Towards an Optimal Staking Design: Balancing Security, User Growth, and Token Appreciation

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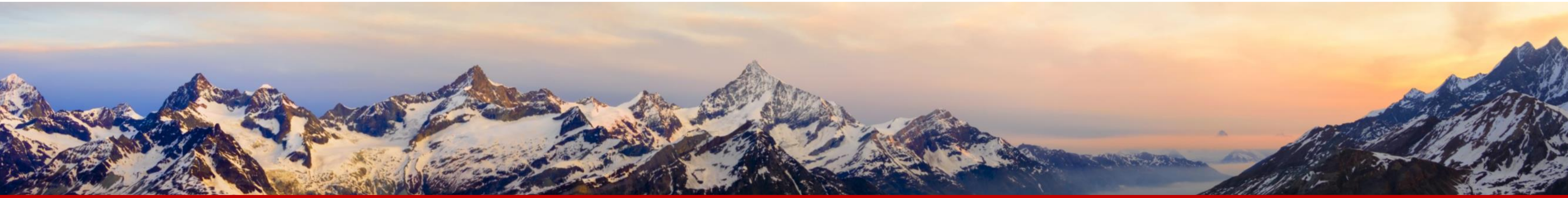

Overview

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Research Question

How do staking design choices vary across Proof-of-Stake blockchains and how do these affect the trade-offs between economic security, promoting user growth, and token value?

Methods

- Qualitative Analysis:
  - Comparative analysis of common staking design parameters across popular POS blockchains
  - Discussion of trade-offs associated with staking design choices, in particular the trade-off between *static* and *dynamic* security
- Empirical Analysis:
  - Preliminary panel data analysis estimating the relationship between various staking design parameters and staking outcomes

Results

- Strategic divergence among blockchains in terms of static and dynamic security measures
- The preliminary empirical analysis lends tentative support to the intuitions developed in the paper, further analysis is needed

Overview

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1. Introduction

Literatur Review

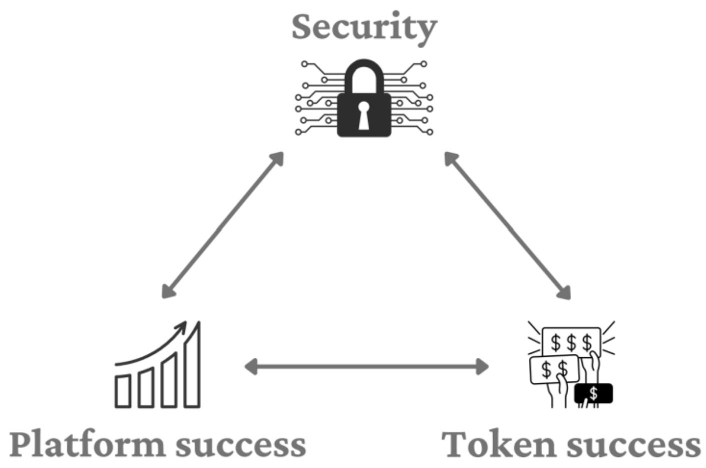
- **Comparative description** of different POS consensus mechanisms (e.g. Saleh (2020), Schaaf et al. (2021))
- Analysis of different types of **security threats**:
  - 51% attacks (Huang et al. (2021), Pierro and Tonelli (2022))
  - Double spending (Iqbal (2021), Karpinski et al. (2021))
  - Asset centralization (Kogan et al. (2023), Sai et al. (2021), Irresberger et al. (2020))
- **Analysis of various aspects of staking design**:
  - On-chain lending (Chitra (2021))
  - Staking rewards (Kose et al. (2021))
  - Delegation pools (Gersbach et al. (2022))
  - Liquid staking (Gogol et al. (2024))
  - Interplay between staking, token prices, and reward rates (Cong et al. (2022))
- **Comparative analysis of openness** of different POS consensus mechanisms (Noh et al. (2023))

