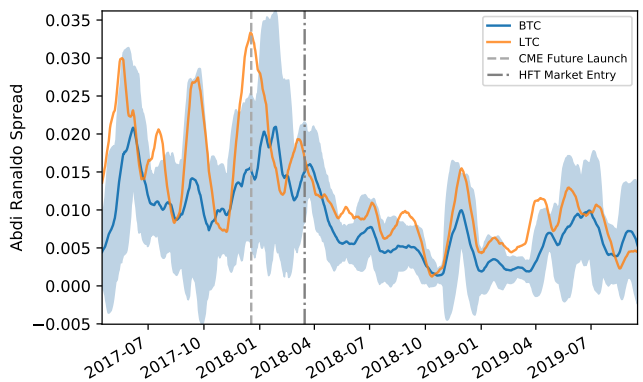
Difference-in-Differences Analysis: CME Future Launch

- Treatment group: BTC, Control group: LTC (CME future only for BTC)
- Graphical evidence for parallel trends assumption and stronger impact on LTC

$$|CIP\ Deviation_t| = \alpha + D_t^{BTC} + D_t^{Post} + D_t^{BTC \times Post} + \epsilon_t \tag{3}$$



(I) CIP Deviations of LTC and BTC



(II) Bid-Ask Spread Proxy of LTC and BTC

Figure 5: Market Efficiency Proxies

Diff-in-Diff: CME Future Launch Results

- Absolute value of CIP deviations decreases after CME future launch
- Positive interaction dummy $\rightarrow$ stronger effect for LTC
- But: CME future leaves arbitrageur exposed to idiosyncratic risk of LTC

	$\lvert CIPDev. \rvert$	$Half-Life$	$Volatility$	$ILLIQ_{P\&S}$	$ILLIQ_{Amihud}$	$Spread_{A\&R}$	$Arbitrage-Strat$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
constant	6.43***	3.91***	1.44***	8.79	0.04***	1.85***	1.47***
	(3.96)	(2.79)	(8.59)	(1.59)	(3.13)	(9.31)	(7.39)
D^{BTC}	-3.08***	-1.39	-0.61***	-8.64	-0.04***	-0.71***	-0.62***
	(-3.04)	(-0.79)	(-2.95)	(-1.45)	(-2.98)	(-3.98)	(-3.76)
D^{Post}	-5.42***	-3.48**	-0.41**	-8.65	-0.02	-0.88***	-1.14***
	(-3.31)	(-2.45)	(-2.35)	(-1.57)	(-1.18)	(-4.14)	(-5.73)
$D^{BTC \times Post}$	2.92***	1.39	0.29	8.80	0.01	0.46***	0.55***
	(2.86)	(0.79)	(1.41)	(1.48)	(1.02)	(2.59)	(3.31)
N	1558	1558	1558	1558	1558	1558	1558
F-Stat	4.92	2.43	23.58	1.83	18.15	13.20	19.91
Adj. R^2	35.63%	9.05%	16.90%	18.82%	27.54%	21.24%	19.18%

Table 2: Diff-in-diff and CME Future launch

Diff-in-Diff: CME Future Launch and Trading Hours

- Rule out that CME future is driver of improved market conditions
- CME future only tradable during the week but crypto markets trade 24/7
- Inside vs. outside trading hours reveals that no significant difference arises
- Hence, the decrease of abs. CIP deviations must be due to another driving force

	$\lvert CIPDev. \rvert$ (1)	*Volatility* (2)	$ILLIQ_{Amihud}$ (3)	$Spread_{A\&R}$ (4)	*Arbitrage − Strat* (5)
constant	1.06***	0.26***	2.97***	1.02***	0.03
	(6.41)	(4.79)	(5.69)	(7.03)	(0.84)
D^{BTC}	-0.12	-0.11***	-2.83***	-0.23*	0.01
	(-1.26)	(-3.84)	(-5.53)	(-1.96)	(0.68)
$D^{Trading\ Hours}$	-0.08	0.13	-0.51*	-0.08	0.06
	(-1.35)	(1.48)	(-1.87)	(-0.51)	(1.28)
$D^{BTC \times Trading\ Hours}$	-0.06	-0.07	0.48*	-0.06	-0.05*
	(-1.10)	(-1.22)	(1.83)	(-0.50)	(-1.79)
N	1116	1116	1116	1116	1116
F-Stat	2.10	10.76	17.43	8.20	1.13
Adj. R^2	0.97%	1.05%	28.94%	0.23%	-0.05%

