Leverage and Stablecoin Pegs[1]

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A Online Appendix

Section A.1 includes additional derivations for statements made in Section II. of the manuscript. Sections A.2-A.6 extend the baseline model in several dimensions mentioned in the manuscript: Section A.2 endogenizes margin requirements in stablecoin margin loans, Section A.3 incorporates benefits from additional uses of stablecoins other than their use in leveraged speculative crypto-trading, and Section A.4 incorporates the motive to borrow stablecoins to speculate on their collapse. Section A.5 derives the equilibrium token supply and stablecoin liquidity under non-observability. Section A.6 presents the choice of ℓ by the issuer when the liquid asset pays a positive interest. Section A.7 checks the robustness of using the BTC/USDT perpetual futures funding rate as a measure of speculative demand considering alternative proxies. Sections A.8 and A.9 report additional figures and tables with auxiliary results mentioned in the manuscript.

A.1 Additional Derivations

A.1.1 Derivatives of lending rate R with respect to y, m, s, λ

The effect of an increase in the cryptocurrency expected return, y, on the lending rate R, is

$$\text{(A.1)} \quad \frac{dR(\lambda,s)}{dy} = \frac{1}{1-m} > 0.$$

Because $F'(e) > y$, an increase in the margin, m, yields

$$\text{(A.2)} \quad \frac{dR(\lambda,s)}{dm} = \frac{y}{(1-m)^2} - \frac{F'\left(e - \frac{m}{1-m}(1-\lambda)s\right)}{(1-m)^2} + \frac{m(1-\lambda)sF''(e - \frac{m}{1-m}(1-\lambda)s)}{(1-m)^3} < 0.$$

An increase in the number of tokens, s, yields

$$\text{(A.3)} \quad \frac{dR(\lambda,s)}{ds} = \frac{m^2(1-\lambda)F''(e - \frac{m}{1-m}(1-\lambda)s)}{(1-m)^2} < 0,$$

[1]The views expressed in this paper are those of the authors and do not necessarily represent those of Federal Reserve Board of Governors, or anyone in the Federal Reserve System.

while an increase in redemptions, λ, yields

$$(A.4)\quad \frac{dR(\lambda,s)}{d\lambda} = -\frac{m^2 sF''(e - \frac{m}{1-m}(1-\lambda)s)}{(1-m)^2} > 0.$$

A.1.2 Details steps for derivation of unique θ^* in global game

Given the private signal, an individual patient investor will update their posterior about θ, which will be uniform in $[x_i - \epsilon, x_i + \epsilon]$ and compute the expected payoff differential

$$(A.5)\quad \Delta(x_i) = \int_{x_i-\epsilon}^{x_i+\epsilon} \nu(\theta,\lambda)\frac{d\theta}{2\epsilon}.$$

If $x_i \geq \overline{\theta} + \epsilon$, the individual patient investor can conclude that $\theta \geq \overline{\theta}$ and will not redeem, independent of their belief about λ ($\Delta(x_i) > 0$). Similarly, if $x_i < \underline{\theta} - \epsilon$, the individual patient investor can conclude that $\theta < \underline{\theta}$ and will redeem, independent of their belief about λ ($\Delta(x_i) < 0$). These are the *upper and lower dominance* regions for θ, where the individual action is independent of the beliefs about the actions of others.

For intermediate $x_i \in [\underline{\theta} - \epsilon, \overline{\theta} + \epsilon)$, the sign of $\Delta(x_i)$ depends on the beliefs about λ. To pin down these beliefs, we focus on a threshold strategy that all patient investors follow. We show that there exists a unique signal threshold x^*, such that every investor redeems if their private signal $x_i < x^*$ and does not redeem if $x_i > x^*$. Given this threshold, an individual investor can form well-defined beliefs about the total number of redemptions by patient investors, denoted by $\lambda^b(\theta, x^*)s$, and given by the probability that other investors receive a private signal below x^*. If $\theta > x^* + \epsilon$, all patient investors get signals $x_i > x^*$, none redeem, and $\lambda^b(\theta, x^*) = \delta$. If $\theta < x^* - \epsilon$, all patient investors get signals $x_i < x^*$, all redeem, and $\lambda^b(\theta, x^*) = 1$. If $x^* - \epsilon \leq \theta \leq x^* + \epsilon$, some patient investors get signals $x_i > x^*$, while others get signals $x_i < x^*$; thus, under the threshold strategy,
$\lambda^b(\theta, x^*) = (1-\delta)\Pr(x_i < x^*) = \delta + (1-\delta)(x^* - \theta + \epsilon)/(2\epsilon)$. The following equation summarizes these beliefs:

$$(A.6)\quad \lambda^b(\theta, x^*) = \begin{cases} 1 & \text{if } \theta < x^* - \epsilon \\ \delta + (1-\delta)(x^* - \theta + \epsilon)/(2\epsilon) & \text{if } x^* - \epsilon \leq \theta \leq x^* + \epsilon \\ \delta & \text{if } \theta > x^* + \epsilon \end{cases}.$$

Using (A.6), an investor can compute the expected payoff differential using their posterior about θ, given the signal x_i and an assumed value for x^*:

$$(A.7)\quad \Delta(x_i, x^*) = \int_{x_i-\epsilon}^{x_i+\epsilon} \nu(\theta, \lambda^b(\theta, x^*))\frac{d\theta}{2\epsilon}.$$

Unlike in (A.5), beliefs in (A.7) are uniquely determined and pin down the payoff differential.

Under a threshold strategy, a patient investor does not redeem ($\Delta(x_i, x^*) > 0$) if $x_i > x^*$ and redeems ($\Delta(x_i, x^*) < 0$) if $x_i < x^*$. By continuity, the investor that receives the threshold signal x^* is indifferent between not redeeming and redeeming, i.e.,

$$\text{(A.8)}\quad \Delta(x^*, x^*) = \int_{x^*-\epsilon}^{x^*+\epsilon} \nu(\theta, \lambda^b(\theta, x^*)) \frac{d\theta}{2\epsilon} = 0.$$

A threshold strategy also implies thresholds for fundamentals $\theta_{\hat{\lambda}}$ and $\theta_{\bar{\lambda}}$ such that the issuer is solvent at $t = 2$ for $\theta \geq \theta_{\hat{\lambda}}$ and has enough liquidity at $t = 1$ for $\theta \geq \theta_{\bar{\lambda}}$ given signal threshold x^* and redemptions $\lambda^b(\theta, x^*)$. These thresholds are determined by $\hat{\lambda} = \lambda^b(\theta_{\hat{\lambda}}, x^*)$ and $\bar{\lambda} = \lambda^b(\theta_{\bar{\lambda}}, x^*)$. Using these, the threshold (A.8) can be expanded to

$$\begin{aligned} \Delta(x^*, x^*) = &- \int_{x^*-\epsilon}^{\theta_{\bar{\lambda}}} \frac{\ell + (1-\ell)\xi}{\lambda^b(\theta, x^*)} \frac{d\theta}{2\epsilon} + \int_{\theta_{\bar{\lambda}}}^{\theta_{\hat{\lambda}}} \left[\theta \frac{X(1-\ell)\left[1 - \frac{\lambda^b(\theta,x^*)-\ell}{\xi(1-\ell)}\right]}{1-\lambda^b(\theta, x^*)} - 1 \right] \frac{d\theta}{2\epsilon} \\ \text{(A.9)} \quad & \\ &+ \int_{\theta_{\hat{\lambda}}}^{x^*+\epsilon} \left[\theta R(\lambda^b(\theta, x^*), s) + (1-\theta) \max\left(\frac{\ell - \lambda^b(\theta, x^*)}{1-\lambda^b(\theta, x^*)}, 0 \right) - 1 \right] \frac{d\theta}{2\epsilon} = 0. \end{aligned}$$

As is typical in the global game literature, we focus on the limiting case where noise $\epsilon \to 0$, which also implies that $\theta_{\hat{\lambda}}, \theta_{\bar{\lambda}} \to x^*$. We will denote by θ^* this common threshold that the fundamentals' thresholds, $\theta_{\hat{\lambda}}, \theta_{\bar{\lambda}}$, and signal threshold, x^*, converge to. Expressing (A.9) in terms of θ^* and changing variables from θ to λ, such that as θ decreases from $x^* + \epsilon$ to $x^* - \epsilon$, λ uniformly increases from 0 to $1 - \delta$, we get

$$\begin{aligned} \bar{\Delta}^* = &\int_{\delta}^{\hat{\lambda}} \left[\theta^* R(\lambda, s) + (1-\theta^*) \max\left(\frac{\ell - \lambda}{1-\lambda}, 0 \right) - 1 \right] \frac{d\lambda}{1-\delta} \\ \text{(A.10)} \quad & \\ &+ \int_{\hat{\lambda}}^{\bar{\lambda}} \left[\theta^* \frac{X(1-\ell)\left[1 - \frac{\lambda-\ell}{\xi(1-\ell)}\right]}{1-\lambda} - 1 \right] \frac{d\lambda}{1-\delta} - \int_{\bar{\lambda}}^{1} \frac{\ell + (1-\ell)\xi}{\lambda} \frac{d\lambda}{1-\delta} = 0. \end{aligned}$$

Existence and Uniqueness of Threshold Equilibrium. $\bar{\Delta}^*$ is continuous in θ^* because all integrands are continuous and the discontinuity in v occurs only at one discrete point, $\hat{\lambda}$. Then, from the existence of the upper and dominance regions, there exists a θ^* such that $\bar{\Delta}^* = 0$. It is, then, easy to show that the expected payoff differential is positive (negative) for an investor who receives signal $x_i > \theta^*$ ($x_i < \theta^*$), and hence the threshold strategy θ^* is indeed an equilibrium. Intuitively, observing a higher signal shifts probability from negative values of v to positive values of v as beliefs about aggregate withdrawals improve using (A.6); recall that noise is uniformly distributed. Given that v changes sign—"crosses zero"—only once, it follows that the posterior average of v is higher (lower) for $x_i > \theta^*$ ($x_i < \theta^*$) and, hence, positive (negative); we refer the reader to Goldstein and Pauzner, 2005, and Kashyap et al. 2024 for the technical details and precise exposition.[2] Finally, observe that $d\bar{\Delta}^*/d\theta^* > 0$, so θ^* and, hence, the threshold equilibrium strategy are unique.

