

An Economic Model of the L1-L2 Interaction^{*}

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Abstract

We provide an economic model of the interaction between a Layer-1 (L1) blockchain and an associated Layer-2 (L2). Our main finding is that, even when the L1 blockchain features value-creating decentralized applications (dApps), there nevertheless exist realistic conditions such that both the L1 blockchain investment and the L1 cryptoasset market value vanish over time. These results arise when the L2 becomes sufficiently attractive for investment relative to the L1, a situation that would occur if developers focus exclusively on improving the L2s while ignoring the L1. Crucially, our results establish that, even if the L2s are intended as the primary vehicle for scaling, developers must nevertheless continue to improve the L1 to avoid an adverse outcome for the L1.

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1 Introduction

Layer-1 (L1) blockchain networks face significant scalability challenges, which have led to the development and adoption of Layer-2 (L2) solutions as a prominent approach to address these issues (John et al., 2025c). In particular, various L2s have emerged in the Ethereum ecosystem, and currently the majority of Ethereum’s transaction activity has moved to these L2 networks.¹ Given this shift, it is crucial to understand the interactions between L1 and L2 systems. However, the existing literature lacks a comprehensive framework for analyzing these interactions. This paper seeks to address this gap by providing a structured approach to studying the dynamics between L1 and L2 networks.

We study a setting in which both an L1 chain and an associated L2 chain support the deployment of decentralized applications (dApps) that create economic value. Our framework captures the idea that dApps generate more economic value, i.e., become more useful, with greater dApp investment. For example, Decentralized Exchanges (DEXs) create economic value by providing liquidity at low cost, and this value created increases with the DEX investment level because higher investment results in greater liquidity at lower transaction costs (Lehar and Parlour, 2025; Capponi and Jia, 2025; Hasbrouck et al., 2022).

A key feature within our framework is that the economic value created by dApps on one layer depends not only on the dApp investment on this layer, but also on the dApp investment from the other layer. Although our framework allows for general interactions, we focus on a negative externality of L2 dApp investment upon L1 dApp economic value. This externality arises because L2 dApps compete with L1 dApps and, therefore, can drive activity away from L1 to L2. For example, a particular DEX can be deployed both on an L1 chain and on the supporting L2s. In such a case, the L2 version of the DEX will compete with the L1 version, reducing the trading activity on the L1 and thus also reducing the economic value generated on the L1.

In our framework, as in practice, part of the economic value created by dApps is captured by dApp investors. Moreover, investors decide whether to invest based on the payoffs they accrue from investments and thus we determine L1 dApp investment and L2 dApp investment

¹In February 2025, the average daily number of transactions conducted on Ethereum L1 was 1.25 million while it was 18.36 million on associated L2s. See <https://l2beat.com/scaling/activity>.

endogenously. Additionally, we model an L1 chain that operates a Proof-of-Stake (PoS) protocol (Saleh, 2021; John et al., 2025a). Thus, investors also have the option to invest in *staking* which is a service that provides security for both the L1 and L2 chains. The payoffs to staking are funded by an inflationary transfer from holders of the L1 cryptoasset. Combining all pieces together, we are able to characterize the equilibrium L1 staking and the equilibrium prices of L1 and L2 cryptoassets.

Our primary finding, established by Proposition 2, is that the existence of L2 can undermine L1 dApp investment. We show that if the productivity of an L2, a process that measures technological capacity or attractiveness of the L2 chain, grows sufficiently faster than L1 productivity, then L1 dApp investment vanishes with time (see Corollary 1). Importantly, we show that this adverse outcome for L1 can be completely avoided as long as L1 productivity growth is not too far below L2 productivity growth. In such a case, the L1 investment grows along with the L2 investment over time (Proposition 3). Thus, our results establish that L2s need not be detrimental for L1 and that continued technological development of L1 could enable both layers to thrive simultaneously. This outcome is in contrast to the case where L1 development is abandoned and as a result L1 dApp investment collapses.

Within our analysis, L1 dApp investment underpins L1 cryptoasset market value. This connection is important because the security of modern PoS blockchains requires a sufficiently high market value of their native cryptoasset (Saleh, 2021; John et al., 2025b). As a consequence, the security of L1 depends on the L1 dApp investment. Our results thus suggest that, in the current design, the existence and success of L2s could become a fundamental security issue for L1 blockchains if L1 becomes sufficiently unattractive for dApps relative to L2s. As L2s become increasingly popular, an important message from our work is that L1 developer efforts should not only be focused on improving L2 experience (e.g., EIP-4844) but rather also ensure that L1 user experience does not significantly fall behind.

It is important to recognize that the erosion of L1 security would ultimately become a problem for associated L2s as well, because their security inherently depends on L1 security. However, this dependence on L1 security is not internalized within the current design of L2s. While the value generated on the L1 reinforces L1 security, the value generated on the L2 does not. Currently, the only pathway for the value created on L2s to flow to L1 is through

transaction fees but the fees are set at a low level purposefully to make L2s attractive in the first place. In fact, the recent upgrade EIP-4844 *lowered* fees for L2 users and thereby reduced the value transfer from L2 to L1 even more. Ultimately, the solution to the problem that we describe could entail an introduction of a mechanism that would properly internalize the benefits of L1 security to L2 users. Rather than speculating regarding such a mechanism, we leave this point of inquiry for future work.