Table 3: CME Future Launch and Trading Hours

Panel Regression: Jane Street Market Entry

- Both currencies traded on crypto exchanges → both are affected
- Strong decrease in CIP deviations
- Effect on LTC even stronger
- Significant increase of market efficiency proxies after HFT entry

	$\lvert CIPDev. \rvert$		$Half - Life$		$Volatility$		$ILLIQ_{P\&S}$		$ILLIQ_{Amihud}$		$Spread_{A\&R}$		$Arbitrage - Strat$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
constant	5.08***	2.44**	2.95**	3.48	1.53***	0.59***	6.48	4.56	0.03***	0.03***	1.88***	0.83***	1.25***	0.46***
	(3.55)	(2.35)	(2.47)	(1.40)	(8.61)	(4.12)	(1.50)	(1.23)	(2.94)	(3.77)	(10.26)	(5.08)	(7.52)	(3.06)
D^{BTC}	-2.37***	-0.27	-1.00	-0.28	-0.58***	-0.20*	-6.21	-5.40	-0.03***	-0.03***	-0.62***	-0.22**	-0.49***	-0.03
	(-2.76)	(-0.36)	(-0.74)	(-0.15)	(-3.52)	(-1.66)	(-1.33)	(-1.34)	(-2.82)	(-4.18)	(-3.74)	(-2.02)	(-3.78)	(-0.37)
D^{Post}	-4.10***	-2.23***	-2.48**	-3.66*	-0.63***	-0.12	-6.28	-5.76	-0.00	-0.00	-1.08***	-0.64***	-0.97***	-0.52***
	(-2.85)	(-3.05)	(-2.04)	(-1.96)	(-3.40)	(-0.93)	(-1.45)	(-1.41)	(-0.35)	(-0.25)	(-5.44)	(-4.96)	(-5.79)	(-5.58)
$D^{BTC \times Post}$	2.23***	0.65	0.98	1.66	0.29*	0.08	6.25	5.92	0.00	0.00	0.39**	0.20*	0.43***	0.12
	(2.58)	(0.80)	(0.72)	(1.00)	(1.71)	(0.65)	(1.34)	(1.39)	(0.20)	(0.11)	(2.25)	(1.66)	(3.27)	(1.33)
N	1558	1558	1558	1558	1558	1558	1558	1558	1558	1558	1558	1558	1558	1558
F-Stat	3.33	41.87	1.60	14.10	26.93	66.11	0.92	0.53	20.64	20.64	19.38	56.83	19.52	21.63
R^2	24.20%	50.20%	5.34%	18.19%	29.17%	52.46%	12.59%	14.53%	24.47%	27.29%	36.83%	55.69%	16.66%	25.77%
Controls	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES

Table 4: Panel Regression of Jane Street Entry

Drivers of CIP Deviations

- Short-sale constraints Illustration
- Default Risk

	Panel A: $y_t := \Delta\,[i_t^* - i_t + f_t - s_t] \times 100$						Panel B: $y_t := \Delta\,\lvert[i_t^* - i_t + f_t - s_t]\rvert \times 100$					
	(1a)	(2a)	(3a)	(4a)	(5a)	(6a)	(1b)	(2b)	(3b)	(4b)	(5b)	(6b)
Intercept	-0.00	-0.00	-0.01	-0.01	-0.01	0.35***	-0.01	0.00	-0.01	-0.01	-0.00	0.33***
	(-0.12)	(-0.15)	(-0.42)	(-0.45)	(-0.56)	(10.26)	(-0.59)	(0.18)	(-0.43)	(-0.40)	(-0.36)	(8.96)
y_{t-1}	-0.27***		-0.14***	-0.14***	-0.14***	-0.13*	-0.22***		-0.10**	-0.10**	-0.11**	0.00
	(-5.42)		(-2.69)	(-2.65)	(-2.69)	(-1.81)	(-3.73)		(-2.26)	(-2.20)	(-2.39)	(0.01)
Ret_S	0.04***		0.02**	0.02**	0.02**	0.05*	-0.01		-0.00	-0.00	-0.00	0.01
	(3.22)		(2.47)	(2.48)	(2.53)	(1.92)	(-1.25)		(-0.27)	(-0.28)	(-0.22)	(0.54)
Ret_S^2	-0.00		0.00	0.00	0.00	0.01**	0.00		0.00	0.00	0.00	0.01***
	(-0.10)		(0.34)	(0.35)	(0.39)	(2.14)	(0.95)		(0.67)	(0.66)	(0.66)	(3.17)
Δ Bitfinex Premium		-1.16***	-1.07***	-1.07***	-1.06***	-0.96***		0.93***	0.90***	0.90***	0.89***	1.06***
		(-10.30)	(-8.76)	(-8.81)	(-8.58)	(-6.84)		(6.53)	(6.20)	(6.07)	(6.11)	(5.10)
$\Delta \frac{USDT}{USD} - 1$		0.00	-0.00	-0.00	-0.00	0.05		0.11	0.11	0.11	0.11	0.07
		(-0.02)	(-0.14)	(-0.12)	(-0.09)	(-0.01)		(1.55)	(1.57)	(1.55)	(1.56)	(0.94)
$\Delta\, ILLIQ_{Amihud}$			-168.90	-167.86	-184.92	-132.96			-172.70	-173.04	-191.38	-342.77
			(-0.99)	(-1.00)	(-1.07)	(-0.89)			(-1.32)	(-1.36)	(-1.42)	(-1.61)
$\Delta\, ILLIQ_{P\&S}$				-45607	-41772	0.04				14676	14097	-0.63
				(-1.06)	(-0.95)	(-0.10)				(0.35)	(0.32)	(-0.19)
$\Delta\, Spread_{A\&S}$					3.10	30.75					23.34	58.95**
					(0.34)	(1.17)					(1.27)	(2.11)
$\Delta\, TED$					0.00	0.00					-0.00	-0.01
					(0.63)	(0.26)					(-0.15)	(-0.42)
$\Delta\, VIX$					-0.01	-0.05**					0.00	-0.05***
					(-0.94)	(-2.30)					(0.12)	(-3.13)
N	558	558	558	558	558	558	558	558	558	558	558	558
Durbin-Watson	2.037	2.467	2.278	2.281	2.281	1.219	1.969	2.435	2.232	2.232	2.237	1.22
Adj. R^2	11.24%	40.68%	43.71%	43.65%	43.46%	-	Adj. R^2 5.56%	39.90%	40.89%	40.78%	40.78%	-

Table 5: Drivers of CIP Deviations

Robustness I/III: Ethereum as control group instead of LTC

- In December 2017 OKEx also introduced futures on Ethereum (ETH)
- We use this data for another diff-in-diff regression with respect to inside-vs-outside trading hours
- Replacing LTC by ETH, we again find that there is no significant difference between trading and non-trading hours
- Arbitrage profits for ETH (and LTC) also vanished after HFT entry

	$\lvert CIPDev. \rvert$ (1)	*Volatility* (2)	$ILLIQ_{Amihud}$ (3)	$Spread_{A\&R}$ (4)	*Arbitrage − Strat* (5)
constant	1.01***	0.25***	0.81***	1.03***	0.06*
	(6.57)	(4.98)	(7.31)	(5.28)	(1.87)
D^{BTC}	-0.08	-0.10***	-0.67***	-0.23*	-0.01
	(-1.06)	(-3.42)	(-6.53)	(-1.84)	(-0.40)
$D^{Trading\ Hours}$	-0.04	0.11	-0.21***	-0.12	-0.05
	(-0.55)	(1.59)	(-3.18)	(-0.65)	(-1.22)
$D^{BTC \times Trading\ Hours}$	-0.10*	-0.05	0.18***	-0.02	0.06***
	(-1.67)	(-1.05)	(3.18)	(-0.12)	(3.00)
N	1116	1116	1116	1116	1116
F-Stat	2.74	7.92	18.82	5.88	3.16
Adj. R^2	0.82%	0.94%	21.49%	0.17%	-0.05%

Table 6: BTC and ETH Robustness Check

Robustness II/III: Uncovered Interest Parity (UIP)

- Uncovered Interest Parity (UIP) predicts that forward (future) prices should equal the future spot price, thus predicting future price moves

$$\mathbb{E}_t[\Delta s_T] = r_{t,T} - r^*_{t,T} \ (= f_{t,T} - s_t) \text{ due to CIP} \tag{4}$$

- We find large UIP deviations before HFT entry
- However, similar to conventional currency markets UIP deviations remain larger than CIP deviations even after HFT entry
- Interestingly, there is no stronger effect on LTC compared to BTC in contrast to our findings with respect to CIP

	UIP Deviation
constant	4.11
	(1.19)
D^{BTC}	-1.30
	(-0.53)
D^{Post}	-6.57*
	(-1.83)
$D^{BTC \times Post}$	3.87
	(1.52)
N	299
F-Stat	4.91
Adj. R^2	2.61%

