Staking, Token Pricing, and Crypto Carry

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Introduction

Blockchain-based Ecosystem and Tokens

- Digital platforms, Network innovations, & Blockchain-based Ecosystems
  - Infrastructure for functional trust.
  - A blockchain (decentralized) solution for Web3.
  - Innovations in payment, identification, vesting of interests, etc.

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- Digital platforms, Network innovations, & Blockchain-based Ecosystems
  - Infrastructure for functional trust.
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  - Innovations in payment, identification, vesting of interests, etc.
- Token in the Ecosystem
  - Local medium of exchange and form of compensation.
    - Platforms support particular economic activities (e.g., Filecoin, BAT).
    - Blockchain: preventing double spending, facilitating smart contracts (e.g., escrow account).
  - Platform manages token supply and development through decentralized contribution.
  - Entrepreneurs'/owners' rewards and instruments.
    - Tokens used to gather resources and attract talents.
  - Regulating on-chain behavior using incentives and economic mechanisms.

Tokenomics Landscape

- What tokens are?
  - General payment tokens, platform tokens, product tokens, security tokens.
  - Hybrid between money and investable asset.
  - CBDC, DCEP, monetary policy, etc.
- Token valuation and crypto vol:
  - Means of payment to realize unique trade surplus on the platform.
  - Sources of volatility:
    - Fundamental technology/productivity/policy shocks.
    - Speculation and behavioral factors.
    - Endogenous adoption.

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    - Endogenous adoption.
- Means more under PoS mechanism:
  - Binding voting, governance rights etc.
  - Linking user participation and the consensus mechanism operation.
  - $\rightarrow$ A new pillar of token value.

Literature of Tokenomics: Mechanism, Impact, & Applications

- Protocol games: Nakamoto (2008); Eyal & Sirer (2014); Biais et.al. (2018); Biais et.al. (2019); Saleh (2018); Pagnotta (2018); Chiu and Koeppl (2018), etc.
- Market micro-structure and fee: Easley, O'Hara & Basu (2018, 2019); Huberman, Leshno, and Moallemi (2019); etc.
- Energy cost: O'Dwyer & Malone (2014); Cong, He, and Li (2018); Benetton, Compiani, and Morse (2019).
- Smart contracts, Information & decentralization: Aune, O'Hara, & Slama (2017); Cong & He (2018).
- Risk-sharing & decentralization: Cong, He, and Li (2018).
- Governance/R&D concentration: Alsabah and Capponi (2019); Arnosti and Weinberg (2019); Ferreira et al. (2019)
- Scalability: Abadi & Brunnermeier (2018); Hinzen, John, & Saleh (2019); Chen, Cong, & Xiao (2019).
- Manipulation & Regulation: Griffin & Shams (2020); Cong et al. (2020).
- Platform growth: Gans & Halaburda; Cong, Li, & Wang (2018)
- ICOs: Sochin & Xiong (2018); Li & Mann (2018); Catalini & Gans (2018); Howell, Niessner, and Yermack (2018); Canidio (2018); Chod & Lyandres; Bakos & Halaburda; Malinova & Park (2019).
- Monetary policy & design: Balvers & McDonald (2017); Schilling & Uhlig (2018).
- Auditing: Cao, Cong, & Yang (2018); Cao et al. (2019).
- Payment and remittance: Athey et.al. (2016)
- Alternative asset: Hu, Parlour, & Rajan (2018), Li, Shin, & Wang (2019), etc.
- Gig economy & on-demand labor: Cong, Li, & Wang (2018b)
- Valuation: Cong, Li, & Wang (2018); Buraschi and Pagnotta (2018)
- International finance: Yu & Zhang (2017); Makarov & Schoar (2018), etc

Staking Economy: Background

- Proof-of-Stake (PoS) protocols:
  - inefficiency and environmental costs of PoW (Cong, He, & Li, 2021; Saleh, 2021);
  - Listed in MIT 2022 10 Breakthrough Technologies; Ethereum moving to PoS;
  - Rewards for consensus generation;
  - Pan-PoS: Proof-of-Credit (POC) in NULS, etc.;
- DeFi Staking (Harvey, Ramachandran, & Santoro, 2021):
  - Staking contributes to network security level. Staking reward incentives adoption.
  - Derivatives collateral (Synthetix), liquidity (Curve, Uniswap), money market (Compound), Oracles (ChainLink), insurance, etc.
- Reward determination and slashing, typically quantity based.
- Informational environment: Issuance plan, total staked, etc.; Stakingrewards.com, etc.

Tokens in the Staking Economy

Token: A hybrid asset between money and other investable assets.