Our work contributes to the growing literature on blockchain and decentralized finance (see [John et al. 2022](#), [John et al. 2023](#) and [John and Saleh 2025](#) for overviews). While the literature has focused primarily on L1 blockchains, our work also incorporates L2s and studies the economic interaction between L1 and L2. Prior economics studies of L2s include [Chemaya and Liu \(2022\)](#), [Li \(2023\)](#), [Mamagishvili and Felten \(2023\)](#), [Guasoni et al. \(2024a\)](#) and [Guasoni et al. \(2024b\)](#). [Chemaya and Liu \(2022\)](#) leverage the existence of L2s to empirically identify the extent to which blockchain users value security. [Li \(2023\)](#) and [Mamagishvili and Felten \(2023\)](#) study a specific aspect of L2 security detached from the underlying L1 blockchain.²

The remainder of the paper is organized as follows. We introduce the setup of the model in Section 2. The equilibrium of the model is presented in Section 3. Our main result is derived in Section 4. Section 5 discusses our results and provides guidance for blockchain development. Some concluding remarks are offered in Section 6. We provide proofs to the propositions in the Appendix.

2 Model

We study the interaction between a Layer-1 (L1) chain and a Layer-2 (L2) chain in a discrete-time infinite-horizon setting with time indexed by $t \in \mathbb{N}$. We assume a constant risk-free rate $r > 0$ and impose the absence of arbitrage. The economy is populated by perfectly competitive investors who seek to maximize their investment returns.

In our framework, each chain features a native unit of account, hereafter called the

²[Guasoni et al. \(2024a\)](#) and [Guasoni et al. \(2024b\)](#) provide comprehensive analysis regarding a specific L2 used within the Bitcoin payment system to enable payments at lower costs.

cryptoasset for that chain. Each chain supports the deployment of decentralized applications (dApps) that generate value from dApp investment provided by investors.³ In addition, the L1 chain operates a Proof-of-Stake protocol (Saleh, 2021) such that investors may *stake* L1 cryptoasset to receive inflationary rewards. Section 2.1 below describes L1 and derives the returns from L1 dApps and staking. Section 2.2 describes L2 and derives the return from L2 dApps.

2.1 L1 Chain

The L1 chain offers two types of investment opportunities: dApp investment and staking. We assume that L1 dApp investment is value-generating and that the value created depends on both L1 dApp investment and L2 dApp investment. In contrast, staking is financed purely by an inflationary tax on holders of L1 cryptoasset, and thus staking investors accrue their returns as an inflationary transfer from L1 dApp investors.

2.1.1 L1 dApp Investment

We denote the dApp investment on Layer- i chain made at time t as $TVL_{i,t}$ (short for Total Value Locked), and the net economic value created by dApps on Layer- i between period t and $t + 1$ as $V_{i,t+1}$.⁴ We assume that the value $V_{1,t+1}$ created by the dApps L1 depends on both L1 investment and L2 investment. Specifically, the value is given by:

$$V_{1,t+1} = A_{1,t} \cdot TVL_{1,t}^{\beta_{1,1}} \cdot TVL_{2,t}^{\beta_{2,1}}, \quad (1)$$

where $\{A_{1,t}\}_{t \in \mathbb{N}}$ is a productivity process of L1 dApps. The productivity process broadly measures the technological capacity and the attractiveness of the layer. Following prior literature, we assume that the dApp value creation exhibits network effects which decrease

³In our setup, the native cryptoasset is valuable because it is required to make investments into dApps that generate real value, i.e., the cryptoasset generates the dApp “convenience yield.” In other models in the literature, cryptoassets are valuable because they yield transactional benefits (see, e.g., Biais et al., 2023; Cong et al., 2021, 2022). We view the concepts of the dApp convenience yield and the transactional yield as economically similar—in both cases, cryptoassets are used to capture some real value generated through on-chain activity.

⁴Total Value Locked is a common metric used for dApps which measures the total value of capital invested in a dApp.

with scale (see, e.g., [Cong et al. 2021](#)). That is, we assume that $\beta_{1,1} \in (0, 1)$, which implies that L1 value increases with L1 dApp investment but at a decreasing rate. To capture that L2 dApps compete with L1 dApps and generally draw economic activity away from L1 dApps, we also assume that $\beta_{2,1} < 0$. That is, L1 value creation decreases in L2 dApp investment.

We specify the exogenous productivity process of L1 dApps as:

$$A_{1,t+1} = A_{1,t} \cdot \varepsilon_{1,t+1}, \quad (2)$$

where $\{\varepsilon_{1,t}\}_{t \in \mathbb{N}}$ is an independent identically distributed sequence such that $\varepsilon_{1,t} \geq 0$ and $\mu_{A_1} := \mathbb{E}[\log(\varepsilon_{1,t})] > 0$. The former condition implies non-negativity of $\{A_{1,t}\}_{t \in \mathbb{N}}$ whereas the latter condition ensures that $A_{1,t}$ grows asymptotically.

We assume that a fraction $\phi_1 \in (0, 1)$ of the net surplus created by dApps is captured by investors as opposed to users of dApps (e.g., traders trading with a liquidity pool at a DEX) and this value accrues across all dApp investors pro rata per unit of capital invested, which means that the net dApp return equals $\frac{\phi_1 \cdot V_{1,t+1}}{TVL_{1,t}}$. We assume that L1 dApp investment is made in two different assets: partly in L1 cryptoasset and partly in a stablecoin. We let $\omega_1 \in (0, 1]$ denote the share of investment in the L1 cryptoasset. We let $P_{1,t}$ denote the price of the L1 cryptoasset in period t , implying that the per-unit return on the L1 cryptoasset is equal to $\frac{P_{1,t+1}}{P_{1,t}}$. Then, the gross L1 dApp investment return from t to $t + 1$ is

$$R_{1,t+1} = \underbrace{\frac{\phi_1 \cdot V_{1,t+1}}{TVL_{1,t}}}_{\text{Net Return from L1 dApps}} + \underbrace{\omega_1 \frac{P_{1,t+1}}{P_{1,t}}}_{\text{Return on L1 Cryptoasset}} + \underbrace{1 - \omega_1}_{\text{Return on Stablecoin}} \quad (3)$$

2.1.2 Staking Investment

The current design of blockchains that support L2 requires staking only at the protocol level, i.e., staking occurs only on L1. Importantly, staking has to be made in L1 cryptoasset only and staking rewards are paid in L1 cryptoasset. Thus, staking is financed through an inflationary value transfer from L1 cryptoasset holders.

