Solana Validator Economics: A Primer

Introduction

One of Solana's main value propositions is its extremely low fees. Fees on Solana consist of a base fee and a priority fee. Currently, the base fee is set to 0.000005 SOL per signature with an optional priority fee that increases the likelihood of transaction inclusion within a given block.

The natural question arises of how this fee structure can support a validator set without outside subsidies. In this piece, we break down the economics of validators on Solana for standard, non-archival nodes. While useful tools that detail the potential profit of validators have emerged, they often fail to explain or take into consideration all relevant costs. This article aims to provide a global viewpoint on Solana's validator set rather than offering an analysis of a specific validator's cost structures. Individual validators may be participating in additional out-of-protocol deals or offloading risk in a non-transparent manner.

We also consider out-of-protocol rewards validators can opt into. For example, validators running theJito-Solana client receive additional MEV rewards. However, we do not consider or attempt to quantify other bespoke off-chain arrangements that may affect a validator's profitability, such as internalized order flow markets.

Costs

The primary expense structure of a validator consists of three components:

- Hardware
- Operations (ingress/egress, on-chain voting)
- Opportunity cost of capital and resources

Solana has long been criticized for having extremely high node requirements, preventing its quest for decentralization and credible neutrality. We aim to demystify the actual cost structure for validators without offering a normative viewpoint.

Hardware (Fixed Cost)

One of the highest costs for a validator is hardware - a fixed cost that a validator must pay per month or amortize over a period of time if purchasing hardware off the shelf.

One popular offering that ~14% of Solana validators use is Latitude's bare metal offering, which starts at $350/month. Latitude's c3 large costs anywhere between $370-$470 per month, depending on the region, with the following specifications (not including data egress costs):

Validators should adhere to the following guidelines for managing their hardware, as outlined on Solana's website:

Actual costs vary heavily by region, amongst other factors, making it challenging to estimate. It is important to note that most validators do not manage their own hardware, utilizing dedicated bare metal servers such as Latitude. The Solana Foundation has made long-term deals with other data centers for guaranteed rack availability and month-to-month contracts.

Operations (Variable Cost)

Validators incur two main ongoing costs when running a validator:

- On-chain voting (required for participating in consensus)
- Data bandwidth (ingress/egress)

On-Chain Voting

Solana conducts voting on-chain for consensus, and these vote transactions incur the same fees as any other transaction on the network. Depending on the price of SOL, the fees associated with voting transactions can become the main operational cost for a validator. This is likely a validator's highest cost at a high SOL price. In each epoch (432,000 slots), validators need to vote, and each voting transaction is priced at 0.000005 SOL (voting is privileged; there is no associated priority fee). This amounts to a total of ~2-3 SOL each epoch. Given that an epoch typically spans 2 to 3 days (generally closer to 2 days), the annual cost for voting transactions is ~300-350 SOL, translating to ~1 SOL per day.

Data Bandwidth

The Solana documentation recommends a minimum of a 1GB download/upload speed to maximize data throughput and

minimize a validator's skip rate. Bandwidth is often priced as a variable cost, but the specifics would depend on one's internet service provider.

Like most providers, Latitude does not charge for any marginal ingress cost. Instead, they charge per TB on egress on the order of $0.64 - $3.60 per TB, depending on the region.

By comparison, AWS egress costs can be over $70 per TB, depending on the area and usage.

Estimating egress data bandwidth cost is also dependent on the amount of stake.

This is because higher stake weight equates to being the slot leader more often, which results in more data to propagate (Turbine) and more transactions to forward to future leaders.

Opportunity Cost of Capital and Resources

While much of a validator's burn rate consists of voting costs and server rental, one cost not normally considered is the opportunity cost of capital. When staking, a validator is, by definition, locking up capital to secure the network. In doing so, they are forgoing any other rewards (inside or outside the crypto ecosystem). From a purely economic point of view, other relevant metrics to consider include the risk-free rate on the US dollar (~4% at the time of writing) and other crypto networks' staking APYs.

Additionally, operating a validator requires time and resources. Especially as one's stake grows, it is important to monitor the uptime and skip rate of one's validator to ensure it continues to be performant. This is often a time-consuming process that is the equivalent of an individual's or multiple individuals' full-time occupation, at least for the core vocal individuals who are contributing to the ecosystem.