- Roles of tokens:
  - Bootstrapping and adoption acceleration.
  - Participation and operation of consensus mechanism.
  - User-base stabilization.
  - Native payment.
  - Corporate finance toolkit: financing/incentivizing decentralized contribution.
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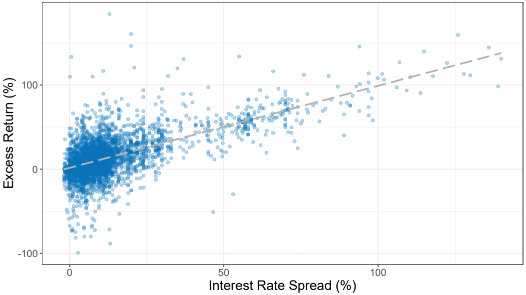
- Commodities:
  - Commodities Futures Trading Commission (CFTC) regards cryptocurrencies as commodities.
  - Staking: the use of tokens as collateral.
  - Using commodities as collateral for raising funds increases the underlying spot price and the convenience yield (Tang & Zhu, 2016).
- Currencies:
  - Adoption and Transaction.
  - Token appreciation vs. exchange rate changes. Staking reward rate vs. deposit rate.
  - Comparable to the foreign exchange market $\longrightarrow$ the uncovered interest parity puzzle.

This Paper

- Modeling the staking economy:
  - A unified framework to understand its use as transaction media, investment assets, and deposit-like instruments for earning rewards.
  - The generation and distribution of staking rewards.
  - Token valuation in the staking economy.
  - The predictability of staking ratio and token pricing.
- Empirical Tests:

- The impact of the staking mechanism.
- UIP Violation.
- Linking token akin to classic classes.
- Carry: A characteristic of any class. → Crypto Carry.



Model

The Staking Economy

- Time: $t \in [0, \infty)$. Native platform token and consumption numéraire.
- Platform:
  - Platform productivity (Cong, Li, & Wang, 2021a,b):

$$\mathrm{d}A_t = \mu^A(\Theta_t)A_t\mathrm{d}t + \sigma^A A_t\mathrm{d}Z_t.$$

  - Θ_t, staking ratio: endogenous, the ratio of the aggregate number of staked tokens to the total.
  - Feedback effect: Staked tokens contribute to the development of the platform by maintaining node operations, facilitating the achievement of consensus, and increasing the security level of network.
- Agents:
  - Unit measure. Allow heterogeneous levels of wealth $\rightarrow$ wealth distribution in the extended model.
  - Solve individual consumption-portfolio problem. Stochastic optimization.
  - Consumption y_t. Wealth $w_t =$ on-chain staked l_t + on-chain tradable x_t + off-chain numeraire n_t.

Agent's Problem

- Agent's trade-off:
  - Transaction convenience of token (Cong, Li, & Wang, 2021a,b): $\mathrm{d}v(x_t) = \mathrm{d}v_t = x_t^{1-\alpha}(e^{u_t}A_t)^{\alpha}\mathrm{d}t - \varphi \mathrm{d}t$.
  - Transaction costs in consumption (numéraire convenience, Bansal & Coleman, 1996; Valchev, 2020):
    $\Psi_t = \Psi_t(y_t, n_t, A_t) \geq 0, \quad \frac{\partial \Psi}{\partial y} > 0 \quad \& \quad \frac{\partial \Psi}{\partial n} < 0.$
  - Aggregate reward process: come from a combination of emission and fees. $R_t = E_t(Q_t, A_t) + F_t(Q_t, A_t) = \iota Q_t + \tau_t Q_t$.
  - Reward rate/yield: $r_t \equiv \frac{R_t}{L_t}$, *where* L_t *is the aggregate no. staked.*
  - Slashing cost rate $c_t < r_t$.
- Agents' problem:
  - $\max_{\{y_s, x_s, l_s\}_{s=t}^{\infty}} \mathrm{E}_t \left[\int_t^{\infty} e^{-\phi(s-t)} \mathcal{U}(y_s) \mathrm{d}s \right]$, s.t.
  - wealth dynamic:
    $\mathrm{d}w_t = [(x_t + l_t)\mu_t + l_t(r_t - c_t) + v_t - y_t - \Psi_t]\mathrm{d}t + (x_t + l_t)\sigma_t \mathrm{d}Z_t = f(y_t, x_t, l_t; w_t, m_t, r_t, A_t)\mathrm{d}t + g(y_t, x_t, l_t; w_t, m_t, r_t, A_t)\mathrm{d}Z_t.$

Solving the Equilibrium

- Dynamic Equilibrium:
  - Staking Ratio Θ_t: $\Theta_t = \Theta(r_t, A_t) = \frac{\int_{[0,1]} \theta_{i,t} w_{i,t} \mathrm{d}i}{\int_{[0,1]} w_{i,t} \mathrm{d}i}$.
  - Endogenous token price $P_t = P(A_t, Q_t)$ with dynamic $\mathrm{d}P_t = P_t \mu_t \mathrm{d}t + P_t \sigma_t \mathrm{d}Z_t$.
  - Each agent solves individual optimization problem;
  - Reward rate determines cross-sectionally: Agents take reward rate as given but equilibrium belief is consistent: $r_t^* = \frac{R_t}{Q_t \Theta(r_t^*, A_t)} = \frac{\rho_t}{\Theta(r_t^*, A_t)} \rightarrow$ a fixed point problem.
  - Token market clearing $\Rightarrow \Theta_t = \Theta(A_t, P(A_t))$.
- Dynamic pricing:
  - Pricing formula PDE:

$$0 = \frac{\partial P}{\partial Q} Q \iota + \frac{\partial P}{\partial A}\left[A\mu^A - (A\sigma^A)^2 H\right] - \left(\frac{\partial P}{\partial A}\right)^2 QI(A\sigma^A)^2 + \frac{1}{2}\frac{\partial^2 P}{\partial A^2}(A\sigma^A)^2 + \left(\frac{\rho}{\Theta^*} - c + \partial_n \Psi\right) P,$$