A.1.3 Derivatives of θ^* with respect to y, m, s, ℓ

Total differentiating (A.10) yields the following derivatives:

$$\frac{d\theta^*}{dx} = -\frac{d\bar{\Delta}^*}{dx}\left[\frac{d\bar{\Delta}^*}{d\theta^*}\right]^{-1} \quad \text{for } x \in \{y, m, s, \ell\}$$

Note $d\bar{\Delta}^*/dx = \int_{\delta}^{\hat{\lambda}} \theta^* {dR(\lambda, s)}/{dx} d\lambda > 0$ for $x \in \{y, m, s\}$, thus they affect ξ^* only through R. Using (A.1)–(A.3) and $d\bar{\Delta}^*/d\theta^* > 0$, we have

$$\text{(A.11)} \quad \frac{d\theta^*}{dy} < 0 \qquad \& \qquad \frac{d\theta^*}{dm} > 0 \qquad \& \qquad \frac{d\theta^*}{ds} > 0.$$

Finally,

$$\begin{aligned}\frac{d\bar{\Delta}^*}{d\ell} &= \frac{d\hat{\lambda}}{d\ell}\left[\theta^* R(\hat{\lambda}, s) - 1\right]\frac{1}{1-\delta} + \int_{\delta}^{\ell}(1-\theta^*)\frac{1}{1-\lambda}\frac{d\lambda}{1-\delta} \\ &- \frac{d\hat{\lambda}}{d\ell}\left[\theta^* \frac{X(1-\ell)\left[1 - \frac{\hat{\lambda}-\ell}{\xi(1-\ell)}\right]}{1-\hat{\lambda}} - 1\right]\frac{1}{1-\delta} + \int_{\hat{\lambda}}^{\bar{\lambda}} \frac{X(1/\xi - 1)}{1-\lambda}\frac{d\lambda}{1-\delta} - \int_{\bar{\lambda}}^{1}\frac{1-\xi}{\lambda}\frac{d\lambda}{1-\delta}.\end{aligned} \tag{A.12}$$

Given that $d\hat{\lambda}/d\ell > 0$ from (7), all the terms in the above condition are positive apart from the last one, which means that the effect of ℓ on θ^* may be ambiguous. This is a typical property in bank-run models, and it is intuitive: It suggests that in the region of beliefs about redemptions that a run materializes, higher liquidity increases the payoff from redeeming because individuals can successfully redeem their tokens with higher probability. We derive below a (weak) sufficient—not necessary—condition for $d\bar{\Delta}^*/d\ell > 0$, which requires that the expected lending rate is below a threshold, supported by the data.

[2] Note that for the existence of a threshold equilibrium the strongest property of one-sided strategic complementarities is not needed and single-crossing of v suffices as Goldstein and Pauzner (2005) also point out. Given our focus on threshold equilibria, we do not make further assumptions.

Under the sufficient condition, we unambiguously obtain

$$\text{(A.13)} \quad \frac{\partial \theta^*}{\partial \ell} < 0.$$

Note that (A.13) can still hold in alternative parameterizations violating the sufficient condition but may also not hold. In the latter cases, the issuer would set $\ell = 0$, which is inconsistent with observed stablecoin reserve portfolios (see Section II.D. for issuer optimization problem).

Sufficient condition for $d\bar{\Delta}^*/d\ell > 0$. Substituting (9) in (A.12) we get that

$$\begin{aligned}
\frac{d\bar{\Delta}^*}{d\ell} = & \frac{d\hat{\lambda}}{d\ell}\left[\theta^* R(\hat{\lambda}, s) - 1\right]\frac{1}{1-\delta} + \int_{\delta}^{\ell}(1-\theta^*)\frac{1}{1-\lambda}\frac{d\lambda}{1-\delta} \\
& - \frac{1}{\ell}\int_{\delta}^{\hat{\lambda}}\left[\theta^* R(\lambda, s) + (1-\theta^*)\max\left(\frac{\ell-\lambda}{1-\lambda}, 0\right) - 1\right]\frac{d\lambda}{1-\delta} \\
& - \frac{d\hat{\lambda}}{d\ell}\left[\theta^*\frac{X(1-\ell)\left[1-\frac{\hat{\lambda}-\ell}{\xi(1-\ell)}\right]}{1-\hat{\lambda}} - 1\right]\frac{1}{1-\delta} - \frac{1}{\ell}\int_{\hat{\lambda}}^{\bar{\lambda}}\left[\theta^*\frac{X(1-\ell)\left[1-\frac{\lambda-\ell}{\xi(1-\ell)}\right]}{1-\lambda} - 1\right]\frac{d\lambda}{1-\delta} \\
& + \int_{\hat{\lambda}}^{\bar{\lambda}}\frac{X(1/\xi - 1)}{1-\lambda}\frac{d\lambda}{1-\delta} + \frac{1}{\ell}\int_{\bar{\lambda}}^{1}\frac{\xi}{\lambda}\frac{d\lambda}{1-\delta}.
\end{aligned} \tag{A.14}$$

Given that $d\hat{\lambda}/d\ell > 0$ from (7), the terms in the last two lines in (A.14) are all positive and, thus, we only need to sign the terms in the first two lines. Add and subtract $d\hat{\lambda}/d\ell \cdot (1-\theta^*) \cdot (\ell-\delta)/(1-\delta)^2$. Then, because (i) $dR(\lambda, s)/d\lambda > 0$ from (3), (ii) $d(\ell-\lambda)/(1-\lambda)/d\ell = -(1-\ell)/(1-\lambda)^2 < 0$, and (iii) $d(1-\lambda)^{-1}/d\lambda > 0$, the sum of the terms in the first two line is strictly higher than

$$\begin{aligned}
& \left[\frac{d\hat{\lambda}}{d\ell} - \frac{\hat{\lambda}-\delta}{\ell}\right]\left[\theta^* R(\hat{\lambda}, s) + (1-\theta^*)\max\left(\frac{\ell-\delta}{1-\delta}, 0\right) - 1\right]\frac{1}{1-\delta} \\
& + (1-\theta^*)\frac{\ell-\delta}{(1-\delta)^2}\left(1 - \frac{d\hat{\lambda}}{d\ell}\right).
\end{aligned} \tag{A.15}$$

The last term is strictly positive because $d\hat{\lambda}/d\ell = X(1-\xi)/(X-\xi) < 1$. Moreover,

$$\theta^* R(\hat{\lambda}, s) + (1-\theta^*)\max\left(\frac{\ell-\delta}{1-\delta}, 0\right) - 1 > \underline{\theta} R(\delta, s) + (1-\underline{\theta})\max\left(\frac{\ell-\delta}{1-\delta}, 0\right) - 1 = 0,$$

because $\theta^* > \underline{\theta}$ and $R(\hat{\lambda}, s) > R(\delta, s)$. If ${d\hat{\lambda}}/{d\ell} - {\hat{\lambda} - \delta}/{\ell} > 0 \Rightarrow \delta < {\xi(X-1)}/{X-\xi}$, then $d\bar{\Delta}^*/d\ell > 0$ always. For δ lower than that threshold, we can derive a sufficient condition for the lending rate such that the absolute value of the terms in the first line in (A.15) is lower than ${1}/{\ell} \int_{\hat{\lambda}}^{1} \frac{\xi}{\lambda} d\lambda$ and, thus, (A.14) is positive. The latter term is strictly higher than ${1}/{\ell}\dot{\xi} \log \xi$, while the absolute value of the former is strictly lower than ${1}/{\ell} \cdot {\xi(X-1)}/{(X-\xi)} \cdot (\max R - 1)$, where we considered the higher possible lending rate and set $\delta = 0$. Thus, it is sufficient that $\max R \leq -\log \xi \cdot {(X-\xi)}/{(X-1)}$ for $d\bar{\Delta}^*/d\ell > 0$. This condition is easily satisfied. For example, given an expected yield of 5% for the illiquid asset, i.e., $X = 2.1$, and a liquidity discount of 25%, i.e., $\xi = 0.75$, it is sufficient that the expected lending rate is lower than 35%, which is the case in our data. As mentioned, the sufficient condition on the lending rate is rather weak and we could be relaxed further if we consider the effect of the other positive terms in (A.14).