Income

A validator's income consists of three primary sources:

- Inflation commission
- Block rewards
- MEV

Inflation Commission

The reward a validator receives is its commission on inflation. Validators participating in consensus receive rewards (in SOL) to incentivize participation. These rewards are paid via inflation. Inflation increases the total outstanding token supply and issues these newly minted tokens to validators.

Validators receive rewards at the end of each Solana epoch. These rewards are a commission on the annual inflation rate, calculated based on several factors:

1. Global Inflation Rate

: Solana defines a predetermined formula to calculate the amount of inflationary rewards per epoch. Determined by Solana's pre-set disinflationary issuance schedule, this rate is crucial for incentivizing early network participation and ensuring monetary stability and security.

1. Stake Percentage

: The fraction of total SOL staked compared to the circulating supply directly impacts the rewards. The greater the stake, the higher the potential rewards.

1. Commission Rate

: Charged by validator-clients, this fee is part of their income for maintaining the network. It is charged as a percentage of the total inflation rewards directed to their validator.

1. Validator Participation

: This includes the uptime and the percentage of slots in which the validator successfully voted, affecting their overall earnings.

Solana's inflation mechanism is designed to reduce over time, starting with an initial rate of 7-9%, a disinflation rate of -14-16%, and eventually stabilizing at a long-term rate of 1-2%. This schedule is intended to balance early network growth with long-term stability.

The impact of these factors on the Solana economy can be simulated using various scenarios. For instance, by assuming an

initial inflation rate of 8%, a disinflation rate of -15%, and a long-term rate of 1.5%, we can project token issuance over time and estimate staking yields based on different percentages of total SOL staked. Commonly, the staking percentages range between 60% and 90%, reflecting the community's engagement and parallels with other Proof-of-Stake protocols.

However, these projections do not account for variables like validator uptime, commissions, yield throttling, or potential slashing incidents. Moreover, the percentage of SOL staked is dynamic, influenced by the economic incentives set by the inflation schedule.

Staking can become a confusing topic quickly, but it is vital to remember that the net effect of inflation, and the common staking regime in PoS networks, is that it is a transfer from non-stakers to stakers.

Staking lowers float (i.e., outstanding token supply), locking tokens into the protocol. At the logical extreme, inflation requires absolute participation. This incentivizes liquid staking tokens (LSTs) for participation and capital efficiency, which one should expect to gain additional adoption on Solana.

Inflationary monetary policies are not inherently bad; rather, they aim to subsidize security today and extend credit toward future demand to offset today's cost. Inflation can be understood as crypto's version of attempting to uncorrelate economic security from financial cycles (demand for blockspace).

Block Rewards

Validators assigned as the leader of a given block receive additional rewards in the form of block rewards. These block rewards consist of 50% of the base fee and 50% of the priority fees (the other half are burned).

Umbra Research

Recent spikes in usage have led to increased priority fees – half of which goes to the leader:

Dune

Solana’s current fee structure, where 50% of a transaction fee is retained by the leader (the validator processing the transaction) and the remaining 50% is destroyed, is well understood by the community as not incentive-compatible. Under this system, a sender is motivated to form an out-of-protocol agreement with the leader to pay the priority fee outside the network (to avoid the burn).

It is important to note that most of a validator’s income comes from the inflation commission, not block rewards. Consequently, the financial benefit of engaging in such side deals today is relatively modest.

A prevalent example of this arrangement is seen in the use of Jito auctions by validators running the Jito-Solana client. This approach alters the continuous block-building process of Solana’s standard protocol by implementing blockspace auctions during the initial phase of their assigned slots.

MEV

MEV, or “Maximal Extractable Value”, refers to a validator’s profit that can be made via their ability to arbitrarily include, exclude, or reorder transactions within the blocks they produce. On Solana, validators assigned leaders have complete control over block packing and scheduling (though many today validators run unmodified forks of the Solana Labs or Jito-Solana client). Validators have incentives to include transactions relayed to them via RPCs and other validators for inclusion in the form of priority fees. Still, there is no stringent requirement for a validator to include those transactions.