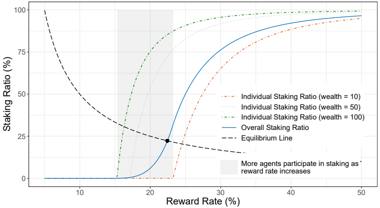
  - $P_t = P(A_t, Q_t) = \frac{1}{Q_t} V(A_t) \rightarrow$ ODE with:

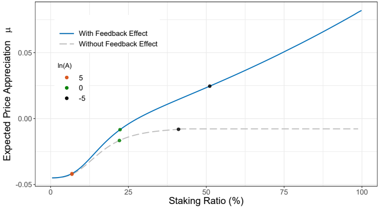
$$0 = V'(A_t)\left[A_t \mu_t^A - (A_t \sigma^A)^2 H\right] - V'(A_t)^2 (A_t \sigma^A)^2 I + \frac{1}{2} V''(A_t)(A_t \sigma^A)^2 + \left(\frac{\rho_t}{\Theta_t} - c_t + \partial_n \Psi_t - \iota_t\right) V(A_t),$$

  - Boundary conditions: $\lim_{A_t \to 0} V(A_t) = 0$ and $\lim_{A_t \to \infty} V(A_t) = \int w_t \mathrm{d}i$. $I = -\frac{\partial_{ww} J}{\partial_w J}$ and $H = -\frac{\partial_{wA} J}{\partial_w J}$.

Model Implications

1. Higher reward fraction attracts more stake, leading to a higher staking ratio. The optimal individual staking ratio increases with reward rate.
2. Higher staking ratio predicts higher appreciation.
3. UIP violated across tokens. Excess returns arise as a compensation for convenience loss.





Extend to Heterogeneous Agents and Wealth Evolution

- Extend Setup
  - Agents differ in wealth and type with a density $m_t = m(w_t)$.
  - Staking ratio: $\Theta_t = \Theta(m_t, r_t, A_t) = \frac{L_t}{Q_t} = \frac{\int_W l(w_t, m_t, r_t, A_t) m_t \mathrm{d}w_t}{\int_W [x(w_t, m_t, r_t, A_t) + l(w_t, m_t, r_t, A_t)] m_t \mathrm{d}w_t}$.

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- Mean-Field-Game Equilibrium
  - Wealth distribution evolves over time; A_t process generates aggregate shocks.
  - Master equation (FAME in numerical solving process, Bilal (2023))

$$
\begin{aligned}
\phi U(w,m,A) =& \mathcal{H}\left(w, \frac{\partial U}{\partial w}(w,m,A), \frac{\partial^2 U}{\partial w^2}(w,m,A), \frac{\partial^2 U}{\partial wA}(w,m,A); m, r, A\right) \\
&+ \int_{\mathbb{R}} \frac{\delta U}{\delta m}(w,m,A,y) \cdot \frac{\partial \mathcal{H}}{\partial \xi}\left(w, \frac{\partial U}{\partial w}(y,m,A), \frac{\partial^2 U}{\partial w^2}(y,m,A), \frac{\partial^2 U}{\partial wA}(y,m,A); m, r, A\right) \mathrm{d}m(y) \\
&- \left[\int_{\mathbb{R}} \frac{\partial}{\partial y} \frac{\delta \hat{U}}{\delta m}(w,m,A,y) \mathrm{d}m(y) + 2\int_{\mathbb{R}} \frac{\partial}{\partial w} \frac{\delta \hat{U}}{\delta m}(w,m,A,y) \mathrm{d}m(y) + \int_{\mathbb{R}\times\mathbb{R}} \frac{\partial^2}{\partial y \partial y'} \frac{\delta^2 \hat{U}}{\delta m^2}(w,m,A,y,y') \mathrm{d}m(y) \mathrm{d}m(y')\right] \\
&- \frac{\partial^2 \hat{U}}{\partial w^2}(w,m,A) - \left[\mu^A A \frac{\partial U}{\partial A}(w,m,A) + \frac{1}{2}(\sigma^A A)^2 \frac{\partial^2 U}{\partial A^2}(w,m,A)\right].
\end{aligned}
$$

- Implications
  - Baseline implications still hold.
  - Heterogeneous responses to aggregate shocks constitute an additional consideration in agents' optimization.
  - Helps discover the on-chain wealth evolution, also staking v.s. inequality (On-going).