Table 7: UIP deviations before and after HFT entry

Robustness III/III: Triangular Arbitrage

- Another arbitrage condition: Triangular Arbitrage
- Arbitrage ratio refers to the ratio of $(\frac{BTC/USD \times USD/EUR}{BTC/EUR} - 1) \times 100$
- Triangular Arbitrage opportunities disappear after HFT entry

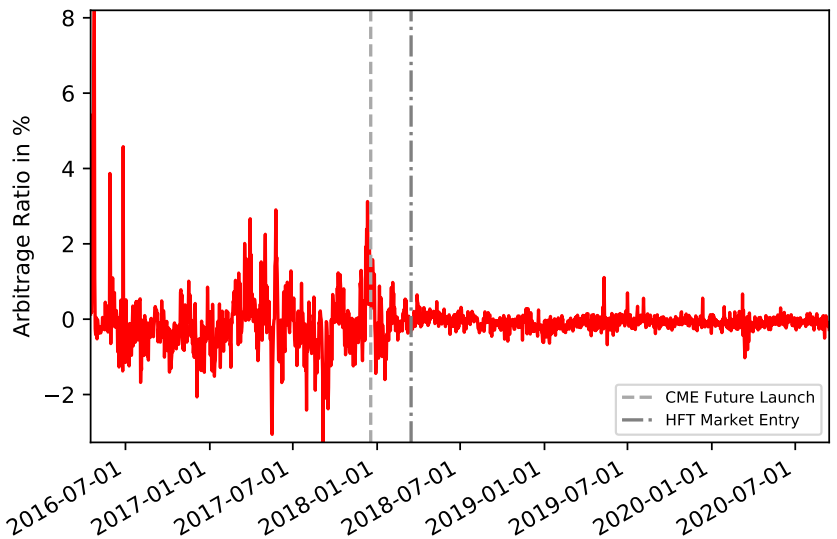


Figure 6: Triangular Arbitrage on Bitstamp

Conclusion

- We find large CIP deviations of up to 15% until 03/2018 which disappear afterwards
- Sophisticated arbitrageurs needed to make basic arbitrage mechanisms hold
- Entry of these arbitrageurs has stronger effect on less liquid market
- Future research:
  - Counterparty risk on other exchanges
  - Price deviations in sample period after Makarov and Schoar (2019)
  - Physically-settled crypto futures and options in the fiat world

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CIP in fiat world

- Du et al. (2018) find persistent CIP deviations after great financial crisis
- However, CIP deviations are small compared to our findings in crypto space

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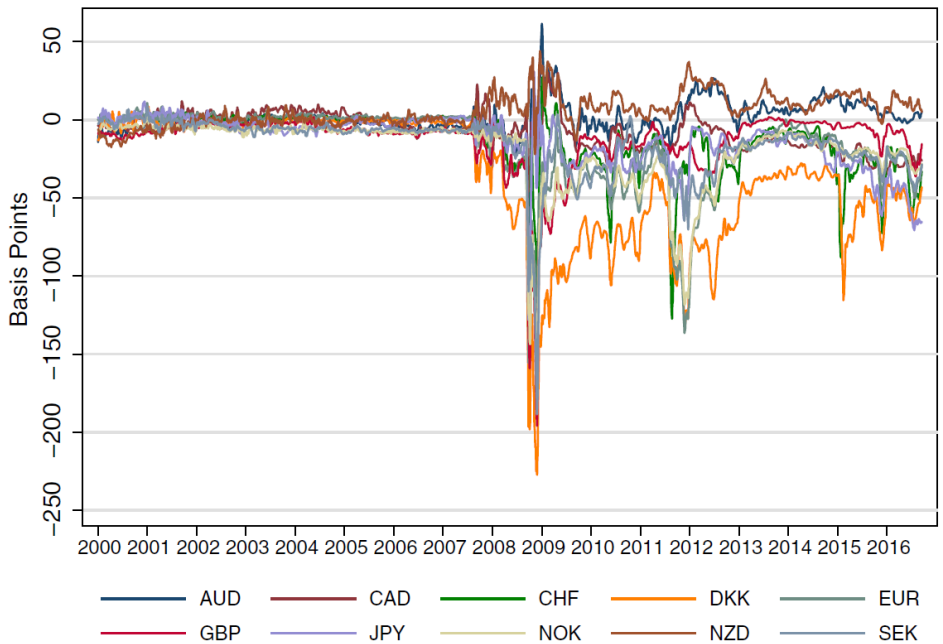

Figure 7: Three-month Libor cross-currency basis
Source: Du et al. (2018)