

Figure 1. **Cash flow diagram for covered interest rate arbitrage with a negative basis.** This figure plots the cash flow of an arbitrageur profiting from a CIP deviation between the future and spot market. The cip deviation, commonly referred as basis, is equal to  $i_{t,t+n}^{usd} - (i_{t,t+n}^{crypto} - \rho_{t,t+n})$  where  $n = 8$  hours,  $i_{t,t+n}^{usd}$  and  $i_{t,t+n}^{crypto}$  denote the USD and crypto interest rates, and  $\rho_{t,t+n} = \frac{1}{n}(f_{t,t+n} - s_t)$  denotes the future premium obtained from the future  $f_{t,t+n}$  and spot  $s_t$  exchange rates. To arbitrage a negative deviation, the arbitrageur sells the future and buys the spots financed with an USD loan. The arbitrageur could earn a risk-free profit equal to an annualized  $|x|\%$  of the trade notional. There is no cash flow at date  $t$ . At date  $t+1$ , due to the specifics of Perpetual Futures, a funding rate payment might be received if  $\frac{F_{t+1,T}}{S_{t+1}} > -0.01$ . At date  $T$ , the arbitrageur receives USD due to the forward contract. The arbitrageur converts that, repays her debt in USD, and is left with a profit equal to the negative of the basis in  $t$ . In essence, the arbitrageur is going long into USD and shorts the crypto interest rate, with the directional cash flow fully hedged by a forward contract.

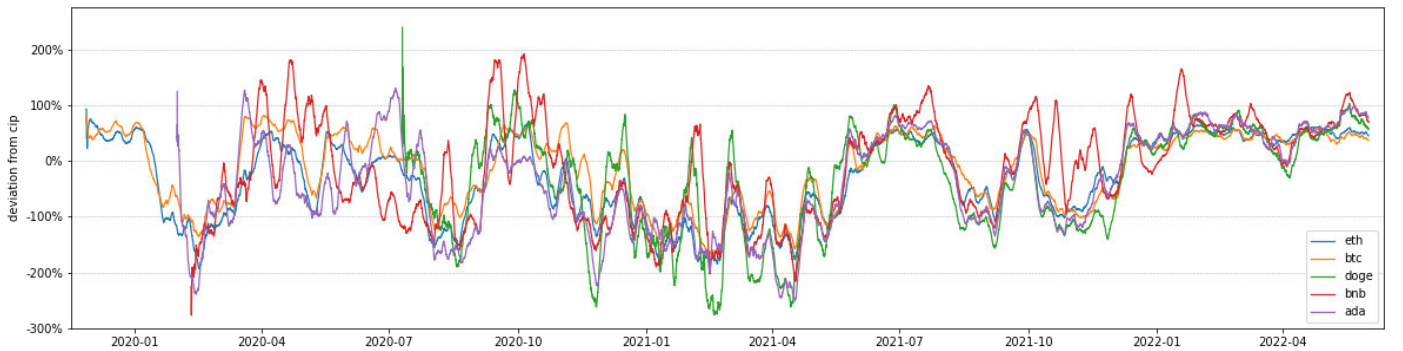
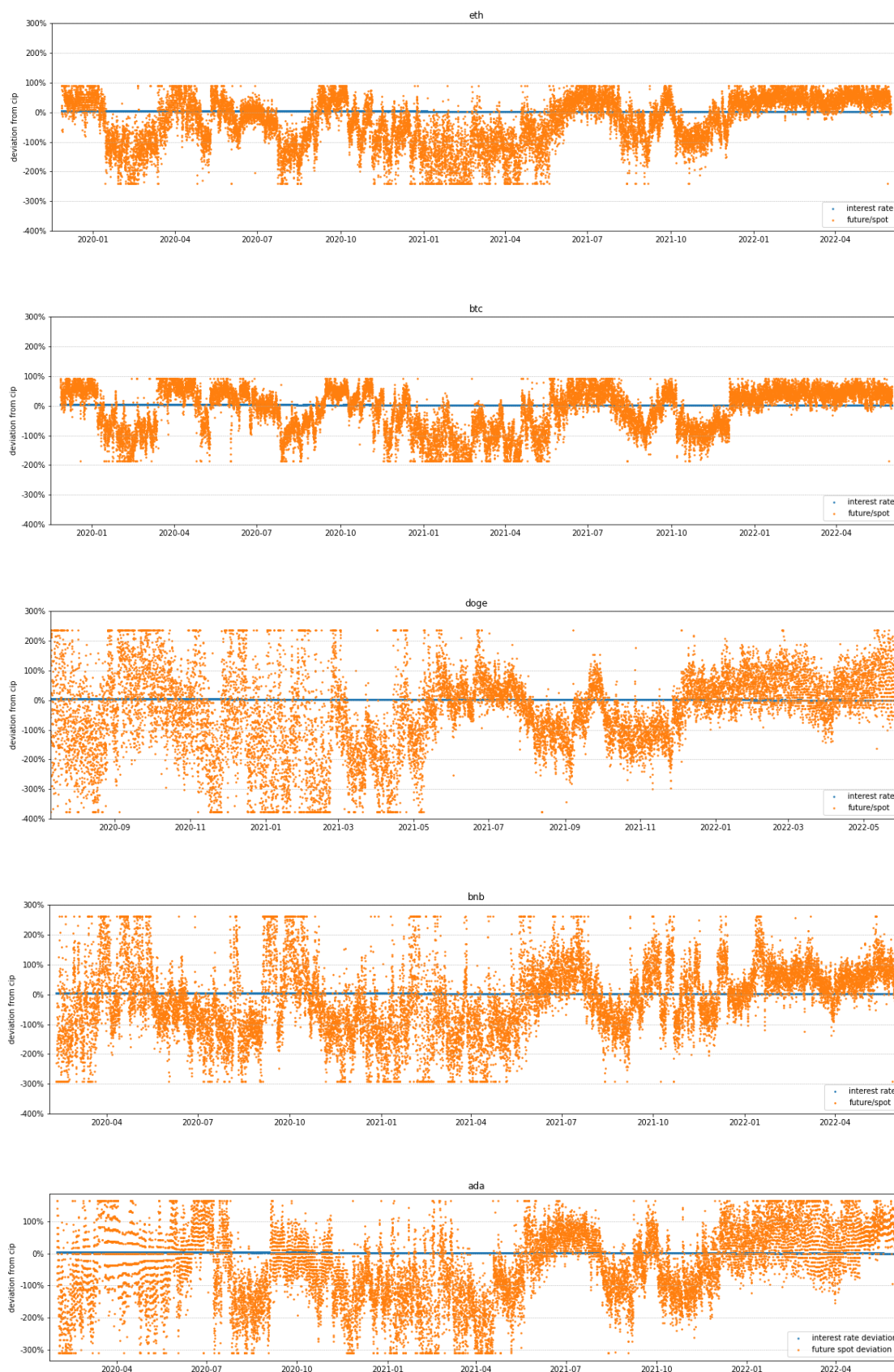