A.1.4 Derivatives of P with respect to y, m, s, ℓ

We show how P changes with the demand and riskiness of cryptocurrencies as well as the size and liquidity of the stablecoin. We first examine the effect stemming from the cryptocurrency demand, y, and riskiness, m, as well as the size of the stablecoin s. For $x \in \{y, m, s\}$ we have

$$\begin{aligned} \frac{dP}{dx} &= (1-\delta)\frac{dR(\delta,s)}{dx}\frac{1-(\theta^*)^2}{2} \\ &- \frac{d\theta^*}{\partial x}\left\{(1-\delta)\left[\theta^* R(\delta,s) + (1-\theta^*)\max\left(\frac{\ell-\delta}{1-\delta}, 0\right)\right] + \delta - (\ell + (1-\ell)\xi)\right\}. \end{aligned} \tag{A.16}$$

Using (A.1)–(A.3) and (A.11), and $\theta^* R(\delta, s) + (1-\theta^*)\max\left({(\ell-\delta)}/{(1-\delta)}, 0\right) > 1 > (\ell + (1-\ell)\xi)$ since $\theta^* > \underline{\theta}$, we have that

$$\frac{dP}{dy} > 0 \qquad \& \qquad \frac{dP}{dm} < 0 \qquad \& \qquad \frac{dP}{ds} < 0. \tag{A.17}$$

In other words, the higher the cryptocurrency demand, the lower the risk, or the smaller the stablecoin circulation is, the higher P is for two reasons. First, a higher y, and lower m or s, increase the payoff conditional on a run not occurring (first term in (A.16)). Second, the probability that a run does not occur increases with y, and decreases with m or s, as the incentives to run are lower, all else equal (second term in (A.16)).

Finally, a change in ℓ changes P according to

$$\frac{dP}{d\ell} = \int_{\theta^*}^{1} (1-\theta)\cdot(\ell > \delta) d\theta + \int_{0}^{\theta^*} (1-\xi) d\theta$$

(A.18)

$$- \frac{d\theta^*}{\partial \ell}\left[\theta^* R(\delta, s) + (1-\theta^*)\max\left(\frac{\ell-\delta}{1-\delta}, 0\right) - (\ell + (1-\ell)\xi)\right] > 0.$$

In other words, the higher the percentage of liquid assets in stablecoin reserves is, the higher P is for two reasons. First, a higher ℓ increases the probability of being paid conditional on a run occurring (first term in (A.18)). Second, the probability that a run does not occur increases with ℓ, all else equal (second term in (A.18)).[3]

A.2 Model Extension: Endogenous Margin Requirements

In the baseline model, we assume that the exchange sets margin m without considering how it should be chosen optimally between traders and investors. Given that levered lending takes place after run uncertainty is resolved, m should not depend on θ^*, but can depend on R. To derive an optimal m we consider a structure—akin to Fostel and Geanakoplos (2008)—under which traders offer investors a menu of contracts $k \in K$ described by a pair (R_k, m_k), where R_k is given, in equilibrium, by (3) for certain m_k. That is, traders offer investors a menu of contracts under all of which they break even. Given that these contracts are offered after redemptions λs have been observed, they are only parameterized by different m_k. Investors will then choose the contract that maximizes their utility.

To introduce a trade-off, we suppose for this extension that investors face a cost c for directly holding the cryptocurrency when the trader defaults. Recall from Section II.A. that R is the expected lending rate, incorporating the payoff when traders default, and that traders will default for cryptocurrency payoff realizations $\tilde{y} < y'_k$, i.e., y'_k is the threshold below which investors receive the collateral for margin m_k and is given by

$$\text{(A.19)}\quad y'_k = (1-m)R_{k,c} \quad \Rightarrow \quad y'_k = \frac{\bar{y}(1-m)R_k - {y'_k}^2/2}{\bar{y} - y'_k},$$

where we replaced the contractual lending rate, $R_{k,c}$, with the expected lending rate, R_k.

The probability that investors incur the cost c is equal to $\int_{\tilde{y}<y'_k} dF(\tilde{y})$. We assume $\tilde{y} \sim U[0, \bar{y}]$ for simplicity and, thus, $y = \bar{y}/2$. Investor's payoff from no redeeming is equal to

[3] As mentioned in Section II.B. if $d\theta^*/d\ell > 0$ and, hence, $dP/d\ell < 0$, then the issuer will choose $\ell = 0$. See the Online Appendix Section A.1.3 for a sufficient condition to exclude this case.

$\theta\left(R_k - c\int_{\tilde{y}<y'_k} dF(\tilde{y})\right) + (1-\theta)\max\left(\frac{\ell-\lambda}{1-\lambda}, 0\right)$. In other words, the expected return from lending the stablecoin, R, is curtailed by the expected cost of holding it when the trader defaults. Among all available contracts $(R_k(m_k), m_k)\ \forall k \in K$, the investor will choose the one that delivers the higher payoff. Given that R_k is a function of m_k, we only need to find the m_k that maximizes the investor's payoff, which is the solution to

(A.20)
$$\theta\frac{\partial R_k}{\partial m_k} - \theta c\frac{\partial y'_k}{\partial m_k}\frac{1}{\bar{y}} + \underline{\psi}_k - \overline{\psi}_k = 0$$

where $\underline{\psi_k}$ and $\overline{\psi}_k$ are the Lagrange multipliers on $m_k \geq 0$ and $m_k \leq \bar{m}$, where $\bar{m}$ is the maximum margin traders would be willing to post given by
$y - \bar{m}F'(e - {}^{m}/{}_{1-m}(1-\lambda)s) = 0$. Recall that ${}^{dR_k(\lambda,s)}/{}_{dm_k}$ is given by (A.2) and is negative. ${}^{dy'_k}/{}_{dm_k}$ is obtained by totally differentiating (A.19)

$$\text{(A.21)}\quad \frac{dy'_k}{dm_k} = \frac{\bar{y}}{\bar{y}-y'_k}\left((1-m)\frac{dR_k}{dm_k} - R_k\right) < 0.$$

For $m \to 0$, the first two terms in (A.20) converge to $y - (1 - {}^{c}/{}_{(\bar{y}-y'_k)})F'(e)$ and is positive only if $c \geq \bar{c} \equiv (\bar{y} - y'_k)(1 - {}^{y}/{}_{F'(e)}) > 0$ given the assumption $F'(e) > y$. For $m \to \bar{m}$, the sum of the first two terms converges to
${}^{dR_k}/{}_{dm_k}|_{m_k=\bar{m}}(1 - c/(\bar{y}-y'_k)(1-\bar{m})) < 0$. Moreover, the sum of the first two terms is strictly decreasing for $F'''' > 0$, which is typical for widely used concave technologies such as Cobb-Douglas production function, and we will assume herein. Hence, the contract that investors choose is unique and depends on the level of c.
Case I. If $c \leq \bar{c}$, then $\underline{\psi}_k > 0$, $\overline{\psi}_k = 0$, and $m_k = 0$, such that our baseline analysis carries through in its entirety.
Case II. If $c \geq \bar{c}$, m_k is interior, i.e., $\underline{\psi}_k = \overline{\psi}_k = 0$. In this case, m_k will be a function of y, λ, and s, and we need to show that our baseline results do not change. Essentially, we need to show that the derivatives of R_k with respect to $x \in \{y, \lambda, s\}$ do not change sign. We show that this is the case for sufficiently high c. Note that

$$\text{(A.22)}\quad \frac{dR_k}{dx} = \frac{\partial R_k}{\partial x} + \frac{\partial R_k}{\partial m_k}\frac{dm_k}{dx}.$$

Given that ${}^{\partial R_k}/{}_{\partial x}$ and ${}^{\partial R_k}/{}_{\partial m_k}$ are given by (A.1)-(A.4), we only need to sign ${}^{dm_k}/{}_{dx}$, which we can compute by totally differentiating (A.20):

$$\frac{dm_k}{dy} = -\frac{\frac{\partial^2 R_k}{\partial m_k \partial y}(\bar{y} - y_k' - c(1-m_k)) + \left(2 - \frac{\partial y_k'}{\partial y}\right)\frac{\partial R_k}{\partial m_k} + c\frac{\partial R_k}{\partial y}}{\frac{\partial^2 R_k}{\partial m_k^2}(\bar{y} - y_k' - c(1-m_k)) + \left(2c - \frac{\partial y_k'}{\partial m_k}\right)\frac{\partial R_k}{\partial m_k}}$$

(A.23)

$$\frac{dm_k}{dx} = -\frac{\frac{\partial^2 R_k}{\partial m_k \partial x}(\bar{y} - y_k' - c(1-m_k)) - \frac{\partial y_k'}{\partial x}\frac{\partial R_k}{\partial m_k} + c\frac{\partial R_k}{\partial x}}{\frac{\partial^2 R_k}{\partial m_k^2}(\bar{y} - y_k' - c(1-m_k)) + \left(2c - \frac{\partial y_k'}{\partial m_k}\right)\frac{\partial R_k}{\partial m_k}},\ \mathrm{x} \in \{\lambda, \mathrm{s}\}.$$