Although the landscape of MEV on Solana is rapidly changing, many negative externalities of MEV impact the broader ecosystem. 58% of all compute is wasted by failed arbitrages:

Jito

However, when the leader of a block is running the Jito-Solana client, MEV can be extracted more efficiently. Searchers can send bundles to the leader for block inclusion via an off-chain auction mechanism. This auction generally encompasses the first 200ms of a given slot:

Due to the competition being based on price rather than speed, a larger portion of the extractable value must be offered in the bundle auction; all the tips from the bundle are allocated to the leader (and passed down to the stakers).

Validators can also vertically integrate and extract MEV by reordering transactions and capturing MEV opportunities themselves. While there is little evidence that this is happening at scale today, the incentive for this behavior is increasing as more retail activity comes to Solana.

The MEV landscape on Solana is rapidly changing and maturing – over 2 million bundles and 8,500 SOL going through Jito over the past week:

Jito

The MEV landscape on Solana is relatively small compared to Ethereum. However, as more individuals use Solana and activity increases, more MEV opportunities will arise, leading to increased income for validators.

Solana Foundation Delegation Program

Becoming a validator and participating in consensus is a permissionless system. However, because of the associated costs, the Solana Foundation has set up a program called the Solana Foundation Delegation Program (SFDP) to assist with offsetting some of the initial validation costs.

The delegation program is currently going through some changes. The revised program aims to provide more substantial support to validators in their initial stages, gradually decreasing over time as they become self-sufficient. This approach encourages validators to attract external staking and maintain high-performance standards. Additionally, the delegation program aims to improve decentralization and prioritizes validators not running on popular offerings, including Latitude, AWS, and Terraswitch.

Under the new system, the Solana Foundation will cover the voting costs of validators for the first year, with a phased reduction: 100% for the first three months, then 75%, 50%, and 25% in subsequent quarters, ceasing after 12 months. This tapered support intends to assist new or small validators with initial costs while motivating them to secure sustainable stake levels.

Additionally, the SFDP is the matching of external stakes at a 1:1 ratio, up to a 100,000 SOL cap from the Foundation. This policy reinforces community-driven staking decisions and incentivizes validators to engage with the broader Solana community. For instance, a validator with 10,000 SOL in external stake will receive an equivalent match from the Foundation, doubling their total stake. Validators with substantial external stake, like 250,000 SOL, will receive the maximum 100,000 SOL match. Performance criteria have also been updated to include baseline requirements and an acceptable skip rate, calculated over a longer period to minimize variance for validators with fewer leader slots in an epoch.

The SFDP will also allocate a base amount of SOL of around 40,000 SOL per participant initially (i.e., approximately the amount of SOL required to break even) from the Foundation's remaining stake after matching. This base delegation is essential for validators to participate in block production. Over time, as more stake gets matched and more Foundation stake is deposited into stake pools, this base amount will decrease. The Foundation also focuses on bolstering the liquid staking ecosystem by depositing stake into stake pools, thus supporting community network orientation.

These SFDP changes, targeting a rollout in late January or early February 2024, aim to uplift the quality and reliability of validators within the Solana network. It's important to note that participation in the SFDP is not mandatory for running a validator on Solana, as the validator set remains permissionless. The majority of successful "community" validators do not have Foundation-delegated stake.

Additional Considerations and Conclusion

Thus far, this post has outlined the revenue and cost structure of validators on Solana in its current state. Well-performing validators must keep up with the latest technical developments and updates on Solana.

Here are some considerations as to what validators today are beginning to consider:

- Most of the transactions on-chain today are spam. What happens if/when the scheduler is deterministic and block packing becomes more efficient?
- Is long-term staking, where stakers with longer time horizons get higher APYs, on the horizon and how might this interact with their individual risk profile?
- Which aspects of their operations, if any, will change when Solana implements programmatic slashing? How might this change not only their behavior but also the behavior of other validators?
- Once Firedancer is implemented, how will that affect their economics? Will all validators run the Firedancer client as the primary client, with the Labs/Jito client as a backup? Will there be a Jito-Firedancer fork?

In this post, we've explored some of the basic mechanisms that underlie the core economics of Solana. This likely reflects the state of validators today, but the landscape is rapidly changing. Validators should consider future upgrades and their implications, including but not limited to deterministic scheduling, long-term staking incentives, programmatic slashing, and the introduction of new clients like Firedancer.

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