Specifically, we assume that the total supply of L1 cryptoasset, $M_{1,t}$, grows at a rate

$\rho > 0$ each period and all newly issued L1 cryptoasset units, $M_{1,t+1} - M_{1,t} = (e^\rho - 1) \cdot M_{1,t}$, are paid to stakers. The staking rewards are paid in proportion to the stake provided. We denote the total number of units staked by S_t . Thus, one unit of staked L1 cryptoasset yields a net payoff of $\frac{M_{1,t+1} - M_{1,t}}{S_t}$ units of L1 cryptoasset and a gross payoff of $1 + \frac{(e^\rho - 1) \cdot M_{1,t}}{S_t}$ units of L1 cryptoasset. To derive the total return to the stakers, this payoff must be multiplied by the gross return per unit on the L1 cryptoasset, which is equal to $\frac{P_{1,t+1}}{P_{1,t}}$. As a consequence, the gross staking return is given by:

$$R_{s,t+1} = \underbrace{\left(1 + \frac{(e^\rho - 1) \cdot M_{1,t}}{S_t}\right)}_{\text{Staking Return in L1 Units}} \times \underbrace{\frac{P_{1,t+1}}{P_{1,t}}}_{\text{Return on L1 Cryptoasset}}. \quad (4)$$

Note that a subscript for the staking return does not reference L1. This is to emphasize that our notion of staking corresponds to staking at the protocol level.

2.1.3 L1 Cryptoasset Market Value

As discussed above, ω_1 part of L1 dApp investment is in L1 cryptoasset. As such, the ability of L1 dApps to generate value leads to L1 dApp investment, which then generates demand for L1 cryptoasset. Additionally, some of the value created by L1 dApps can be captured by stakers through an inflationary tax, and this creates further demand for L1 cryptoasset from stakers. Therefore, the market clearing condition for L1 cryptoasset is given by:

$$\underbrace{M_{1,t} \cdot P_{1,t}}_{\text{L1 Market Value}} = \underbrace{\omega_1 \cdot TVL_{1,t}}_{\text{L1 dApp Investment}} + \underbrace{S_t \cdot P_{1,t}}_{\text{Staking Investment}} \quad (5)$$

2.2 L2 Chain

L2 chain offers one type of investment opportunity: dApp investment. In particular, the L2 does not employ a consensus protocol and instead relies on the L1 chain to record valid transactions. Thus, the protocol-level staking is not available. As with the L1 dApp investment, we assume that the L2 dApp investment is value-generating and the value created depends on both the L1 dApp investment and the L2 dApp investment. Akin to the L1, we assume that the L2 dApp investment requires holding the L2 cryptoasset.

2.2.1 L2 dApp Investment

We assume that the value $V_{2,t+1}$ created by L2 dApps depends on both L1 investment and L2 investment. Specifically, the value is given by:

$$V_{2,t+1} = A_{2,t} \cdot TVL_{1,t}^{\beta_{1,2}} \cdot TVL_{2,t}^{\beta_{2,2}}, \quad (6)$$

where $\{A_{2,t}\}_{t \in \mathbb{N}}$ is a productivity process of L2 dApps. As with L1, we follow the prior literature and assume that the dApp value creation exhibits network effects which decrease with scale (see, e.g., [Cong et al. 2021](#)). That is, we assume that $\beta_{2,2} \in (0, 1)$, which implies that L2 value increases with L2 dApp investment but at a decreasing rate. The effect of L1 dApp investment on L2 value creation captured by $\beta_{1,2}$ can be negative or positive. Indeed, on the one hand, L1 and L2 dApps compete, so higher L1 investment could imply less activity on L2 dApps. On the other hand, L2 adoption generally benefits from L1 adoption, so a higher L1 investment could enhance activity on L2 dApps. Finally, we impose regularity on externalities within our model, requiring that the cross-elasticities of the dApp investment are small relative to the own elasticities of the investment, i.e., we require $|\beta_{1,2} \cdot \beta_{2,1}| < (1 - \beta_{1,1}) \cdot (1 - \beta_{2,2})$.

Similar to L1 productivity, we specify the exogenous productivity process of L2 dApps as:

$$A_{2,t+1} = A_{2,t} \cdot \varepsilon_{2,t+1}, \quad (7)$$

where $\{\varepsilon_{2,t}\}_{t \in \mathbb{N}}$ is an independent identically distributed sequence such that $\varepsilon_{2,t} \geq 0$ and $\mu_{A_2} := \mathbb{E}[\log(\varepsilon_{2,t})] > 0$. The former condition implies non-negativity of $\{A_{2,t}\}_{t \in \mathbb{N}}$ whereas the latter condition ensures that $A_{2,t}$ grows asymptotically.

Finally, we assume that a fraction $\phi_2 \in (0, 1)$ of the net surplus created by dApps is captured by investors as opposed to users of dApps (e.g., traders trading with a liquidity pool at a DEX) and this value accrues across all dApp investors pro rata per unit of capital invested, which means that the net dApp return equals $\frac{\phi_2 \cdot V_{2,t+1}}{TVL_{2,t}}$. We assume that L2 dApp investment is made in two different assets: partly in L2 cryptoasset and partly in a stablecoin.