Since $F''' > 0$, ${}^{\partial^2 R_k}\!/_{\partial m_k^2} < 0$, and ${}^{\partial^2 R_k}\!/_{\partial m_k \partial y} > 0$, ${}^{\partial^2 R_k}\!/_{\partial m_k \partial \lambda} > 0$, ${}^{\partial^2 R_k}\!/_{\partial m_k \partial s} < 0$. Moreover, by totally differentiating (A.19), we get

$$\frac{dy_k'}{dy} = \frac{1}{\bar{y} - y_k'}\left(\bar{y}(1-m)\frac{\partial R_k}{\partial dy} + 2(1-m)R_k - 2y_k'\right)$$

(A.24)

$$\frac{dy_k'}{dx} = \frac{\bar{y}}{\bar{y} - y_k'}(1-m)\frac{\partial R_k}{\partial x},\ \mathrm{x} \in \{\lambda, \mathrm{s}\}.$$

Consider $c \to {}^{\bar{y}}\!/_{1-m_k}{}^{+}$. Then, using (A.21) and (A.24), we get

$$\text{(A.25)}\quad \frac{dm_k}{dy} = -\frac{\frac{(2\bar{y} - 2(1-m_k)R_k)}{(\bar{y} - y_k')}}{2c - \frac{dy_k'}{dm_k}} - \frac{c - \frac{\bar{y}}{(\bar{y} - y_k')}(1-m_k)\frac{\partial R_k}{\partial m_k}}{2c - \frac{\bar{y}}{(\bar{y} - y_k')}(1-m_k)\frac{\partial R_k}{\partial m_k} + \frac{\bar{y}}{(\bar{y} - y_k')}R_k}\frac{\partial R_k/\partial y}{\partial R_k/\partial m_k} < -\frac{\partial R_k/\partial y}{\partial R_k/\partial m_k},$$

$$\text{(A.26)}\quad \frac{dm_k}{d\lambda} = -\frac{c - \frac{\bar{y}}{(\bar{y} - y_k')}(1-m_k)\frac{\partial R_k}{\partial m_k}}{2c - \frac{\bar{y}}{(\bar{y} - y_k')}(1-m_k)\frac{\partial R_k}{\partial m_k} + \frac{\bar{y}}{(\bar{y} - y_k')}R_k}\frac{\partial R_k/\partial \lambda}{\partial R_k/\partial m_k} < -\frac{\partial R_k/\partial \lambda}{\partial R_k/\partial m_k},$$

$$\text{(A.27)}\quad \frac{dm_k}{ds} = -\frac{c - \frac{\bar{y}}{(\bar{y} - y_k')}(1-m_k)\frac{\partial R_k}{\partial m_k}}{2c - \frac{\bar{y}}{(\bar{y} - y_k')}(1-m_k)\frac{\partial R_k}{\partial m_k} + \frac{\bar{y}}{(\bar{y} - y_k')}R_k}\frac{\partial R_k/\partial s}{\partial R_k/\partial m_k} > -\frac{\partial R_k/\partial s}{\partial R_k/\partial m_k}.$$

Using the above, we get from (A.22) that ${}^{dR_k}\!/_{dy} > 0$, ${}^{dR_k}\!/_{d\lambda} > 0$, and ${}^{dR_k}\!/_{ds} < 0$, which means that qualitatively the derivatives of the lending rate with respect to x are the same as in the baseline analysis in Section II.A. where the margin was constant.

It follows that away from the limit, but for $c \geq \bar{c}$, it also suffices to establish the bounds in (A.25)-(A.27). These latter expressions for the bounds hold if

$$2\frac{\partial^2 R_k}{\partial m_k \partial x}\frac{\partial R_k}{\partial m_k} > \frac{\partial^2 R_k}{\partial m_k^2}\frac{\partial R_k}{\partial x},$$

which holds for all $x\{y, \lambda, s\}$ using (A.1)-(A.4) and the cross-derivatives above. Hence, endogenous margins may weaken quantitatively the effect of $\{y, \lambda, s\}$ on R_k—because ${}^{\partial R_k}/_{\partial m_k}$—but qualitatively do not matter.

A.3 Model Extension: Payment services from stablecoins

In this section, we introduce an additional source of demand for stablecoins arising from use cases other than speculation. Such services may accrue from facilitating cross-country payments, services offered exclusively by the digital-asset ecosystem, or tax evasion and illicit activities. The value of these services could be aggregated in a convenience yield V, which can be constant or depend on the number of stablecoins in circulation, that is $V(\lambda, s) \equiv V((1-\lambda)s)$ with ${}^{dV}/_{ds} < 0$ and ${}^{dV}/_{d\lambda} > 0$ following Krishnamurthy and Vissing-Jorgensen (2012). Then, the stablecoin payoff from not redeeming when the issuer does not default is given by $\theta\left(R(\lambda, s) + V(\lambda, s)\right) + (1-\theta)\max\left({}^{\ell-\lambda}/_{1-\lambda}, 0\right)$. A positive convenience yield increases the payoff and decreases the probability of a run *ceteris paribus*. Moreover, if the convenience yield decreases in the number of stablecoins, then the stabilization mechanism operating via the redemptions channel is strengthened. The stabilization mechanism via the liquid portfolio share continues to operate in the absence of a convenience yield.

A.4 Model Extension: Speculating on Stablecoin Collapse

In the baseline model, we considered that investors lent their stablecoins to traders, who want to take leverage on cryptocurrencies after run uncertainty has been resolved. Yet, traders may want to borrow the stablecoins before run uncertainty is resolved so that they can also speculate on the collapse of the stablecoin. The idea is that promised repayment is denominated in stablecoins and, thus, if the stablecoin price collapses to zero after a run, traders would need to repay zero without losing their pledged collateral.

We consider a very simple extension of the model to introduce this motive. There are two types of traders and investors: A and B. Both types are identical with the difference that type A traders borrow stablecoins from type A investors before $t = 1$, while type B traders borrow stablecoins from type B investors after $t = 1$. We assume that the tokens lent early are circulated back to other stablecoin investors, who want to lend them after run uncertainty is resolved at $t = 1$. Type A investors are of mass $1 - \delta$, which is equal to patient type B investors. Traders of both types have the same endowment and each type has its own, distinct, outside technology. A-traders still need to pledge collateral, thus they buy the cryptocurrency on margin as in the baseline model. Thus, the return on the outside options is given by $\rho_A = F'[e - {}^{m}\!/\!{(1-m)}(1-\delta)s]$ for A-traders and $\rho_B = F'[e - {}^{m}\!/\!{(1-m)}(1-\delta)s]$ for B-traders, in equilibrium when a run does not occur. The run decision for the B-investors is the same as in Section II.B. and the stablecoin price they are willing to offer is given by (11) with the difference that the lending rate will be different. Next, we derive the lending rate and the participation decision for the A-investors.

Denote by $\hat{R}$ the expected lending rate for borrowing before $t = 1$. As before, A-traders will break even with their outside option but in this case, they additionally do not need to repay anything when the stablecoin collapses in a run or when the issuer default conditional on a run not occurring, because the price of tokens goes to zero. Hence, their participation constraint is

(A.28)
$$\int_{\theta^*}^{1} [\theta(y - (1-m)\hat{R}) + (1-\theta)y] d\theta + \int_0^{\theta^*} y d\theta = m\rho_A,$$

yielding

(A.29) $$\hat{R} = \frac{y - m\rho_A}{1-m} \frac{2}{1-\theta^{*2}}.$$

The first term in the left-hand side of (A.28) is the payoff to A-traders conditional that a run does not occur: with probability θ ($\geq \theta^*$) the issuer is solvent and A-traders need to repay their stablecoin-denominated loan, while with probability $1-\theta$ the issuer is insolvent and tokens are worth zero, so A-traders can pocket the cryptocurrency return in its entirety. The second term in the left-hand side of (A.28) is the payoff to A-traders conditional on a run: A-traders pocket the whole cryptocurrency return because their stablecoin-denominated loan is worth zero. The right-hand side in (A.28) is the outside-option payoff.

Using (1) and (A.29), we can compare the lending rates for lending before and after $t = 1$, R and $\hat{R}$. It is easy to see that $\hat{R} > R$. This result is intuitive. Traders face a trade-off when borrowing early: If the run occurs, they gain a lot and are willing to offer high lending rates. But, if the run does not occur, they will pay higher lending rates with probability θ.