Figure 2. **Deviations from covered interest parity based on short-term crypto futures.** This figure plots the 7-day moving averages of the Perpetual Future CIP deviation, measured in percentage for the five most prominent crypto currencies by volume. CIP implies that the deviation should be zero. The cip deviation, commonly referred as basis, is equal to  $i_{t,t+n}^{usd} - (i_{t,t+n}^{crypto} - \rho_{t,t+n})$  where  $n = 8$  hours,  $i_{t,t+n}^{usd}$  and  $i_{t,t+n}^{crypto}$  denote the USD and crypto interest rates, and  $\rho_{t,t+n} = \frac{1}{n}(f_{t,t+n} - s_t)$  denotes the future premium obtained from the future  $f_{t,t+n}$  and spot  $s_t$  exchange rates. The currencies are denoted by their usual abbreviations: Ether (eth), Bitcoin (btc), Dogecoin (doge), Binance Coin (bnb), Cardano (ada).

**Table 1. Summary statistics for Perpetual Futures based covered interest parity deviations.** This table reports the mean basis from 11/2019-06/2022 against the USD for the five most prominent crypto markets by volume. Standard deviations are shown in parentheses. The CIP deviation was 47.5% for ETHUSD in 2019 with a 30.71% standard deviation. The cip deviation, commonly referred as basis, is equal to  $i_{t,t+n}^{USD} - (i_{t,t+n}^{crypto} - \rho_{t,t+n})$  where  $n = 8$  hours,  $i_{t,t+n}^{USD}$  and  $i_{t,t+n}^{crypto}$  denote the USD and crypto interest rates, and  $\rho_{t,t+n} = \frac{1}{n}(f_{t,t+n} - s_t)$  denotes the future premium obtained from the future  $f_{t,t+n}$  and spot  $s_t$  exchange rates. The interest rates for USD and crypto are obtained as a basket from the two most liquid money markets (Aave and Compound) and are commonly referred as crypto market interest rates. The currencies are denoted by their usual abbreviations: Ether (eth), Bitcoin (btc), Dogecoin (doge), Binance Coin (bnb), Cardano (ada).