We let $\omega_2 \in (0, 1]$ denote the share of investment in the L2 cryptoasset.⁵ We let $P_{2,t}$ denote the price of L2 cryptoasset in period t , implying that the per unit return on L2 cryptoasset is equal to $\frac{P_{2,t+1}}{P_{2,t}}$. Then, the gross L2 dApp investment return from t to $t + 1$ is

$$R_{2,t+1} = \underbrace{\frac{\phi_2 \cdot V_{2,t+1}}{TVL_{2,t}}}_{\text{Net Return from L2 dApps}} + \underbrace{\omega_2 \frac{P_{2,t+1}}{P_{2,t}}}_{\text{Return on L2 Cryptoasset}} + \underbrace{1 - \omega_2}_{\text{Return on Stablecoin}} \quad (8)$$

2.2.2 L2 Cryptoasset Market Value

As discussed above, ω_2 part of L2 dApp investment is in the L2 cryptoasset. In turn, the ability of L2 blockchain dApps to generate value leads to endogenous L2 dApp investment, which then generates demand for the L2 cryptoasset. Since L2 staking does not exist, all L2 cryptoasset holders invest in L2 dApps. As a consequence, the market clearing condition for L2 cryptoasset is given by:

$$\underbrace{M_2 \cdot P_{2,t}}_{\text{L2 Market Value}} = \underbrace{\omega_2 \cdot TVL_{2,t}}_{\text{L2 dApp Investment}} \quad (9)$$

where $M_2 > 0$ denotes the constant supply of L2 cryptoasset. This equation determines the price of the L2 cryptoasset.

3 Equilibrium Analysis

In this section, we determine the equilibrium L1 and L2 dApp investment as well as the staking investment. In turn, given the supply and demand for L1 cryptoasset and L2 cryptoasset, we derive their equilibrium prices.

As we impose no arbitrage, there exists a risk-neutral pricing measure $\mathbb{Q}$ such that any investment i must satisfy the following no-arbitrage condition:

$$1 + r = \mathbb{E}^{\mathbb{Q}}[R_{i,t+1} \mid \mathcal{F}_t], \quad (10)$$

⁵In practice, a significant portion of the dApp investment on L2s is in terms of L1 cryptoasset. Nonetheless, there is no fundamental reason for this being the case and thus we expect that the share of L2 dApp investment in L1 cryptoasset would reduce over time. In turn, we consider an extreme case in which L1 cryptoasset is not used on L2. Our results can therefore be interpreted as reflective of a possible steady-state.

where $R_{i,t+1}$ denotes the t to $t+1$ gross return for investment i and $\mathcal{F}_t$ denotes the information set at the beginning of period t . Intuitively, Equation (10) asserts that the risk-adjusted expected gross return for any investment i must be equal to the gross return of a risk-free bond where the risk adjustment is embedded by the measure change from the physical measure to the risk-neutral $\mathbb{Q}$ -measure.

We impose a regularity on the $\mathbb{Q}$ -measure by assuming that the one-period-ahead pricing kernel, $Z_{t,t+1}$, depends directly on the two exogenous shocks, $\varepsilon_{1,t+1}$ and $\varepsilon_{2,t+1}$ and that the pricing kernel is square-integrable. That is, we assume that there exists $Z : \mathbb{R}_+^2 \mapsto \mathbb{R}_+$ such that $Z_{t,t+1} = Z(\varepsilon_{1,t+1}, \varepsilon_{2,t+1})$ and $\mathbb{E}[Z_{0,1}^2] < \infty$, where $\mathbb{E}^\mathbb{Q}[R_{i,t+1} \mid \mathcal{F}_t] = \mathbb{E}[Z_{t,t+1}R_{i,t+1} \mid \mathcal{F}_t]$ for any asset i .

We solve for a stationary equilibrium in which the risk-adjusted net return of each cryptoasset is constant. Specifically, we find equilibria where there exist net returns $\bar{r}_1$ and $\bar{r}_2$ satisfying the following restriction for all $t \in \mathbb{N}$ and $i \in \{1, 2\}$:

$$1 + \bar{r}_i = \mathbb{E}^\mathbb{Q}\left[\frac{P_{i,t+1}}{P_{i,t}} \mid \mathcal{F}_t\right]. \quad (11)$$

Our equilibrium requires that all time t variables are decided with time t available information. Specifically, all time t quantities (e.g., $P_{i,t}$, $TVL_{i,t}$) are measurable with respect to $\mathcal{F}_t = \sigma(A_{1,0}, A_{2,0}, \dots, A_{1,t}, A_{2,t})$ which is the sigma-algebra generated by the exogenous L1 and L2 productivity processes up to time t .

Definition 1. *The stationary equilibrium is characterized by*

- *L1 cryptoasset $\mathbb{Q}$ -expected return $\bar{r}_1$ and L2 cryptoasset $\mathbb{Q}$ -expected return $\bar{r}_2$,*
- *L1 cryptoasset price sequence $\{P_{1,t}\}_{t \in \mathbb{N}}$ and L2 cryptoasset price sequence $\{P_{2,t}\}_{t \in \mathbb{N}}$,*
- *staking ratio θ^* ,*
- *L1 dApp investment sequence $\{TVL_{1,t}^*\}_{t \in \mathbb{N}}$ and L2 dApp investment sequence $\{TVL_{2,t}^*\}_{t \in \mathbb{N}}$*

such that all investments are all correctly priced, i.e., Equation 10 holds for $i = 1, 2, s$, and the supply and demand clear in both the L1 and L2 cryptoasset markets, i.e., Equations 5 and 9 hold for all t .

The unique stationary equilibrium of the model is given by the following result.