1. Introduction

The Economics of Staking

- Designers of POS mechanisms aim to incentivize validators, users, and in some cases investors to join the platform.
- In doing so, they generally follow three goals:
  - **Improve economic security → high staking volume**
    While marginal gains to security may be decreasing, more value locked in the protocol makes it more secure
  - **Increase growth → ecosystem development and low fees**
    To create an ecosystem that is attractive and cost-effective for users, the platform can invest in development, marketing, and - if possible - ask for low transaction fees
  - **Promote token success → low levels of inflation**
    Inflation dilutes the rewards that stakers receive and drives down token prices. Thus, POS mechanism designers may want to aim for low inflation

The Staking Trilemma



Source: Center for Cryptoeconomics

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2. Qualitative Analysis

Overview of Selected Staking Design Parameters

- While facing the previously described trade-offs, POS designers set a mix of policy parameters
- The design space for POS consensus mechanisms is large and includes many possible parameters
- However, some are common across POS blockchains. These include
  - the validator reward rate,
  - the inflation rate (growth rate of the token supply),
  - slashing penalties with varying degrees of severity,
  - minimum staking amounts,
  - minimum staking periods.

Comparison of Selected Staking Parameter Choices

Blockchain	Average Reward Rate (pct.)	Average Inflation Rate (pct.)	Minimum Staking Period (days)	Minimum Staking Amount[a]	Slashing
Algorand	8.5	2.5	0	0.1 ALGO (0.06 USD)	Reduced rewards
Avalanche	8.4	5.8	14	25 AVAX (7.44 USD)	Reduced rewards
Cardano	3.8	3.3	0	0	Reduced rewards
Cosmos	18.9	14	14	0	Collateral slashing
Ethereum	4.5	0.1	0	32 ETH (615 USD)	Collateral slashing
Solana	6.3	7.3	2-3[b]	0	Collateral slashing
Polkadot	14.3	7.4	28	1 DOT (0.09 USD)	Collateral slashing

[a] Average USD value of minimum staking amount between 2021-2023
[b] Solana minimum duration is 1 epoch, which is roughly 2-3 days

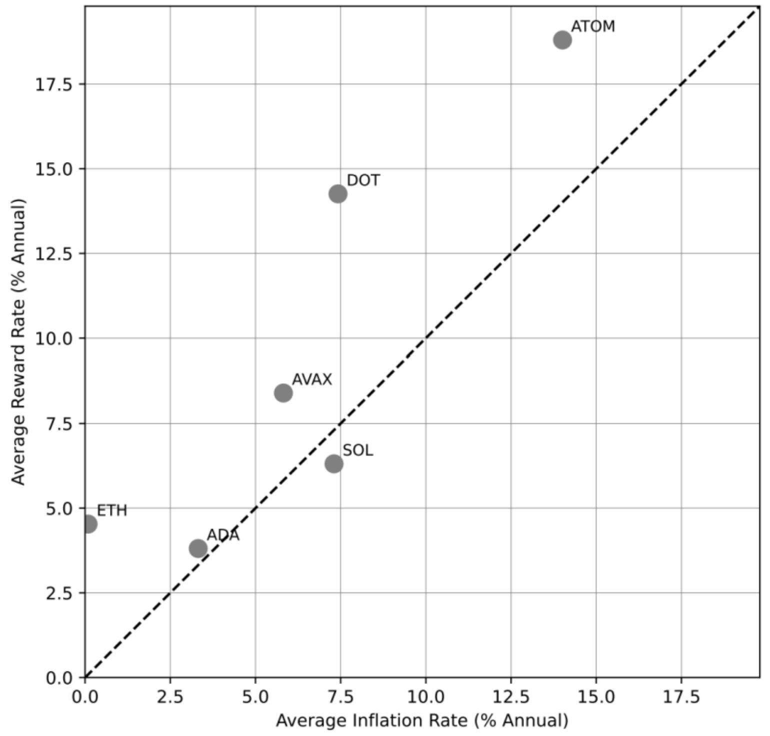
Source: Information compiled by the Center for Cryptoeconomics from various sources (see paper for more detail)

2. Qualitative Analysis

Staking Rewards

- Trade-offs among three key factors:
  - **Static security:** Higher staking rewards → Incentive for existing validators to honestly participate in the consensus mechanism → Increase in the **quality of the validator set**
  - **Dynamic security:** Higher staking rewards → Incentive for new validators to join the ecosystem → **Larger validator set** and staking pool, thereby improving the security of the consensus mechanism
  - **Token success:**
    - Higher staking rewards → Increased demand for staking → Lower circulating supply and higher token prices
    - Higher staking rewards → Increased issuance → Inflation lower token prices