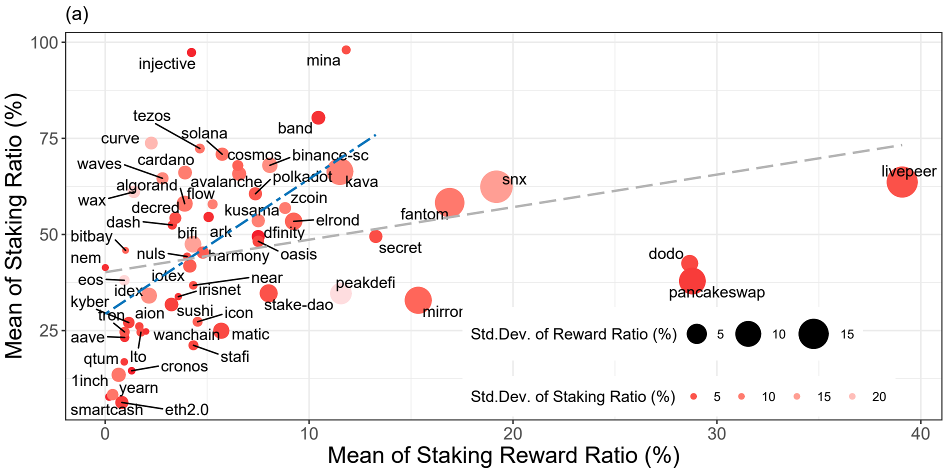
Empirical Evidence

Data

- 66 stakable tokens with largest market values, daily observations from stakingrewards.com.
- 80.35% of the total PoS cap; 97.88% of the total DeFi cap; 64.34% of the total crypto cap excluding BTC.
- July 2018-Nov 2022. overlaps with the initial birth and rapid growth of "staking", also the bear market in 2022.

Token	Reward Rate, r (%, Annual)		Staking Ratio, Θ (%)		Daily Return (%)		Token	Reward Rate, r (%, Annual)		Staking Ratio, Θ (%)		Daily Return (%)	
	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.		Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.
0x	0.60	0.29	2.78	0.27	0.80	6.58	kusama	14.09	0.78	52.09	9.62	0.17	5.95
1inch	3.25	5.97	8.08	9.11	−0.38	5.50	kyber	2.76	2.35	32.92	7.24	−0.18	5.93
aave	4.96	1.48	21.49	3.15	0.06	6.00	livepeer	63.81	31.30	63.60	4.74	−0.27	11.48
aion	6.65	1.76	26.05	3.35	0.17	6.72	lto	7.30	1.23	24.58	4.38	0.67	7.14
algorand	11.08	43.69	59.61	12.55	−0.09	5.76	matic	19.10	12.97	28.06	5.70	0.44	6.80
ark	9.30	0.52	54.56	1.42	−0.04	6.27	mina	11.96	1.44	97.77	5.96	−0.38	6.27
avalanche	9.68	1.82	64.45	7.47	0.15	6.80	mirror	40.28	37.59	25.40	10.46	−0.58	7.43
band	12.07	1.86	78.79	2.77	0.02	6.91	near	11.43	1.91	38.27	4.30	0.04	6.67
bifi	8.37	3.33	28.25	25.46	−0.18	6.46	nem	0.02	0.01	41.41	1.42	−0.16	4.78
binance-sc	9.58	5.37	74.36	12.10	0.03	3.93	neo	2.54	1.30			0.05	5.45
bitbay	2.25	0.53	45.89	6.81	0.96	19.71	nuls	9.18	0.98	44.22	4.09	0.17	6.89
cardano	5.50	2.12	67.58	9.13	0.10	5.36	oasis	13.24	3.30	50.71	3.87	−0.24	6.58
celo	6.48	0.49	6.03	4.52	2.72	13.10	olympus	56.18	42.30	51.26	16.79	−1.17	5.21
cosmos	11.10	3.26	67.07	6.20	0.04	6.13	osmosis	39.86	16.86	36.60	8.55	−0.74	5.49
cronos	12.78	2.58	15.92	1.92	−0.66	4.50	pancakeswap	75.39	26.50	29.38	12.87	−0.07	5.82
curve	2.53	1.80	77.88	19.38	−0.20	6.93	peakdefi	44.18	16.63	41.11	21.14	−0.45	5.36
dash	6.28	0.28	52.48	2.46	−0.09	5.62	polkadot	12.76	1.73	57.87	6.06	0.15	5.67
decred	6.70	1.99	56.55	5.87	0.01	5.01	qtum	5.68	0.88	16.85	2.50	0.09	5.26
dfinity	10.00	3.47	67.51	12.72	−0.64	4.93	secret	25.69	2.83	54.09	7.27	0.05	6.91
dodo	59.71	9.77	59.76	19.79	−0.66	5.95	smartcash	2.49	0.55	7.79	0.81	0.12	6.40
dydx	13.80	1.78	34.08	3.50	−0.46	6.54	snx	22.99	23.72	59.53	14.51	0.16	6.32
elrond	15.58	6.46	55.00	6.14	0.22	5.77	solana	7.23	2.64	72.50	7.18	0.07	6.25
eos	11.83	13.22	29.76	25.48	−0.08	5.08	stafi	20.10	2.80	21.67	2.75	−0.15	7.37
eth2.0	9.69	10.49	7.51	3.04	0.24	3.89	stake-dao	22.68	9.10	24.21	12.08	−0.39	7.10
fantom	29.40	27.47	55.87	9.44	0.26	8.31	sushi	11.93	9.99	30.15	3.04	−0.39	6.39
flow	8.73	0.90	54.85	7.36	−0.62	5.32	terra	8.66	3.60	26.86	12.89	−0.86	23.88
harmony	9.62	1.55	45.13	5.15	0.14	6.92	tezos	6.03	1.82	72.73	9.46	−0.04	5.63
icon	17.45	3.49	27.26	6.56	0.20	6.15	tron	3.87	1.24	27.77	8.37	0.09	4.65
idex	9.41	10.36	37.68	11.69	0.13	8.42	wanchain	8.12	0.57	24.75	1.67	0.19	6.24
injective	5.75	1.42	97.34	0.83	−0.41	6.25	waves	4.91	1.94	61.18	15.08	0.05	6.29
iotex	10.17	3.65	41.80	6.19	0.09	6.62	wax	2.55	2.11	67.66	21.14	0.00	5.78
irisnet	10.64	0.60	33.82	1.93	0.40	8.12	yearn	15.84	18.39	6.24	8.31	0.06	6.33
kava	20.86	17.18	61.81	12.50	0.10	6.06	zcoin	16.03	3.27	56.89	10.16	0.35	4.72