Proposition 1. Stationary Equilibrium

In the stationary equilibrium,

- The L1 cryptoasset $\mathbb{Q}$ -expected return is

$$\bar{r}_1 = e^{-\rho} \mathbb{E}^{\mathbb{Q}}[\varepsilon_{1,t}^{-\gamma_{1,1}} \cdot \varepsilon_{2,t}^{-\gamma_{1,2}}] - 1, \quad (12)$$

where $\gamma_{1,1}$ and $\gamma_{1,2}$ are defined as:

$$\gamma_{1,1} = \frac{\beta_{2,2} - 1}{(\beta_{1,1} - 1)(\beta_{2,2} - 1) - \beta_{1,2}\beta_{2,1}}, \quad \gamma_{1,2} = -\frac{\beta_{2,1}}{(\beta_{1,1} - 1)(\beta_{2,2} - 1) - \beta_{1,2}\beta_{2,1}}. \quad (13)$$

- The L2 cryptoasset $\mathbb{Q}$ -expected return is

$$\bar{r}_2 = \mathbb{E}^{\mathbb{Q}}[\varepsilon_{2,t}^{-\gamma_{2,2}} \cdot \varepsilon_{1,t}^{-\gamma_{2,1}}] - 1, \quad (14)$$

where $\gamma_{2,2}$ and $\gamma_{2,1}$ are defined as:

$$\gamma_{2,2} = \frac{\beta_{1,1} - 1}{(\beta_{2,2} - 1)(\beta_{1,1} - 1) - \beta_{2,1}\beta_{1,2}}, \quad \gamma_{2,1} = -\frac{\beta_{1,2}}{(\beta_{2,2} - 1)(\beta_{1,1} - 1) - \beta_{2,1}\beta_{1,2}}. \quad (15)$$

- Equilibrium dApp investment for $i \in \{1, 2\}$ is

$$TVL_{i,t}^* = \left(r - \omega_i \cdot \bar{r}_i\right)^{\gamma_{i,i}} \cdot \left(r - \omega_{-i} \cdot \bar{r}_{-i}\right)^{\gamma_{i,-i}} \cdot (\phi_i A_{i,t})^{-\gamma_{i,i}} \cdot (\phi_{-i} A_{-i,t})^{-\gamma_{i,-i}}, \quad (16)$$

where $\bar{r}_i$ are given by Equations (12)-(14) and $\gamma_{i,i}$ and $\gamma_{i,-i}$ are given by Equations (13) and (15).

- Equilibrium staking ratio is

$$\theta^* = \frac{(1 + \bar{r}_1) \times (e^\rho - 1)}{r - \bar{r}_1}, \quad (17)$$

where $\bar{r}_1$ is given by Equation (12).

- *L1 cryptoasset price is*

$$P_{1,t} = \frac{\omega_1 \cdot TVL_{1,t}^*}{M_{1,0} \cdot (1 - \theta^*)} e^{-\rho t}, \quad (18)$$

where $TVL_{1,t}^*$ is given by Equation (16) and θ^* is given by Equation (17).

- *L2 cryptoasset price is*

$$P_{2,t} = \frac{\omega_2 \cdot TVL_{2,t}^*}{M_2}, \quad (19)$$

where $TVL_{2,t}^*$ is given by Equation (16).

4 Results

In this section, we analyze the unique stationary equilibrium derived in Proposition 1. We first show that, under realistic conditions, the L1 dApp investment and the market value of the L1 cryptoasset vanish asymptotically (Proposition 2). We then demonstrate that, when the L1 productivity growth is sufficiently close to the L2 productivity growth, the adverse effects to L1 do not arise (Proposition 3).

Our main result, which establishes the risk that L2s pose to L1, is given by the following:

Proposition 2. *L1 Fails With Probability One*

If the following condition holds:

$$|\beta_{2,1}| \times \mu_{A_2} > (1 - \beta_{2,2}) \times \mu_{A_1}, \quad (20)$$

then L1 dApp investment and L1 cryptoasset market value vanish asymptotically. That is, condition (20) implies that with probability one:

$$\lim_{t \rightarrow \infty} TVL_{1,t} = 0 \quad \text{and} \quad \lim_{t \rightarrow \infty} M_{1,t} P_{1,t} = 0. \quad (21)$$

Proposition 2 presents realistic conditions such that both the L1 dApp investment and the L1 cryptoasset market value converge to zero with probability one. Interestingly, even though the productivity of L1 blockchain grows, i.e., $\mu_{A_1} > 0$, it is not sufficient for the L1 dApp investment and the L1 cryptoasset market value to also grow. In fact, Proposition 2

highlights that L1 can essentially fail despite the underlying technology having the potential to generate increasing economic value.

Proposition 2 establishes eventual L1 failure given the condition in Equation (20). Thus, it is important to understand the economic circumstances in which it holds. Equation (20) holds under the following circumstances:

- (A) L2 productivity growth is high relative to L1 productivity growth, i.e., $\mu_{A_2} \gg \mu_{A_1}$;
- (B) L2 investment returns increase rapidly in L2 dApp investment, i.e., $\beta_{2,2} \rightarrow 1^+$;
- (C) L2 dApps exhibit a large negative externality upon L1 dApps, i.e., $|\beta_{2,1}|$ is large.

We proceed with a series of corollaries that formalize each of the circumstances and clarify the underlying economics. We begin with the first corollary corresponding to (A):

Corollary 1. L1 fails when L2 is relatively productive

If the ratio of L2 dApp productivity growth and L1 dApp productivity growth is sufficiently large, then L1 fails eventually with probability one. That is, if $\frac{\mu_{A_2}}{\mu_{A_1}}$ is sufficiently large, then Equation (21) holds with probability one.