A.5 Token Supply and Stablecoin Liquidity Without Observability

In the paper we derive the optimal choice of s and ℓ under observability. However, as noted, the choice of ℓ may not be observable in real time contrary to s. The issuer may still use a combination of ℓ and s to maintain the peg in response to crypto-related shocks between $t = 0$ and $t = 1$ but cannot credibly commit to a certain choice of ℓ given that it is not observable. This information resembles an incomplete contract whereby the issuer may deviate from the choice of ℓ after the peg is stabilized (see Online Appendix in Kashyap et al. 2023). The issuer will maximize the profits accruing to them when choosing ℓ and s but will only internalize the effect of s and not ℓ on the peg stability condition $P = 1$. Yet, the issuer will still internalize the effect of both ℓ and s on the run threshold θ^*, since the run may happen later at $t = 1$. Then, the optimality condition with respect to ℓ is

$$\text{(A.30)}\quad \frac{1-(\theta^*)^2}{2}\frac{d\Pi(\delta)}{d\ell}s - \theta^*\Pi(\delta)s\frac{d\theta^*}{d\ell} = 0,$$

which together with $P = 1$ yields the optimal (ℓ, s). Comparing (A.30) to (14) we see that former misses a wedge W equal to

$$\text{(A.31)}\quad W = -\frac{{}^{dP}\!/_{d\ell}}{{}^{dP}\!/_{ds}}\Pi(\delta)\left(\frac{1-(\theta^*)^2}{2} - \theta^*\frac{d\theta^*}{ds}s\right).$$

For a given s, the issuer will choose a lower (higher) ℓ if $W > 0$ ($W < 0$) when ℓ is unobservable compared to the case that it is.[4] In turn, this means that the change in s should be higher (lower) to stabilize the peg for the same level of crypto-related shocks. Importantly, the issuer will use both stabilization mechanisms to maintain the peg even when ℓ is unobservable. The following Proposition shows that the sign of W depends on the level of run risk.

Proposition 3. *There exist a unique $\hat{\theta} \in (0,1)$ such that W in (A.31) is positive for $\theta^* < \hat{\theta}$ and negative for $\theta^* > \hat{\theta}$.*

The proof is straightforward. Since ${}^{dP}\!/_{ds} < 0$ and ${}^{dP}\!/_{d\ell} > 0$ from (A.17) and (A.18), the sign of W depends on the sum of the terms in the parenthesis, which is continuous in θ^*, negative for $\theta^* \to 1$ and positive for $\theta^* \to 0$, while ${}^{d\theta^*}\!/_{ds}$ is positive and increasing in θ^*. Hence, $\hat{\theta}$ exists and is unique. This result is intuitive. When ℓ is not observable, the issuer has an incentive to deviate but at the same time still internalizes how the choice of ℓ matters

[4] To see this, note that the solution under observable ℓ can be implemented in an environment where ℓ is not observable under a Pigouvian tax/subsidy on liquid holdings ℓ: A negative (positive) W calls for tax (subsidy), implying lower (higher) ℓ than in the unconstrained equilibrium with unobservable ℓ.

for run risk and, thus, their expected profits. If run risk is low, i.e., $\theta^* < \hat{\theta}$ and $W > 0$, the issuer deviates toward a lower ℓ, and vice versa if run risk is high. Investors anticipate this deviation and respond by redeeming more or fewer tokens compared to the case of observable ℓ.

Proposition 3 also has implications for the viability of the stablecoin when the speculative demand for cryptocurrencies wanes. In particular, suppose that there is a shock pushing y below $1 + m[F'(e) - 1]$. If ℓ is observable, the issuer would set $\ell = 1$ and keep the stablecoin running with $\theta^* = 0$, i.e., no run risk (Proposition 2). But, with unobservable ℓ, the issuer will have an incentive to deviate toward $\ell < 1$. Investors would anticipate this and redeem all their tokens immediately; otherwise, they would be exposed to run risk without the proper compensation. By continuity, the same would hold for y close to, but higher than, $1 + m[F'(e) - 1]$, even though expected lending rates would be (somewhat) higher than one for this level of y. Overall, stablecoins are not viable for low enough y under non-observability of ℓ, which also provides an additional rationale why issuers may want to disclose their reserves more frequently during crypto turmoil, similar to what USDC did in May 2022.

A.6 Positive interest on liquid assets

This section extends the baseline model to allow for a positive interest rate on the liquid assets. For simplicity and without loss of generality, we assume that the liquid asset pays off $r \geq 1$ from $t = 1$ to $t = 2$, while it continues to pay zero interest from $t = 0$ to $t = 1$. The case that $r = 1$ corresponds to a zero (net) interest rate in the baseline model. This extension should suffice for the purpose of studying how r matters for the $t = 2$ profits of the issuer and, hence, the choice of ℓ. To maintain a risk premium over the liquid asset we also set the illiquid asset payoff to be a function of r, i.e., $X(r)$.

The issuer's profits are then given by

$$\int_{\theta^*}^{1} \theta \left[X(r)(1-\ell)\left(1 - \frac{(\delta - \ell)^+}{\xi(1-\ell)}\right) + (\ell - \delta)^+ r - (1-\delta) \right]^+ s d\theta$$

(A.32)

$$+ \int_{\theta^*}^{1} (1-\theta) \left[(\ell - \delta)^+ r - (1-\delta) \right]^+ s d\theta.$$

The issuer will earn an interest rate on remaining liquid assets after repaying impatient investors, $\ell - \delta$; should the difference be positive. This may also allow the issuer to remain solvent even in the bad state that the illiquid asset pays zero. This requires that $r > \bar{r} = \frac{1-\delta}{(\ell-\delta)^+}$. Note that for $\ell \to 1$, which implies $\theta^* \to 0$, the profits are $(1-\delta)(r-1)s$.

If the issuer remains solvent in the bad state of the world, then investors could lend their tokens to traders and earn the lending rate. Denote by $\tilde{\lambda}$ the maximum level of withdrawals such that the issuer remains solvent in the bad state given by $\tilde{\lambda} = max\left(\delta, \frac{lr-1}{r-1}\right)$.

The run threshold θ^* is determined by

$$\bar{\Delta}^* = \int_{\delta}^{\tilde{\lambda}} [R(\lambda, s) - r] \frac{d\lambda}{1-\delta} + \int_{\tilde{\lambda}}^{\hat{\lambda}} \left[\theta^* R(\lambda, s) + (1-\theta^*) \left(\frac{\ell - \lambda}{1-\lambda}\right)^+ r - r\right] \frac{d\lambda}{1-\delta}$$

(A.33)

$$+ \int_{\hat{\lambda}}^{\overline{\lambda}} \left[\theta^* \frac{X(1-\ell)\left[1 - \frac{\lambda - \ell}{\xi(1-\ell)}\right]}{1-\lambda} - r\right] \frac{d\lambda}{1-\delta} - \int_{\overline{\lambda}}^{1} \frac{\ell + (1-\ell)\xi}{\lambda} r \frac{d\lambda}{1-\delta} = 0.$$

For $\lambda \in [\delta, \tilde{\lambda})$, the issuer is solvent both in the good and bad state, and investors can lend out their tokens. For $\lambda \in [\tilde{\lambda}, \hat{\lambda})$, the issuer defaults in the bad state but may invest any remaining liquidity $(\ell - \lambda)^+$ at $t = 1$ in the liquid asset to earn r, which increases the payoff from not withdrawing when the bad state realizes. The payoffs in other regions are as in the baseline model, though note that the payoff from withdrawing at $t = 1$ increases with r in all regions. Also, the cutoffs $\hat{\lambda}$ and $\overline{\lambda}$ are functionally the same due to the simplifying assumption that the liquid asset pays interest only from $t = 1$ to $t = 2$; however, changing r affects $\hat{\lambda}$ through $X(r)$. It is also easy to show that $\tilde{\lambda} \leq \ell < \hat{\lambda}$, i.e., the level of withdrawals needed to make the issuer insolvent in the good state is higher than the level needed for insolvency in the bad state.

The stablecoin price is given by

$$P = (r > \bar{r}) \cdot \int_{\theta^*}^{1} \{(1-\delta)R(\delta, s)/r + \delta\} \, d\theta$$

$$+ (r \leq \bar{r}) \cdot \int_{\theta^*}^{1} \left\{(1-\delta)\left[\theta R(\delta, s)/r + (1-\theta)\max\left(\frac{\ell - \delta}{1-\delta}, 0\right)\right] + \delta\right\} d\theta$$

(A.34)

$$+ \int_{0}^{\theta^*} (\ell + (1-\ell)\xi) d\theta,$$

where the $t = 2$ return from lending the token, $R(\delta, s)$, needs to be discounted by r but not the rest of the cash flow as they accrue at $t = 1$ and can thus earn r. Note that if $r > \bar{r}$, the issuer may be solvent in the bad state, and thus, investors can earn the lending rate in both states conditional on a run not occurring. Otherwise, if $r \leq \bar{r}$, investors receive pro-rata the remaining liquid resource in the bad state.

The issuer chooses ℓ and s to maximize (A.32) subject to $P = 1$, and with θ^* and P

be determined by (A.33) and (A.34). Figure A.5 plots the profits of the issuer, for different levels of ℓ and r, normalized over the profits for $\ell = 0.63$; this is an illustrative parametrization of the model, which should not be taken as a realistic calibration.[5] Nevertheless, the qualitative properties we highlight are general and do not depend on the choice of initial parameters. In particular, for both zero and positive but low-enough interest rates, the issuer optimally sets $\ell < 1$ to maximize profits, thus exposing the stablecoin to run risk. However, for a high enough interest rate, profits are maximized $\ell = 1$, alleviating any run risk.