Staking Ratio Increases with Staking Reward Ratio (1)



Staking Ratio Increases with Staking Reward Ratio (2)

Table 2: Staking ratio with respect to the staking reward ratio.
This table tests the relationship between staking ratio, $\Theta_{i,t}$, and the aggregate staking reward ratio, $\rho_{i,t}$, in the same period. The coefficient of $\rho_{i,t}$ is significantly positive, which implies higher staking reward results in a higher staking ratio as Proposition 2 shows. The effect is robust under multiple tests, including controls (coin age, market value, volatility, the proxies of platform productivity and user type), fixed effects (token-specific, time, and token age), and different horizons (weekly and monthly). Robust standard errors clustered by token are reported in parentheses. ***,**,* indicate statistical significance at the 1%, 5% and 10% respectively.

	$StakingRatio_{i,t}$							
	7-day					30-day		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\rho_{i,t}$	0.779***	0.428***	0.452***	0.372***	0.453***	0.794***	0.436***	0.238***
	(0.030)	(0.027)	(0.029)	(0.032)	(0.040)	(0.065)	(0.066)	(0.051)
$\frac{1}{100}\log(Cap)_{i,t}$			3.519***	1.299***	5.199***		0.994	0.696
			(0.230)	(0.321)	(0.499)		(0.701)	(0.656)
$\frac{1}{100}Volatility_{i,t}$			−0.002	0.313***	0.517***		1.325	−0.176
			(0.075)	(0.105)	(0.172)		(1.145)	(1.148)
$a_{i,t}$				−0.022***	−0.049***		−0.021	−0.072***
				(0.006)	(0.005)		(0.013)	(0.014)
$whale_{i,t}$				0.195***	0.759***		0.149**	0.026
				(0.036)	(0.052)		(0.071)	(0.071)
$Y^0_{i,t}$				−0.059***			−0.024	
				(0.012)			(0.022)	
$Y^1_{i,t}$				−0.017**			−0.013	
				(0.008)			(0.015)	
Fixed Effects								
Token		Y	Y	Y	Y		Y	Y
Time		Y	Y	Y			Y	
Token Age					Y			Y
Observations	5,660	5,660	4,876	1,364	1,364	1,339	308	308
R^2	0.088	0.050	0.102	0.166	0.352	0.089	0.172	0.416

Staking Ratio Predicting Token Price Returns (1)

Table 4: Staking ratio and token prices.
This table presents the analysis of how the staking ratio predicts token price appreciation. The main independent is the staking ratio of the previous period, $StakingRatio_{i,t-1}$. The dependent $r_{price_{i,t}}$ is the log price change. The results show that the coefficient is significantly positive, which implies that a higher staking ratio will predict higher token price appreciation. Considering that there exists factor effects in the cryptocurrency market, we also add the market price return r_{MKTt}, the market cap term $\log(Cap)_{i,t-1}$, the network adoption term $\Delta Network_{i,t-1}$, the previous return $r_{price_{i,t-1}}$, and additional platform-relevant controls. After adding these controls, the estimated coefficient of staking ratio is still significant. We also do the test in different horizons and with fixed effects to show the robustness of the results. Robust standard errors clustered by token are reported in parentheses. ***,**,* indicate statistical significance at the 1%, 5% and 10% respectively.