Corollary 1 establishes that L2 productivity can actually be detrimental to L1. This result demonstrates that the L1 dApp investment and the market value of the L1 cryptoasset vanish if the growth rate of the L2 dApp productivity is sufficiently higher than the growth rate of L1 dApp productivity, i.e., if $\frac{\mu_{A_2}}{\mu_{A_1}}$ is sufficiently high. Intuitively, L2 dApps draw activity away from L1 to L2. When L2 dApp productivity grows sufficiently faster than L1 dApp productivity growth, the investment moves from L1 to L2 rapidly. Then, since L2 dApp investment imposes a negative externality on L1 dApp activity, the incentives for L1 dApp investment decrease even further with increasing L2 dApp investment. As time progresses, the L1 dApp investment vanishes completely.

Our next corollary corresponds to (B):

Corollary 2. L1 fails if L2 dApp returns increase sufficiently rapidly in investment

If the marginal returns of the L2 dApp investment decrease at a sufficiently slow rate, then L1 eventually fails with probability one. That is, there exists $\underline{\beta}_{2,2} \in (0, 1)$ such that $\beta_{2,2} > \underline{\beta}_{2,2}$ implies that Equation (21) holds with probability one.

Corollary 2 demonstrates that, if returns from the L2 dApp investment are not sufficiently concave, then the L1 dApp investment and the market value of the L1 cryptoasset eventually vanish. This result arises because, when L2 dApp investment returns are not sufficiently concave, the incentives for L2 dApp investment are stronger. In particular, L2 dApp investment returns always exhibit diminishing marginal returns, but when these returns are not sufficiently concave, the rate at which L2 dApp returns diminish is relatively low, and thus the L2 dApp investment is relatively high. In turn, when the returns of L2 dApp investments are not sufficiently concave, the L2 dApp investment increases at a sufficient rate to undermine L1 dApp investment due to the negative externality from the L2 dApp investment on L1 dApp activity. Thus, as a consequence, the L1 dApp investment and the L1 cryptoasset value vanish asymptotically.

Our final corollary corresponds to (C):

Corollary 3. *L1 fails if L2 imposes large negative externality on L1*

If L2 dApps exhibit a sufficiently large negative externality on L1 dApps, then L1 eventually fails with probability one. That is, if $|\beta_{2,1}|$ is sufficiently large, then Equation (21) holds with probability one.

Corollary 3 establishes that if L2 dApp investment imposes a sufficiently high negative externality on L1 dApp activity, the L1 dApp investment and the L1 cryptoasset value vanish asymptotically. This result is straightforward. In particular, since L2 dApp productivity is growing, L2 dApp investment is also growing. Moreover, if the negative externality from L2 dApp investment to L1 dApp activity is sufficiently large, the incentive for L1 dApp investment is sufficiently lower and as L2 dApp investment grows, L1 dApp investment declines and vanishes asymptotically.

While we highlight three channels driving our L1 failure result, one particular channel, namely relative productivity growth between L1 and L2, is within the control of the developer community. Indeed, while the concavity of L2 dApp investment returns, $\beta_{2,2}$, and the negative externality of L2 on L1, $\beta_{2,1}$, may be difficult to alter, the productivity growth of L1 and L2, μ_{A_1} and μ_{A_2} , are determined by improvements to the protocols implemented by developers.

Our final result highlights that, even with a negative externality from L2 to L1 (i.e., $\beta_{2,1} < 0$) and L2 investment returns increasing rapidly in L2 investment (i.e., $\beta_{2,2}$ approaching unity), there exists nevertheless a level of L1 productivity growth such that L1 thrives:

Proposition 3. L1 Thrives Given Sufficient Productivity

Given any model parameters, there exists $\underline{\mu} > 0$ where $\underline{\mu}$ is independent of μ_{A_1} and μ_{A_2} such that $\frac{\mu_{A_1}}{\mu_{A_2}} > \underline{\mu}$ implies that the L1 dApp investment and the L1 cryptoasset market value grow without bound asymptotically. That is, $\frac{\mu_{A_1}}{\mu_{A_2}} > \underline{\mu}$ implies the following with probability one:

$$\lim_{t \rightarrow \infty} TVL_{1,t} = \infty \quad \text{and} \quad \lim_{t \rightarrow \infty} M_{1,t}P_{1,t} = \infty. \quad (22)$$

Proposition 3 establishes that, regardless of the negative externality from L2 to L1 and irrespective of the attractiveness of L2 investment, there nonetheless exists a level of L1 productivity growth relative to L2 productivity growth such that both the L1 dApp investment and the L1 cryptoasset market value grow without bound. Importantly, this result highlights that overemphasizing L2 productivity at the expense of L1 productivity would be deleterious to the L1. Of particular note, Propositions 2 and 3 collectively imply that adverse effects to the L1 can be overcome with an appropriate balance of developer activity between the L1 and the L2. To that end, our results demonstrate that developers should not focus exclusively on efforts to improve the L2 (e.g., EIP-4844) and should also continue working on improving the user experience from engaging directly on the L1.

5 Discussion

Our work formalizes the idea that L2s could pose a direct threat to the economic health of L1 networks, fundamentally altering the incentives for both developers and investors on a L1 platform such as Ethereum. While L2 solutions may improve scalability, they can also undermine the economic viability of L1. The primary finding highlights a crucial issue: the existence of a successful L2 with popular dApps can diminish the demand for L1 dApps, thereby creating a negative feedback loop for the L1, in which L1 dApp investment and its cryptoasset market value decline over time.

The most significant implication of this result is the potential impact on the security of L1 blockchains, particularly those using Proof-of-Stake consensus mechanisms. If L1 becomes relatively less attractive compared to L2 in terms of its technology, the L1 dApp investment and L1 cryptoasset market value may approach zero over time. Since the L1 Proof-of-Stake blockchains rely on the market value of their native L1 cryptoassets for network security (see [Saleh 2021](#) and [John et al. 2025b](#)), this decline in value could threaten the blockchain’s ability to maintain a secure and decentralized network.