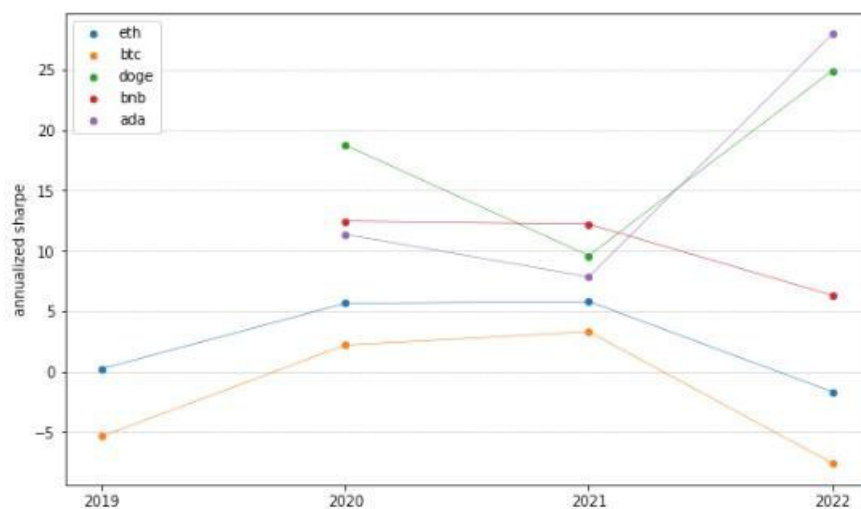
		2019	2020	2021	2022	all
eth	mean	0.475	-0.4488	-0.5551	0.4863	-0.3017
	std	(0.3071)	(0.7725)	(0.8434)	(0.2272)	(0.8324)
btc	mean	0.5625	-0.1257	-0.4544	0.4379	-0.1374
	std	(0.2736)	(0.7049)	(0.7498)	(0.2272)	(0.7393)
doge	mean		-0.3852	-0.7021	0.497	-0.3591
	std		(1.5524)	(1.3002)	(0.6249)	(1.3454)
bnb	mean		-0.2789	-0.3128	0.6451	-0.1273
	std		(1.3142)	(1.1832)	(0.5351)	(1.2071)
ada	mean		-0.55	-0.606	0.5891	-0.3715
	std		(1.1214)	(1.0902)	(0.618)	(1.128)

Figure 3. The figure displays the cip violations divided between the interest rate deviation and the future/spot deviation. It includes all five currencies Ether (eth), Bitcoin (btc), Dogecoin (doge), Binance Coin (bnb), Cardano (ada) against the USD. In contrast to traditional finance the basis is very large. Note, that the annualized future premium  $\rho_{t,t+n} = \frac{1}{n}(f_{t,t+n} - s_t)$  is scaled with  $\frac{1}{n}$ , in the case of 8 hours Perpetual Futures the scalar is denoted as  $\frac{1}{3*365}$ . During times of stress in the nascent crypto markets the liquidity in trading books can become thin, which might lead to extremes in the price reporting. We address these outliers by winsorizing at  $\pm 2$  standard deviations (95% confidence). The interest rate deviation is significantly smaller than the future premium. Further, the cip violation shows a high variance, especially at the beginning of the markets. Across the currencies the deviation becomes positive and less volatile since the beginning of 2022.