Reward Rate vs Inflation Rate, 2021-2023



Source: own figure based on data from www.stakingrewards.com

2. Qualitative Analysis

Minimum Staking Amount

- The minimum staking amounts may influence POS-blockchains along two dimensions:
  - **Static security:** Higher minimum staking requirements → More skin in the game → Improved quality of existing validator set
  - **Dynamic security:** Lower minimum staking requirements for validators → Lower entry barriers for new validators → Larger validator set and staking pool

- An increase in the minimum staking amount potentially improves the static security but decreases the dynamic security of the consensus mechanism.

Minimum Staking Amounts

Blockchain	Minimum Staking Amount[a]
Algorand	0.1 ALGO (0.06 USD)
Avalanche	25 AVAX (7.44 USD)
Cardano	0
Cosmos	0
Ethereum	32 ETH (615 USD)
Solana	0
Polkadot	1 DOT (0.09 USD)

2. Qualitative Analysis

Minimum Staking Duration

- The minimum staking duration may influence POS-blockchains again along two dimensions of static and dynamic security:
  - **Static security:** Longer lock-up periods → Increase in the level of commitment validators have to the protocol (reputation damages become more costly, etc.) → Improved quality of existing validator set (also reduced "bank-run" risk)
  - **Dynamic security:** Longer lock-up periods → Higher token price risk, reduced transaction and consumption convenience on the network → Higher entry barriers for new validators → Larger validator set and staking pool

- As with the minimum staking amount, higher minimum staking periods may increase static security but reduce dynamic security.

Minimum Staking Durations

Blockchain	Minimum Staking Period (days)
Algorand	0
Avalanche	14
Cardano	0
Cosmos	14
Ethereum	0
Solana	2-3[b]
Polkadot	28

2. Qualitative Analysis

Slashing Penalties

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- Slashing policies can again be evaluated in terms of the trade-off between static security and dynamic security:
  - **Static security:** Severe slashing penalties → Financial losses to malicious actors → Quality of existing validator set increases → Given a static set of validators, slashing increases the security of the protocol
  - **Dynamic security:** Severe slashing penalties → Potential risk even to honest validators (downtime penalties, etc.) → Higher barriers to entry for potential new validators wishing to join the platform.

- As a result, slashing may improve static security and but have a negative effect on dynamic security.

Slashing Penalties

Blockchain	Slashing
Algorand	Reduced rewards
Avalanche	Reduced rewards
Cardano	Reduced rewards
Cosmos	Collateral slashing
Ethereum	Collateral slashing
Solana	Collateral slashing
Polkadot	Collateral slashing

3. Empirical Analysis

Data and Model

Model

- Random-effects model with the following specification:

$$\Delta SR_{i,t} = \beta_0 + \beta_1 r_{i,t-1} + \beta_2 \pi_{i,t-1} + \beta_3 r_{i,t-1}\pi_{i,t-1} + \beta_4 MA_{i,t-1} + \beta_5 MD_{i,t-1} + \beta_5 SD_{i,t-1} + \gamma \boldsymbol{X} + \varepsilon_{i,t-1}$$

- $\boldsymbol{SR_{i,t}}$: Staking ratio for blockchain i in week t
- $\boldsymbol{r_{i,t-1}}$: Nominal reward rate (p.a.) for blockchain i in week $t-1$
- $\boldsymbol{\pi_{i,t-1}}$: Inflation rate (p.a.) for blockchain i in week $t-1$
- $\boldsymbol{MA_{i,t-1}}$: Minimum staking amount for blockchain i in week $t-1$
- $\boldsymbol{MD_{i,t-1}}$: Minimum staking duration for blockchain i in week $t-1$
- $\boldsymbol{SD_{i,t-1}}$: Collateral slashing dummy for blockchain i in week $t-1$
- $\boldsymbol{X}$: Controls for market return of native token, price volatility of native token, market capitalization of native token, weekly trading volume, and market return of BTC, as well as the staking ratio in week $t-1$