The weakening of L1 security would eventually pose a problem for the associated L2s, as their security is inherently dependent on L1 security. The critical issue is that this dependency is not fully internalized by the current design of L2s. While the value generated on the L1 increases the value of the L1 cryptoasset and thus reinforces L1 security, the value generated on the L2 has the opposite effect on the L1 security. Currently, the only way the value generated on L2s can flow to L1 to support its security is through transaction fees, which are intentionally kept low to make L2s more appealing.

Our results do not necessarily imply that network security and decentralization will be compromised in practice. Presumably, developers would attempt to remedy the problem that we describe once it becomes widely recognized. One potential way to address the issue would require a design change, introducing a mechanism that could properly account for the value of L1 security to L2 users. The goal of our work is to highlight early on that, under the current design, as L2 networks grow in popularity, the security of L1 blockchains could become increasingly at risk.

Ultimately, our results underscore the urgency for developers to continue to support the L1 blockchain and, by implication, the value of its cryptoasset. In particular, while development activity on L1 continues, the most prominent recent efforts in this regard have focused on enhancing the user experience of L2s (e.g., EIP-4844). Our work highlights the need for developers to ensure that the L1 user experience does not fall significantly behind.

6 Conclusion

In this paper, we present an economic model to examine the interaction between a Layer-1 blockchain and its corresponding Layer-2 solution. Our key finding is that, even if the L1 blockchain hosts value-generating decentralized applications, there are plausible conditions under which both the investment in the L1 blockchain and the market value of its cryptoasset approach zero over time. Notably, given sufficient developer activity supporting the L1, the L1 and L2 could thrive simultaneously. Our results thus underscore the importance for developers to improve the L1 user experience even if L2s are receiving increasingly more attention.

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A Appendix

A.1 Proofs

The proofs are written in the order that they are derived. In particular, no proof invokes a result that is derived later. Rather, each proof relies only on the results derived earlier, thereby avoiding any potential circular arguments.

Lemma 1. Equilibrium dApp Investment

The equilibrium dApp investment at time t for Layer- i is given as follows:

$$TVL_{i,t}^* = \left(r - \omega_i \cdot \bar{r}_i\right)^{\gamma_{i,i}} \cdot \left(r - \omega_{-i} \cdot \bar{r}_{-i}\right)^{\gamma_{i,-i}} \cdot (\phi_i A_{i,t})^{-\gamma_{i,i}} \cdot (\phi_{-i} A_{-i,t})^{-\gamma_{i,-i}}, \quad (\text{A.1})$$

where $\gamma_{i,i}$ and $\gamma_{i,-i}$ are defined as follows for $i \in \{1, 2\}$:

$$\gamma_{i,i} = \frac{\beta_{-i,-i} - 1}{(\beta_{i,i} - 1)(\beta_{-i,-i} - 1) - \beta_{i,-i}\beta_{-i,i}}, \quad \gamma_{i,-i} = -\frac{\beta_{-i,i}}{(\beta_{i,i} - 1)(\beta_{-i,-i} - 1) - \beta_{i,-i}\beta_{-i,i}}. \quad (\text{A.2})$$

Proof.

Applying Equations (3) and (8) separately to Equation (10) yields $\forall i \in \{1, 2\}, t \in \mathbb{N}$:

$$r - \omega_i \cdot \bar{r}_i = \phi_i A_{i,t} \cdot (TVL_{i,t})^{\beta_{i,i}-1} \cdot (TVL_{-i,t})^{\beta_{-i,i}}. \quad (\text{A.3})$$

Further, applying a log transformation on both sides yields $\forall i \in \{1, 2\}, t \in \mathbb{N}$:

$$(\beta_{i,i} - 1) \log(TVL_{i,t}) + \beta_{-i,i} \log(TVL_{-i,t}) = \log\left(r - \omega_i \cdot \bar{r}_i\right) - \log(\phi_i A_{i,t}). \quad (\text{A.4})$$

Then, solving the system of equations (A.4) yields $\forall i \in \{1, 2\}, t \in \mathbb{N}$:

$$\log(TVL_{i,t}^*) = \gamma_{i,i} \cdot \log\left(r - \omega_i \bar{r}_i\right) + \gamma_{i,-i} \log\left(r - \omega_{-i} \bar{r}_{-i}\right) - \gamma_{i,i} \log(\phi_i A_{i,t}) - \gamma_{i,-i} \log(\phi_{-i} A_{-i,t}), \quad (\text{A.5})$$

where $\gamma_{i,i}$ and $\gamma_{i,-i}$ are defined in Equation (A.2) for $i \in \{1, 2\}$. Then, the result follows directly from applying exponential transformations to both sides of Equation (A.5). $\square$

Proof of Proposition 1.

Proof. Lemma 1 implies equilibrium dApp investment is given by Equation (16). Then, the equilibrium staking level being given by Equation (17) is implied by applying Equation (16) to Equation (4) and then taking the $\mathbb{Q}$ -expectation while applying Equation (10). In turn, the L1 cryptoasset price being given by Equation (18) is implied by applying Equation (17) to Equation (5). The L2 cryptoasset price being given by Equation (19) is given directly by Equation (9). Finally, the $\mathbb{Q}$ -expected return for the Layer- i cryptoasset being given by Equations (12) and (14) is established by computing $\frac{P_{i,t+1}}{P_{i,t}}$ from Equations (18) and (19) respectively, then applying Equation (16) and taking the $\mathbb{Q}$ -expectation. $\square$

Lemma 2. $A_{i,t}$ Long-Run Growth Rate

For $i \in \{1, 2\}$, the following result holds with probability one:

$$\lim_{t \rightarrow \infty} \frac{1}{t} \log(A_{i,t}) = \mu_{A_i}. \quad (\text{A.6})$$

Proof.