A.7 Robustness for Measuring Expected Returns

We check that using Binance's BTC/USDT perpetual futures funding rate is a robust proxy for expected returns. One concern is that using the BTC/USDT perpetual futures as a proxy of y overweights idiosyncrasies specific to Bitcoin. In Table A.5, we show pairwise correlations of the BTC/USDT time series with several others. Binance also has perpetual futures that settle into Binance USD, another stablecoin, and we show that funding rates across perpetual futures are highly correlated regardless of which stablecoin they settle in. Another concern is that all futures funding rates on Binance reflect idiosyncrasies specific to Binance, rather than aggregate expected returns for cryptocurrency beyond Binance. We compare Binance's number with another large exchange, FTX, and find that funding rates are similar across the exchanges, confirming that the funding rates are not principally capturing exchange-specific factors. Finally, we show that perpetual futures funding rates are closely linked to expected returns embedded in crypto futures traded on the CME.

To address concerns about idiosyncrasies specific to Bitcoin, USDT, or Binance, we show correlations across several different contracts (BTC, ETH, and DOGE) settled in different types of stablecoins (USDT, BUSD, and FTX's USD) and across both Binance and FTX. We include DOGE as it is known as a highly speculative currency and was arguably started as a joke. The last two columns are the expected return measures we infer from CME futures, which we describe below. Combined, all the series are highly correlated, indicating that variation in our main measure of y, BTC/USDT on Binance, is not principally reflecting something specific to BTC, USDT, or Binance instead of speculative expected returns. measures

We can also proxy for y using the expected return embedded in crypto futures traded on the CME. Unlike the highly levered offshore perpetual futures, these futures are vanilla

[5]We have set $y = 4$, $m = 0.1$, $e = 1$, $F(x) = \zeta x^{\alpha}$ with $\zeta = 2$ and $\alpha = 0.5$, $\delta = 0.55$, $\xi = 0.4$, and $X = 1.4r + 0.6$. We have considered three cases for r: $r = 1.0$ (zero interest rate), $r = 1.2$ (positive and low-enough interest rate), and $r = 1.4$ (positive and high-enough interest rate).

futures and like equity index futures. The CME sets the rules for the derivatives, and they have standard monthly expirations. These crypto futures are widely used by U.S.-based institutional investors who want to speculate on the price of Bitcoin or Ether but are unwilling or unable to hold cryptocurrencies directly. While the futures have embedded leverage, they are considerably less levered than the offshore perpetual futures.[6]

We calculate expected returns y for Bitcoin and Ether using the futures prices. Let $F_{t,t+n}$ denote the price of a future at time t with delivery at $t+n$, and let $z_{t,t+n}$ denote the n-period discount factor implied by the risk-free rate. We can infer expected returns using a no-arbitrage argument comparing the present value of $F_{t,t+n}$ and $F_{t,t+n+1}$. The expected return is

$$\text{(A.35)} \quad \mathbb{E}_{t,t+n \to t+n+1}[y] \equiv \left(\frac{z_{t,t+n+1}}{z_{t,t+n}}\right) \frac{F_{t,t+n+1}}{F_{t,t+n}}$$

We use the overnight-indexed swap curve to estimate the n-period discount factors: $z_{t,t+n} = 1/(1 + y^{\text{OIS}}_{t,t+n}/12)^{(1/12)}$ where $y^{\text{OIS}}_{t,t+n}$ is the n-month OIS yield. We prefer to use consecutive futures rather than the front-month future versus the spot because the futures include leverage which may introduce a bias relative to the spot price.

In principle, we can use the ratio of contracts with any expiration to calculate expected returns between the two contracts' expirations. We focus on the first and second front-month contracts for two reasons. First, using the shortest maturity contracts helps control for any distortions introduced by an upward-sloping term structure of risk premia. Second, the liquidity of derivative contracts falls considerably at longer terms.

Figure A.6 plots our measure of expected returns for Bitcoin and Ether. Given the tremendous bull market in cryptocurrencies over the past several years, expected returns are almost always positive, although they dipped negative in late 2018 and briefly during the 2020 pandemic. The average expected return for Bitcoin using the measure is 5.0% from December 2017 to November 2022, ranging from −10.8% in December 2018 to 23.5% in February 2021. The ETH expected return has a shorter history because the future was introduced later, but from February 2021 to November 2022 it averaged 4.8% with a standard deviation of 7.3% compared to BTC's 3.9% average and 5.3% standard deviation over the same period.

We test the model's prediction that lending rates are increasing in y by regressing

[6] As of June 2022, the CME requires 50 percent (60 percent) margin for BTC (ETH) futures, allowing roughly 1× (0.67×) leverage. See `https://www.cmegroup.com/markets/cryptocurrencies.html`.

Tether's lending rate on FTX on our measure of expected returns using

$$\text{USDT Lending Rate}_t = \alpha + \beta \mathbb{E}[Ret^{BTC}] + \gamma X_t + \varepsilon_t$$

where X_t is a vector of controls. Table A.6 shows the regression results. A 1pp increase in $\mathbb{E}[Ret^{BTC}]$ increases the stablecoin lending rates by between 0.8 and 1.4pp, depending on the control variables. Across all specifications, there is a positive and significant relationship between lending rates and expected returns. Figure A.7 is a scatter plot between expected returns on Bitcoin and Tether lending rates showing a positive relationship.

One concern is that we confound expected speculative returns with the term structure of risk premium. We control for this problem by including an expected return for the SPX equity index using the same logic: we compare the present value of the first and second front-month for the SPX. Including this control in column (6) does not change the statistically strong relationship between expected returns and lending rates.

A.8 Appendix Figures

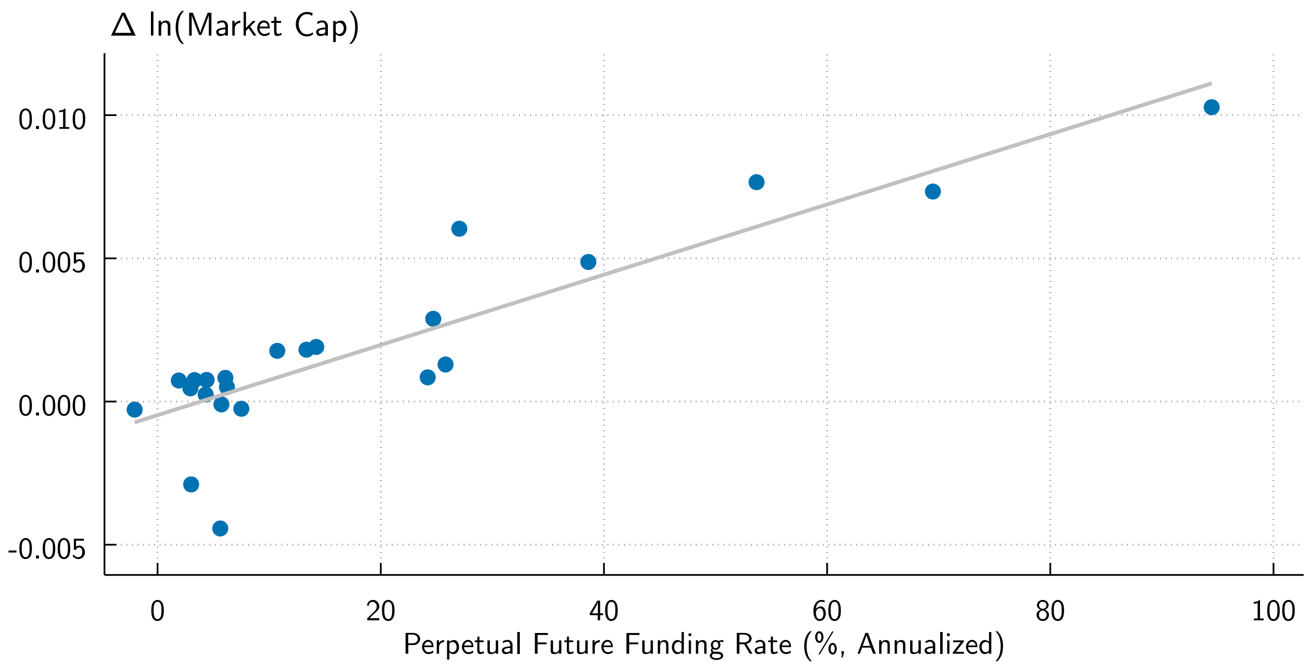

Figure A.1: Speculation and USDT Market Cap. Figure plots the monthly average of the daily perpetual future funding rate and daily change in Tether's market cap.