	$r_{price_{i,t}}$								
	1-day			7-day			30-day		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$StakingRatio_{i,t-1}$	0.009***	0.032***	0.027***	0.066**	0.180***	0.170***	0.208*	0.416	0.403*
	(0.003)	(0.007)	(0.007)	(0.026)	(0.070)	(0.055)	(0.121)	(0.308)	(0.230)
r_{MKTt}	0.968***	1.029***		0.844***	0.700***		2.445***	2.257***	
	(0.008)	(0.014)		(0.074)	(0.143)		(0.386)	(0.552)	
$\log(Cap)_{i,t-1}$	−0.002***	−0.003***	−0.004***	−0.027***	−0.033***	−0.034***	−0.120***	−0.133***	−0.114***
	(0.000)	(0.001)	(0.001)	(0.005)	(0.006)	(0.008)	(0.026)	(0.026)	(0.031)
$r_{price_{i,t-1}}$		0.021**	0.028**		0.010	−0.051		0.137**	−0.064
		(0.009)	(0.012)		(0.029)	(0.032)		(0.062)	(0.068)
$\Delta Network_{i,t-1}$		0.168***	0.182***		0.189	0.289**		0.849	0.372
		(0.027)	(0.028)		(0.184)	(0.142)		(1.195)	(0.888)
$a_{i,t-1}$		0.004***	0.005***		0.033***	0.024***		0.050	0.039
		(0.001)	(0.001)		(0.010)	(0.008)		(0.048)	(0.039)
$StakingRatio_{i,t-1} \cdot Y^0{}_{i,t-1}$		−0.001	0.007		0.005	0.035		−0.444*	−0.001
		(0.005)	(0.005)		(0.047)	(0.037)		(0.258)	(0.203)
$StakingRatio_{i,t-1} \cdot Y^1{}_{i,t-1}$		−0.008**	−0.004		−0.039	−0.034		−0.199	−0.122
		(0.004)	(0.003)		(0.035)	(0.026)		(0.146)	(0.099)
Fixed Effects									
Token	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time			Y			Y			Y
Observations	41,544	10,887	10,887	5,872	1,530	1,530	1,347	334	334
R^2	0.266	0.345	0.009	0.036	0.043	0.028	0.092	0.164	0.075

Staking Ratio Predicting Token Price Returns (2)

	$r_{price\,i,t}$											
	Bull-Bear								PoS-DeFi			
	1-day				7-day				1-day		7-day	
	Bitcoin as Indicator		Ethereum as Indicator		Bitcoin as Indicator		Ethereum as Indicator					
	Bull	Bear	Bull	Bear	Bull	Bear	Bull	Bear	pan-PoS	DeFi	pan-PoS	DeFi
$\Theta_{i,t-1}$	0.045***	0.017*	0.034***	0.024**	0.331***	0.058	0.183**	0.148	0.035**	0.041***	0.216	0.253***
	(0.010)	(0.011)	(0.009)	(0.011)	(0.010)	(0.111)	(0.092)	(0.158)	(0.016)	(0.009)	(0.189)	(0.085)
$r_{MKT\,t}$	0.931***	1.126***	0.947***	1.118***	0.539***	0.667***	0.281	0.623**	1.008***	1.072***	0.883***	0.481**
	(0.050)	(0.041)	(0.044)	(0.047)	(0.050)	(0.173)	(0.246)	(0.247)	(0.043)	(0.044)	(0.216)	(0.189)
$\log(Cap)_{i,t-1}$	−0.002***	−0.004***	−0.003***	−0.003**	−0.027***	−0.048***	−0.029***	−0.013	−0.001**	−0.005***	−0.025***	−0.040***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.007)	(0.006)	(0.011)	(0.001)	(0.001)	(0.004)	(0.009)
$r_{price\,i,t-1}$	0.048	−0.017	0.019	0.019	−0.039	0.053	−0.016	−0.026	0.022	0.032	0.054**	−0.001
	(0.037)	(0.077)	(0.017)	(0.100)	(0.037)	(0.052)	(0.022)	(0.058)	(0.029)	(0.063)	(0.025)	(0.038)
$\Delta Network_{i,t-1}$	0.161***	0.190*	0.159***	0.213*	0.411***	−0.554	0.273	−0.309	0.133***	0.225**	0.123	0.404***
	(0.056)	(0.107)	(0.058)	(0.114)	(0.056)	(0.507)	(0.284)	(0.322)	(0.051)	(0.096)	(0.331)	(0.110)
$a_{i,t-1}$	0.004**	0.005***	0.004**	0.005*	0.038***	0.046***	0.036***	0.027*	0.004**	0.030**	0.034***	0.076
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.011)	(0.013)	(0.016)	(0.002)	(0.014)	(0.013)	(0.048)
$\Theta_{i,t-1} \cdot Y^0{}_{i,t-1}$	−0.000	−0.010	0.003	−0.006	0.008	−0.030	0.041	−0.001	0.006	−0.006	0.066	0.005
	(0.007)	(0.006)	(0.010)	(0.007)	(0.007)	(0.068)	(0.094)	(0.045)	(0.005)	(0.008)	(0.070)	(0.087)
$\Theta_{i,t-1} \cdot Y^1{}_{i,t-1}$	−0.009**	−0.011*	−0.009**	−0.006**	−0.084***	−0.025	−0.042	−0.065**	−0.004*	−0.011**	−0.021	−0.049
	(0.003)	(0.005)	(0.004)	(0.003)	(0.003)	(0.053)	(0.061)	(0.031)	(0.002)	(0.005)	(0.052)	(0.075)
Fixed Effects												
Token	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	6,305	4,582	6,777	4,110	859	671	957	573	5,959	6,758	835	951
R^2	0.255	0.443	0.268	0.395	0.034	0.054	0.032	0.020	0.387	0.323	0.059	0.037