**Table 2. Perpetual Future CIP arbitrage.** The table reports the arbitrage profits as annualized mean return and standard deviation for the 8h Perpetual Future basis for Ether (eth), Bitcoin (btc), Dogecoin (doge), Binance Coin (bnb), Cardano (ada) during the 11/2019 – 06/2022 period. Standard deviation is reported in parentheses. In the last two rows, we also report for each currency the annualized Sharpe ratio and annualized Sharpe ratio adjust by an AR(1) process<sup>1</sup>. All profits are calculated with low transaction costs - accessible for larger funds - on the future and spot trades. The table is divided in 2x5 columns. **Non-conditional** reports the profits with no infrastructure restrictions, agents can exploit a positive and negative basis. **Conditional** reports the profits considering that agents cannot exploit a positive basis. A positive basis requires the arbitrageur to short the spot and long the future. However, in crypto markets shorting the spot currency is (a) not supported by the major exchanges and (b) requires full collateralization. Due to a lack of infrastructure and cost of capital arbitrageurs generally refrain from exploiting a positive basis.

		non-conditional					conditional				
		2019	2020	2021	2022	all	2019	2020	2021	2022	all
eth	ann_return	0.0959	0.2321	0.2697	-0.0066	0.2025	0.0102	0.1862	0.244	0.014	0.1741
	ann_std	(0.1887)	(0.0328)	(0.0414)	(0.0146)	(0.0499)	(0.0022)	(0.0302)	(0.0404)	(0.0091)	(0.0321)
	ann_sharpe	0.24	5.65	5.8	-1.66	3.35	-18.41	4.61	5.32	-0.4	4.33
	ann_sharpe_ar1	0.27	5.84	6.25	-1.29	3.58	-26.25	5.16	6.06	-0.42	4.89
btc	ann_return	0.0011	0.1094	0.2103	-0.0364	0.1214	0.0089	0.0917	0.1899	0.0038	0.1131
	ann_std	(0.0091)	(0.0285)	(0.0548)	(0.0071)	(0.0391)	(0.003)	(0.0226)	(0.0543)	(0.0024)	(0.0372)
	ann_sharpe	-5.35	2.19	3.3	-7.57	2.2	-13.65	1.97	2.96	-5.83	2.1
	ann_sharpe_ar1	-6.1	2.83	3.54	-8.0	2.44	-14.98	2.12	3.1	-5.77	2.2
doge	ann_return		1.7942	0.8742	0.5678	1.0395		0.9673	0.557	0.1048	0.5615
	ann_std		(0.0935)	(0.0881)	(0.0221)	(0.0802)		(0.0862)	(0.0709)	(0.0091)	(0.0675)
	ann_sharpe		18.74	9.59	24.9	12.58		10.72	7.44	9.58	7.87
	ann_sharpe_ar1		16.5	11.46	36.73	13.22		9.36	11.11	11.98	8.74
bnb	ann_return		0.6417	0.6109	0.1435	0.5387		0.3444	0.3694	0.0142	0.2958
	ann_std		(0.0478)	(0.0477)	(0.0199)	(0.0441)		(0.0307)	(0.0395)	(0.0043)	(0.0323)
	ann_sharpe		12.45	12.2	6.32	11.45		9.72	8.62	-0.79	8.11
	ann_sharpe_ar1		15.64	14.41	7.58	13.86		14.13	12.03	-0.93	11.41
ada	ann_return		0.6174	0.4967	0.6839	0.5775		0.3952	0.3484	0.1719	0.3354
	ann_std		(0.0503)	(0.0596)	(0.0239)	(0.0512)		(0.0458)	(0.0564)	(0.0111)	(0.0471)
	ann_sharpe		11.35	7.84	27.91	10.62		7.61	5.65	13.92	6.41
	ann_sharpe_ar1		15.3	7.63	35.34	11.53		10.85	5.64	16.38	7.11