Data

- Obtained from *stakingrewards.com*
- Daily observations from 1 January 2022 to 31 December 2023
- Sample Ethereum, Solana, Polkadot, Cardano, Avalanche, and Cosmos blockchains
- Aggregated to weekly averages
- Sample size: 550 observations

3. Empirical Analysis

Results

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Table 2. Change in staking ratio $SR_{i,t}$ with respect to staking design parameters

	$\Delta SR_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
$r_{i,t-1}$	0.006	0.090	0.077	0.042	0.044
	(0.018)	(0.076)	(0.053)	(0.049)	(0.048)
$\pi_{i,t-1}$	-0.039	0.181*	0.240*	0.211	0.211
	(0.057)	(0.108)	(0.125)	(0.134)	(0.133)
$r_{i,t-1}\pi_{i,t-1}$	0.002	-0.006	-0.006	-0.004	-0.004
	(0.002)	(0.005)	(0.004)	(0.005)	(0.005)
$MD_{i,t-1}$		-0.080	-0.077*	-0.073*	-0.073*
		(0.048)	(0.042)	(0.040)	(0.040)
$SD_{i,t-1}$		-0.166	-0.284**	-0.243*	-0.245*
		(0.108)	(0.129)	(0.136)	(0.133)
$MA_{i,t-1}$		-0.004	-0.005*	-0.006**	-0.006**
		(0.003)	(0.003)	(0.003)	(0.003)
$SR_{i,t-1}$	-0.003	-0.071*	-0.077*	-0.082**	-0.082**
	(0.004)	(0.040)	(0.041)	(0.039)	(0.038)
$r_{PRICE,i,t-1}$			0.006	0.004	0.002
			(0.004)	(0.005)	(0.008)
$Vol_{i,t-1}$			-0.001	-0.003	-0.003
			(0.002)	(0.003)	(0.003)
$log(Cap)_{i,t-1}$			0.187**	0.050	0.043
			(0.092)	(0.139)	(0.144)
$log(Volume)_{i,t-1}$				0.138	0.150
				(0.090)	(0.098)
$r_{BTC,i,t-1}$					0.005
					(0.008)
N	550	482	482	482	482
Overall R^2	0.009	0.040	0.048	0.050	0.050

Note: Clustered standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. $SR_{i,t-1}$ refers to the average staking ratio in week $t-1$, $r_{i,t-1}$ to the average staking reward rate per annum in week $t-1$, $\pi_{i,t-1}$ to the average inflation rate per annum in week $t-1$, $MD_{i,t-1}$ to the minimum staking duration in week $t-1$, $SD_{i,t-1}$ is a dummy variable for whether the protocol includes collateral slashing in week $t-1$, $MA_{i,t-1}$ is the average minimum staking amount in USD in week $t-1$, $r_{PRICE,i,t-1}$ the weekly return on the token price in week $t-1$. $Vol_{i,t-1}$ represents the volatility of the token price in week $t-1$, $log(Cap)_{i,t-1}$ the logarithm of the tokens market capitalization in week $t-1$, and $log(Volume)_{i,t-1}$ the respective weekly trading volume of the token in week $t-1$. Finally, $r_{BTC,i,t-1}$ refers to the weekly market return of Bitcoin in week $t-1$.

- In general, results should be seen as preliminary and interpreted with caution
- However, some point estimates are statistically significant at the 5% confidence level and confirm the previously outlined intuition
    - An increase in the minimum staking amount is associated with a decline in the staking ratio in the following week, holding everything else constant

4. Discussion

- The paper highlights a **strategic divergence among blockchain networks** in terms of static and dynamic security measures.
- Blockchains can focus either on improving the quality of the validator set for **static security** or expanding the set of validators for **dynamic security**.
  - Solana, Algorand, and Cardano prioritize dynamic security with low or no slashing and minimal staking requirements.
  - Ethereum, Polkadot, and Cosmos take a static security approach with stricter staking requirements.
  - Avalanche is an exception to this rule.
- The preliminary **empirical analysis lends tentative support** to intuition behind the trade-off between static and dynamic security.
- Overall, we conclude that there is **no single best staking design**, it depends on the specific strategies followed by the blockchains.
- Further empirical research including other measures validator quality (e.g. uptime) as well as measures for decentralization could be useful.

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