UIP Violation

- UIP: $E_t[S_{t+1} - S_t] = i_t - i_t^*$
  - Test (Fama, 1984): If UIP holds, $\beta = 0$.

$$\lambda_{i,t+1} = \alpha + \beta(r_t^f - r_{i,t} + c_{i,t}) + \epsilon_{i,t+1},$$
$$\text{where } \lambda_{i,t} = \log P_{i,t+1} - \log P_{i,t} + (r_{i,t} - c_{i,t}) - r_t^f,$$

  - Empirically: $\beta < 0$ (Valchev, 2020, etc.), $\Rightarrow$ higher interest is associated with higher excess return.
- Result: $\beta < 0$ ($\simeq -1$) no matter what token is chosen as the local currency.

Local	Horizon: 7-day			Horizon: 30-day			Local	Horizon: 7-day			Horizon: 30-day		
Currency	Coef., β	Std. Err.	R^2	Coef., β	Std. Err.	R^2	Currency	Coef., β	Std. Err.	R^2	Coef., β	Std. Err.	R^2
Currency & mainstream cryptocurrencies.													
US Dollar	−1.02	(0.002)	0.18	−1.12	(0.030)	0.04	Ethereum	−1.04	(0.001)	0.20	−1.09	(0.016)	0.05
Bitcoin	−1.02	(0.001)	0.20	−1.08	(0.018)	0.05							
Cryptocurrencies in our sample.													
1inch	−0.92	(0.002)	0.27	−0.72	(0.025)	0.05	kyber	−1.03	(0.001)	0.13	−1.01	(0.007)	0.03
aave	−1.03	(0.001)	0.16	−1.14	(0.014)	0.04	livepeer	−0.92	(0.000)	0.38	−0.52	(0.003)	0.08
aion	−0.90	(0.010)	0.08	−0.24	(0.354)	0.00	lto	−0.95	(0.016)	0.06	−0.16	(0.107)	0.00
algorand	−1.00	(0.000)	0.39	−1.12	(0.017)	0.05	matic	−1.06	(0.000)	0.26	−1.12	(0.007)	0.08
ark	−1.00	(0.003)	0.15	−0.90	(0.037)	0.04	mina	−1.06	(0.001)	0.15	−0.39	(0.049)	0.01
avalanche	−1.13	(0.002)	0.17	−1.34	(0.037)	0.06	mirror	−0.99	(0.000)	0.64	−0.88	(0.001)	0.25
band	−1.01	(0.001)	0.16	−1.05	(0.016)	0.04	near	−1.10	(0.001)	0.17	−1.42	(0.025)	0.05

Crypto Carry & Predictability of Returns

- Carry (Koijen et.al., 2018):

$$\text{return} \equiv \text{carry} + \mathbb{E}[\text{price appreciation}] + \text{unexpected price shock.}$$

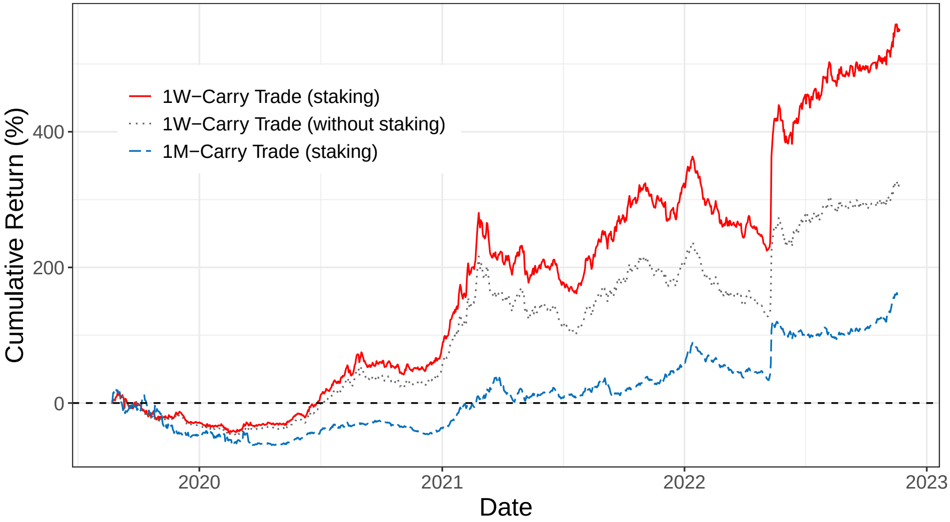
- Crypto carry (under CIP): $\text{carry}_t \equiv \frac{r_t - c_t - r^f}{1 + r^f}$.
- Return Predictability: $\text{ExcessReturn}_{i,t} = a_i + b_{t-1} + c\text{Carry}_{i,t-1} + \epsilon_{i,t}$.
- Carry trade portfolio: Long high carry & short low; long top 50%.