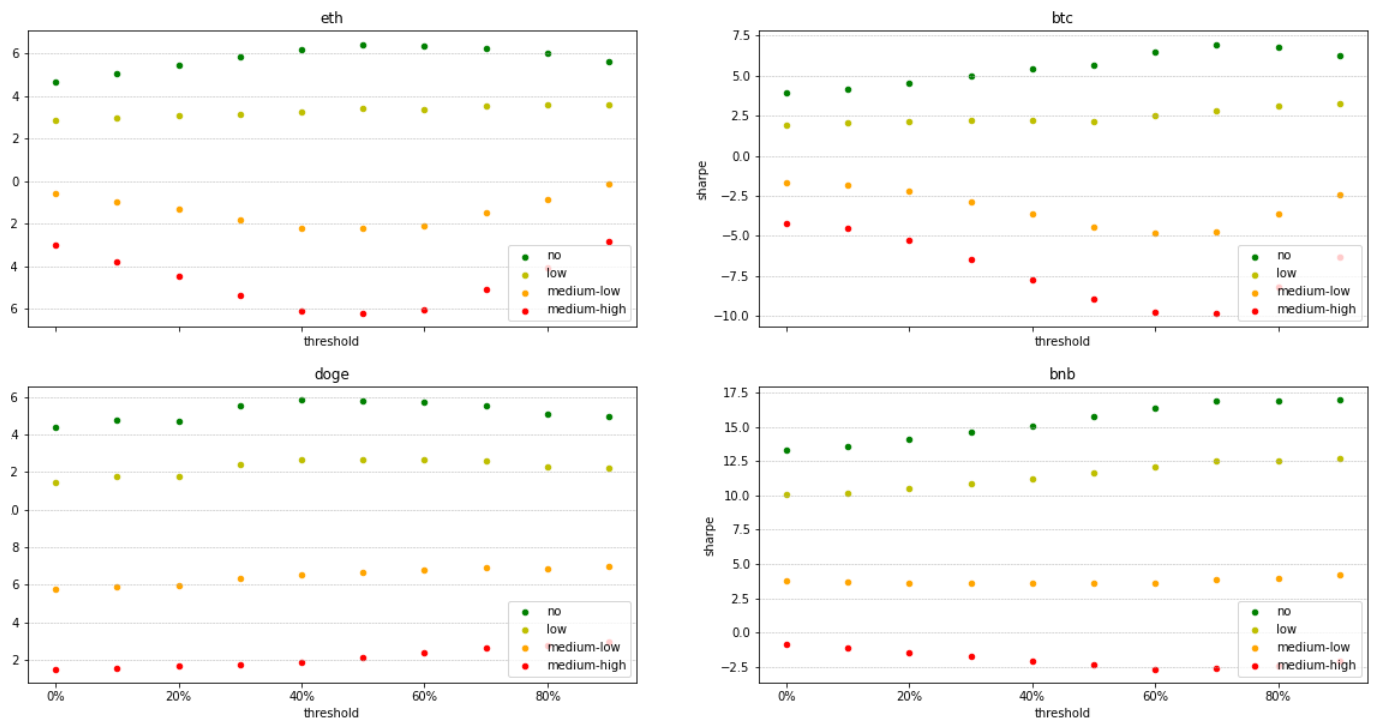


**Figure 4. Sharpe ratios over time.** The figure denotes the annualized Sharpe ratios over time for each cryptocurrency. It indicates a decline in arbitrage profitability for the largest cryptocurrencies Ether (eth) and Bitcoin (btc). Furthermore, less traded cryptocurrencies such as Dogecoin (doge), Binance coin (bnb), and Cardano (ada) seem to have a higher level of profitability. All profits are calculated with low transaction costs - accessible for larger funds - on the future and spot trades.

<sup>1</sup> Please see Andrew W. Lo (2002): The Statistics of Sharpe Ratios for the original source of the discussion.  
<https://alo.mit.edu/wp-content/uploads/2017/06/The-Statistics-of-Sharpe-Ratios.pdf>

Table 3. **Fee impact on arbitrage profits.** The table reports the results when iterating over several common fee tiers. Throughout our reporting profits have been calculated with low transaction costs - accessible for larger funds – marked in grey. Generally, the fees for trading the spot market are significantly larger than the fees for the derivatives. Fee tiers are attributed to the 30-day trading volume. We attribute **medium-high** fees with a 30-day trading volume below \$1mn, typically a retail trader. **Medium-low** fees attribute to a 30-day trading volume below \$120mn. **Low fees** attribute to a 30-day trading volume below \$2.5bn, typically large funds. No fees can be negotiated with customized contracts, for example for market makers. The results indicate that the arbitrage opportunity can only be exploited by professional traders, as professional traders have access to more beneficial fee tiers. For the smallest traders, the arbitrage profits can be „eaten away“ by the costs of trading.