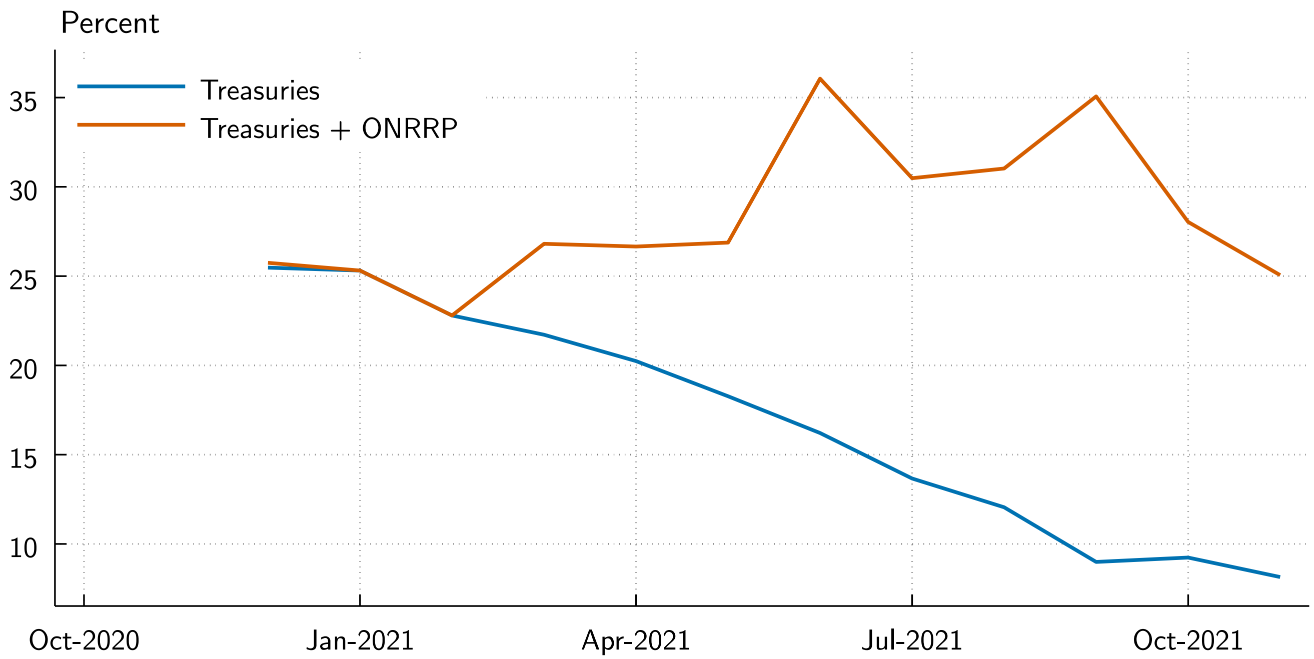

Figure A.2: Prime Money-Market Mutual Fund Holdings of Treasuries and ONRRPs. Figure the ratio of total prime money fund assets held in Treasuries or in Treasuries plus investments at the Federal Reserve. Data from the Office of Financial Research's U.S. Money Market Fund Monitor.

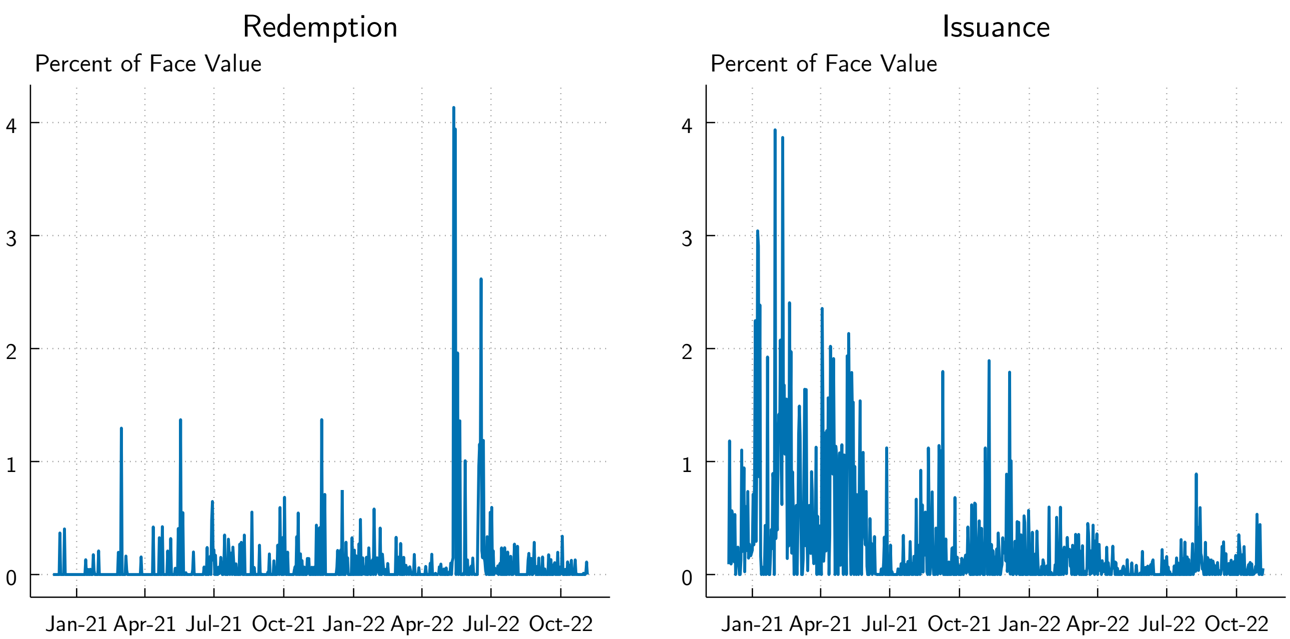

Figure A.3: Tether Redemptions and Issuance. Left panel plots the daily redemptions and issuance of Tether as a percent of its face value. Redemptions are defined as the change in the face value of the stablecoin's market capitalization on date t divided by the face value on date $t-1$ for days with net redemptions, and zero otherwise. Right panel plots the analogous measure for days with net issuance, and zero otherwise.

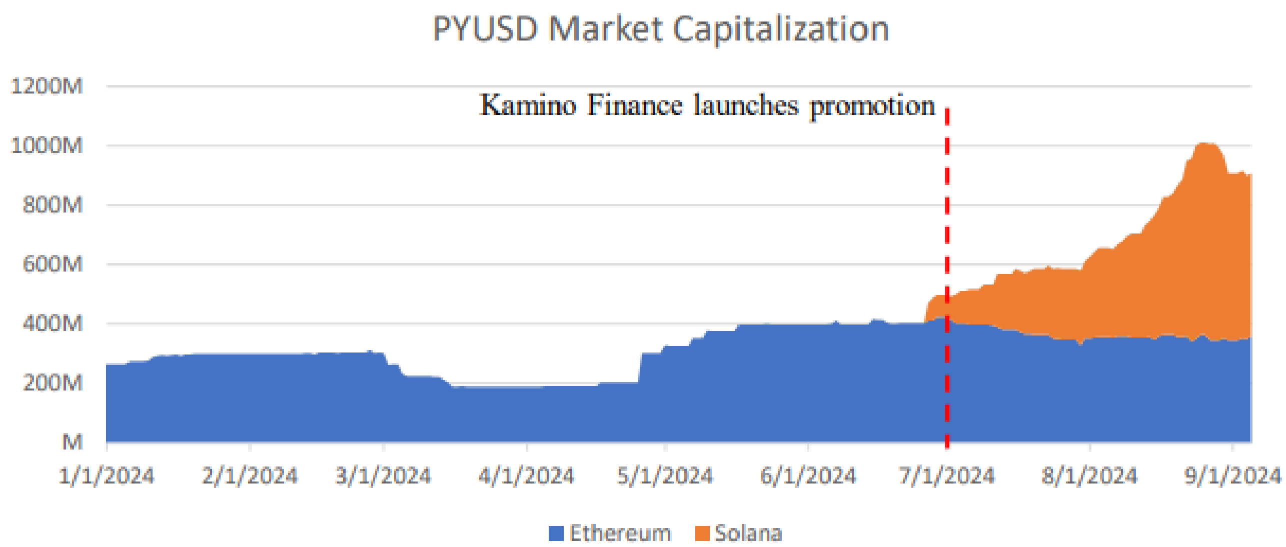

Figure A.4: PYUSD and Kamino. Figure plots the market capitalization of PYUSD before and after the introduction of the Kamino lending platform in Solana.

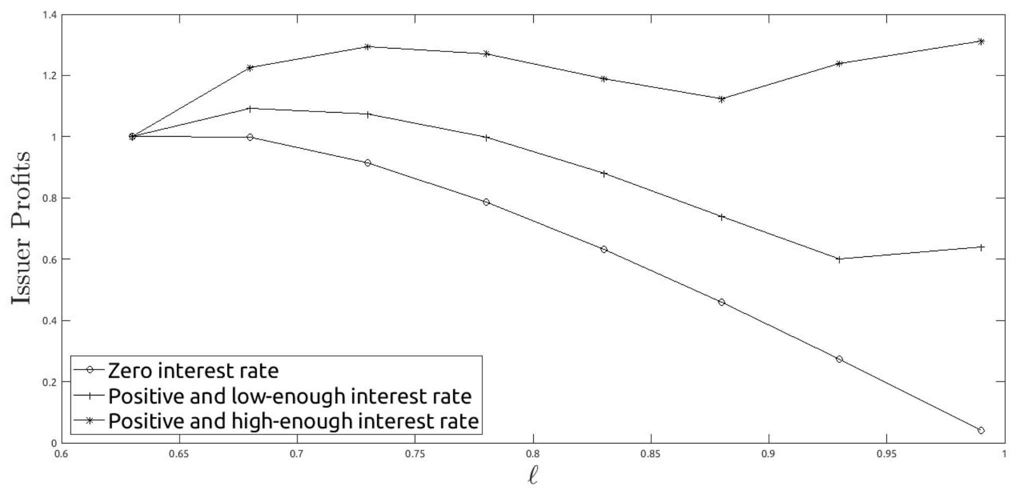

Figure A.5: Stablecoin issuer's profit for different ℓ and r.