For all $t > 0$ and $i \in \{1, 2\}$, Equation (2) and (7) imply the following:

$$\frac{1}{t} \log(A_{i,t}) = \frac{1}{t} \log(A_{i,0}) + \frac{1}{t} \sum_{s=0}^{t-1} \log(\varepsilon_{i,s+1}). \quad (\text{A.7})$$

Then, taking $t \rightarrow \infty$ in Equation (A.7) and invoking the strong law of large numbers implies the desired result for $i \in \{1, 2\}$:

$$\lim_{t \rightarrow \infty} \frac{1}{t} \log(A_{i,t}) = \mathbb{E}[\log(\varepsilon_{i,1})] = \mu_{A_i} \quad \text{a.s.} \quad (\text{A.8})$$

$\square$

Lemma 3. $TVL_{i,t}$ Long-Run Growth Rate

For $i \in \{1, 2\}$, the following result holds with probability one:

$$\lim_{t \rightarrow \infty} \frac{1}{t} \log(TVL_{i,t}) = -\gamma_{i,i} \mu_{A_i} - \gamma_{i,-i} \mu_{A_{-i}}. \quad (\text{A.9})$$

Proof.

For all $t > 0$ and $i \in \{1, 2\}$, Equation (16) implies the following:

$$\frac{1}{t} \log(TVL_{i,t}) = \frac{1}{t} \log(TVL_{i,0}) - \frac{\gamma_{i,i}}{t} \log(A_{i,t}) - \frac{\gamma_{i,-i}}{t} \log(A_{-i,t}) + \frac{\gamma_{i,i}}{t} \log(A_{i,0}) + \frac{\gamma_{i,-i}}{t} \log(A_{-i,0}). \quad (\text{A.10})$$

Then, taking $t \rightarrow \infty$ in Equation (A.10) and invoking Lemma 2 implies the desired result for $i \in \{1, 2\}$:

$$\lim_{t \rightarrow \infty} \frac{1}{t} \log(TVL_{i,t}) = -\gamma_{i,i} \mu_{A_i} - \gamma_{i,-i} \mu_{A_{-i}} \quad \text{a.s.} \quad (\text{A.11})$$

□

Lemma 4. $TVL_{i,t}$ Goes to Zero if $\zeta_i > 0$

For $i \in \{1, 2\}$, if $\zeta_i := \gamma_{i,i} \mu_{A_i} + \gamma_{i,-i} \mu_{A_{-i}} > 0$, then the following result holds with probability one:

$$\lim_{t \rightarrow \infty} TVL_{i,t} = 0. \quad (\text{A.12})$$

Proof.

Lemma 3 implies that, for all $i \in \{1, 2\}$, there exists a measure one set such that for all sample paths, there exists a T such that the following holds:

$$\forall t > T : TVL_{i,t} \leq TVL_{i,0} e^{-\frac{\zeta_i}{2}t}. \quad (\text{A.13})$$

Then, within the aforementioned measure one set, Equation (A.13) and $\zeta_i > 0$ imply:

$$\limsup_{t \rightarrow \infty} TVL_{i,t} \leq 0, \quad (\text{A.14})$$

so that applying $TVL_{i,t} \geq 0$, which implies $\liminf_{t \rightarrow \infty} TVL_{i,t} \geq 0$ to Equation (A.14) yields the desired result for $i \in \{1, 2\}$:

$$\lim_{t \rightarrow \infty} TVL_{i,t} = 0 \quad \text{a.s.} \quad (\text{A.15})$$

□

Lemma 5. $TVL_{i,t}$ Goes to Infinity if $\zeta_i < 0$

For $i \in \{1, 2\}$, if $\zeta_i := \gamma_{i,i} \mu_{A_i} + \gamma_{i,-i} \mu_{A_{-i}} < 0$, then the following result holds with probability

one:

$$\lim_{t \rightarrow \infty} TVL_{i,t} = \infty. \quad (\text{A.16})$$

Proof.

Lemma 3 implies that, for all $i \in \{1, 2\}$, there exists a measure one set such that for all sample paths, there exists a T such that the following holds:

$$\forall t > T : TVL_{i,t} \geq TVL_{i,0} e^{-\frac{\zeta_i}{2}t}. \quad (\text{A.17})$$

Then, taking $t \rightarrow \infty$ in Equation (A.17) and invoking $\zeta_i < 0$ yields the desired result for $i \in \{1, 2\}$:

$$\lim_{t \rightarrow \infty} TVL_{i,t} = \liminf_{t \rightarrow \infty} TVL_{i,t} = \infty \quad \text{a.s.} \quad (\text{A.18})$$

□

Lemma 6. Market Value Asymptotic Behavior

For $i \in \{1, 2\}$, the following results hold pointwise:

$$\lim_{t \rightarrow \infty} TVL_{i,t} = 0 \implies \lim_{t \rightarrow \infty} M_{i,t} P_{i,t} = 0 \quad \text{and} \quad \lim_{t \rightarrow \infty} TVL_{i,t} = \infty \implies \lim_{t \rightarrow \infty} M_{i,t} P_{i,t} = \infty. \quad (\text{A.19})$$

Proof.

This result follows directly from Equations (18) and (19). □

Proof of Proposition 2.

Proof. By direct verification, Equation (20) implies $\zeta_1 := \gamma_{1,1} \mu_{A_1} + \gamma_{1,2} \mu_{A_2} > 0$. Then, this result follows directly from Lemmas 4 and 6. □

Proof of Proposition 3.

Proof. This result follows from Lemmas 5 and 6. □