		no	low	medium-low	medium-high
eth	ann_return	0.352300	0.202500	-0.076400	-0.280300
	ann_std	(0.05)	(0.0499)	(0.0503)	(0.051)
	ann_sharpe	6.340000	3.350000	-2.220000	-6.190000
btc	ann_return	0.253800	0.121400	-0.125000	-0.305100
	ann_std	(0.0391)	(0.0391)	(0.0398)	(0.0408)
	ann_sharpe	5.600000	2.200000	-4.020000	-8.350000
doge	ann_return	1.306600	1.039500	0.542600	0.179400
	ann_std	(0.0811)	(0.0802)	(0.0791)	(0.0787)
	ann_sharpe	15.740000	12.580000	6.480000	1.900000
bnb	ann_return	0.725400	0.538700	0.191400	-0.062600
	ann_std	(0.0447)	(0.0441)	(0.0437)	(0.044)
	ann_sharpe	15.470000	11.450000	3.610000	-2.190000
ada	ann_return	0.800000	0.577500	0.163600	-0.139000
	ann_std	(0.0517)	(0.0512)	(0.0509)	(0.0513)
	ann_sharpe	14.820000	10.620000	2.550000	-3.370000



**Figure 5. Optimization of the trading activity.** For each currency the illustration shows the development of profit, reported as the annualized Sharpe ratio, in dependence of the trading activity. Higher trading activity leads to more fees, especially for the lower fee tiers. The trading activity is steered by introducing a “no-action” zone or threshold. If the absolute cip deviation is smaller than the threshold the arbitrageur does not execute a trade. We iterate the threshold between (0% and 100%), whereas 0% trades always and 100% only trades if the cip deviation is larger than  $\pm 100\%$ . The currencies are denoted by their usual abbreviations: Ether (eth), Bitcoin (btc), Dogecoin (doge), Binance Coin (bnb), Cardano (ada).

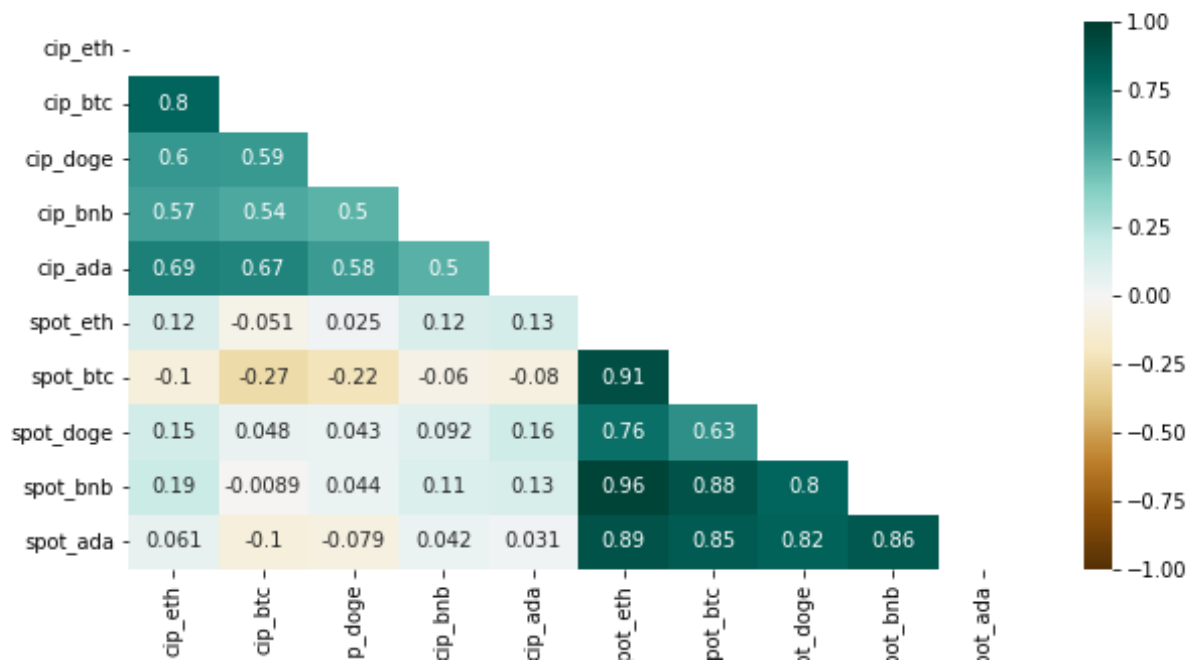


Figure 6. **Correlation of cip deviation and spot.** The illustration reports the correlation between the bases among each cryptocurrency. The correlation between the Ether (eth) and Bitcoin (btc) basis is 0.8. The results indicate, that the cip deviations significantly co-relate. The currencies are denoted by their usual abbreviations: Ether (eth), Bitcoin (btc), Dogecoin (doge), Binance Coin (bnb), Cardano (ada).