Table 7: Statistics of carry strategies.

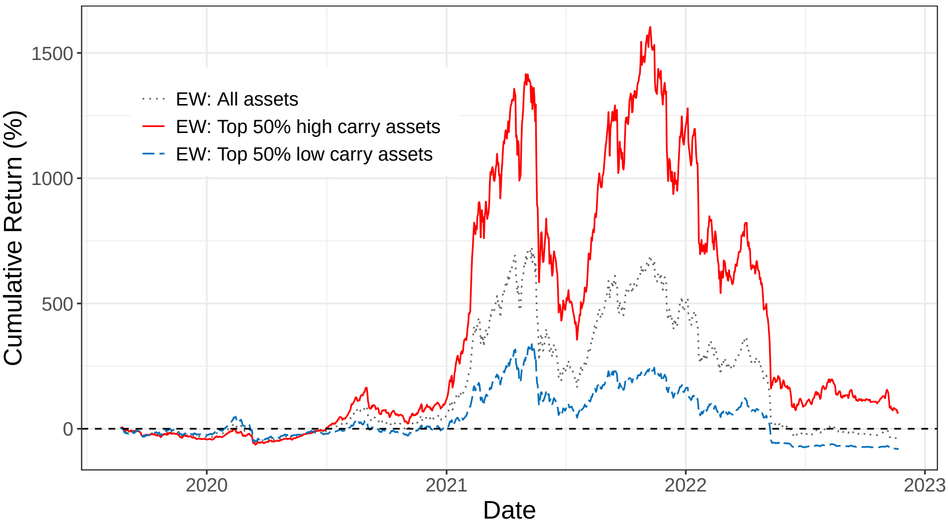
This table reports the statistics of three strategies. The first three rows report the results of the long-short carry strategy, which are corresponding to Figure 5. The rows below report long strategies, including equal-weighted benchmark, the strategy that long only top 50% high carry tokens with equal weight, and the strategy that long only top 50% low carry tokens with equal weight, which are corresponding to Figure 6. For each strategy, the annualized mean, standard deviations, skewness, kurtosis, maximum drawdown (MDD) and Sharpe ratio are reported.

Strategy	Mean (Annual, %)	St.dev. (Annual, %)	Skewness	Kurtosis	MDD (%)	Sharpe Ratio (Annual)
Long-short Strategy:						
1W-Carry Trade (Staking)	0.658	0.411	1.410	18.772	29.966	1.602
1W-Carry Trade (Non-staking)	0.525	0.411	1.404	18.719	35.920	1.277
1M-Carry Trade (Staking)	0.451	0.569	1.260	20.508	69.497	0.791
Long Strategy:						
EW All assets	0.156	0.782	−1.576	7.672	92.934	0.199
EW High Carry	0.494	0.813	−1.103	4.687	90.419	0.608
EW Low Carry	−0.164	0.804	−1.804	9.907	95.645	−0.204

Cumulative Returns of a Crypto Carry Strategy



Average Cumulative Returns of Top 50% High Carry Assets



Excess Return Predicted by Carry

- $ExcessReturn_{i,t} = a_i + b_{t-1} + cCarry_{i,t-1} + \epsilon_{i,t}$

Table 8: Carry and excess returns

This table reports the results from the panel regression of (48), estimated c and robust standard errors clustered by tokens are reported. Without token-specific and time fixed effects, c represents the total predictability of returns from carry from both its passive and dynamic components. Including crypto specific fixed effects will remove the predictable return component of carry coming from passive exposure to tokens with different unconditional average returns. Robust standard errors are reported in parentheses. ***,**,* indicate statistical significance at the 1%, 5% and 10% respectively.

Panel A: 7-day	$\text{ExcessReturn}_{i,t}$			
	(1)	(2)	(3)	(4)
$\text{Carry}_{i,t-1}$	0.956***	0.901***	0.968***	0.917***
	(0.028)	(0.043)	(0.025)	(0.039)
Fixed Effects				
Token		Y		Y
Time			Y	Y
Observations	5,745	5,745	5,745	5,745
R^2	0.230	0.100	0.289	0.130
Panel B: 30-day	$\text{ExcessReturn}_{i,t}$			
	(1)	(2)	(3)	(4)
$\text{Carry}_{i,t-1}$	0.968***	0.773***	1.009***	0.846***
	(0.166)	(0.253)	(0.138)	(0.218)
Fixed Effects				
Token		Y		Y
Time			Y	Y
Observations	1,301	1,301	1,301	1,301
R^2	0.038	0.011	0.056	0.018

Further Discussion & Conclusion

Conclusion

- Further discussions:
  - Long-run fees and transformation from platform token to security token.
  - Network security level $L_t P_t$.
  - Wealth distribution: from on-chain to total wealth.

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- Staking Ratio as reflection of consensus mechanisms operation:
  Dynamic Token Valuation.
- Implication as a hybrid asset & comparison with classical assets:
  UIP Violation and Crypto Carry.
- Emerging, economically intriguing, practically relevant, & exciting.

Staking, Token Pricing, and Crypto Carry

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