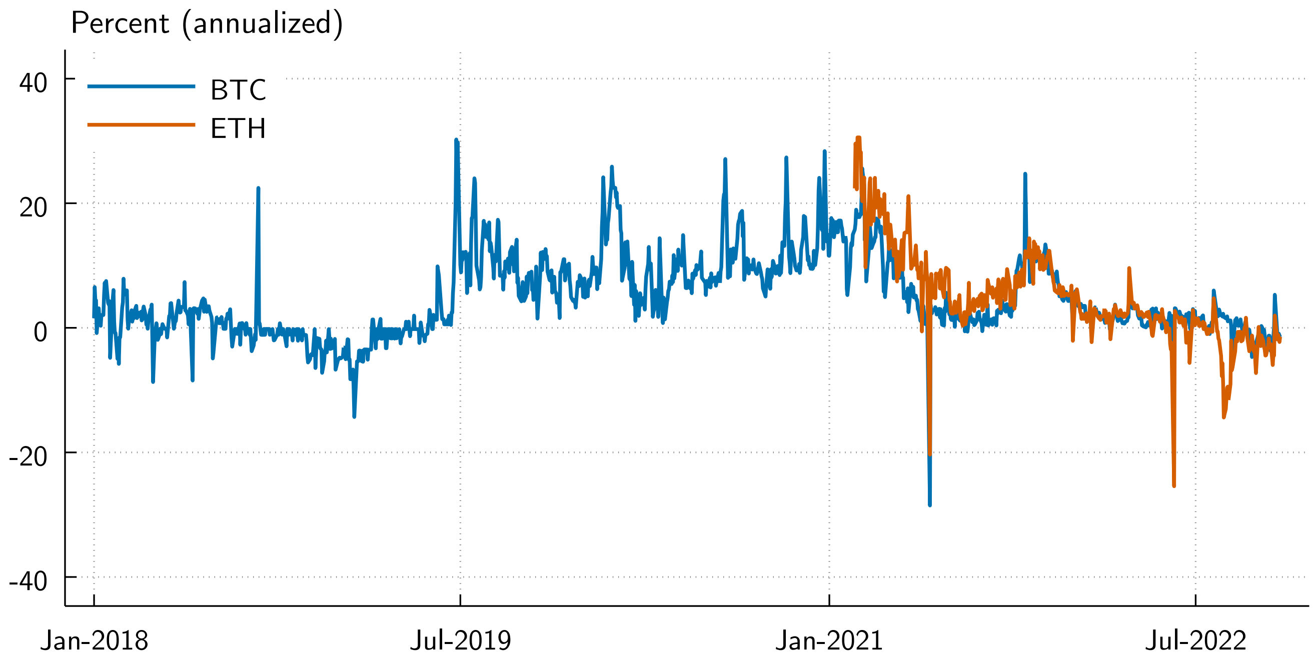

Figure A.6: Futures-Implied Expected Returns Figure plots the one-month/one-month expected return on Bitcoin and Ether estimated using the difference in present values for one-month futures prices relative to two-month futures prices. Present values are calculated using OIS interest rates, and futures prices are CME future prices.

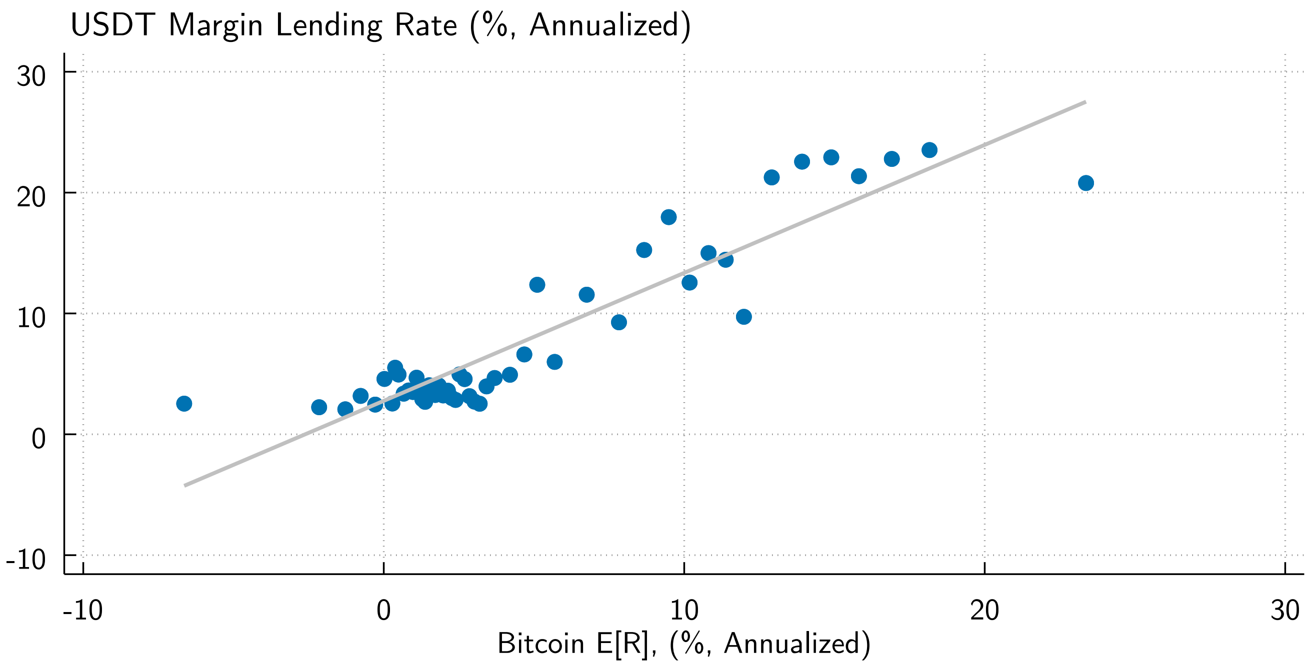

Figure A.7: Stablecoin Lending Rates and Futures-Implied Expected Returns. Figure plots a binscatter of the one-month/one-month expected return on Bitcoin against USDT's margin lending rate on the FTX exchange.

A.9 Appendix Tables

Haircut (%)	**Coin**	**Ticker**	**FTX**	**Binance**	**Bitfinex**	**Kraken**
Major Coins	Bitcoin	BTC	5	5	0	0
	Ether	ETH	10	5	0	0
	Cardano	ADA	*n.a.*	10	70	10
	Ripple	XRP	10	15	50	*n.a.*
	Solana	SOL	15	10	30	10
	Dogecoin	DOGE	10	5	80	*n.a.*
	Litecoin	LTC	10	10	0	30
	Avalanche	AVAX	15	20	80	50
	Tron	TRX	15	50	70	50
Stablecoins	Tether	USDT	5	0	0	10
	USD Coin	USDC	0	0	0	10
	Binance USD	BUSD	0	0	*n.a.*	*n.a.*
	Dai	DAI	15	*n.a.*	25	10
Average	Major Coins		11	14	42	21
	Stablecoins		5	0	8	10

Table A.1: Haircuts. The Table gives haircuts across FTX, Binance, Bitfinex, and Kraken. FTX haircut is 1 minus the initial weight; Binance haircut is 1 minus the collateral rate. Average is an unweighted average of the haircuts in the corresponding rows above. Collateral haircuts updated as of November 2022, except Binance numbers are October 2022. A lower haircut implies that a larger share of the asset's nominal price can be used to back a levered position. While there is heterogeneity across exchanges, stablecoins have lower haircuts. Note that exchange deposits are economically equivalent to a non-tradeable stablecoin issued by the exchange and have similarly low haircuts. Suppose a trader wants to use ten times leverage to buy \$100 of BTC. The margin requirement depends on the trader's collateral. Using Binance haircuts, if the trader posts AVAX as collateral, they must provide $\$10/(1-20\%) = \$12.5$ of AVAX. If, however, the trader posts USDT as collateral, they need to post only $\$10/(1-0\%) = \$10$ of USDT. Posting a stablecoin as collateral requires 20% less equity capital from the trader.

	1 Largest	3 Largest	5 Largest	10 Largest	All
	1	2	3	4	5
FTX Tether Lending Rate$_t$	0.05***	0.03***	0.02**	0.03*	0.03***
	(23.77)	(2.70)	(2.04)	(1.91)	(4.39)
N	273	673	1,074	1,989	5,668
R^2	0.31	0.14	0.04	0.03	0.09
TVL Weighted	No	No	No	No	Yes
Avg. TVL ($ millions)	183	150	104	65	15

Table A.2: FTX Lending Rates and Defi Lending Rates. Table presents regression $R_{j,t}^{Defi} = \alpha + \beta_1 R_t^{USDT} + \varepsilon_{i,t}$ where R_t^{USDT} is Tether's margin lending rate from the FTX exchange and $R_{j,t}^{Defi}$ is the lending rate at the Defi lending platform j. Defi lending rates from DefiLlama, spanning all protocols in the lending category that include Tether. Observations are daily, and we winsorize defi lending rates at the 5 and 95 percentile to reduce the influence of outliers. Protocols are calculated using their average 2022 total value lock (TVL) in US dollars. Column 5 includes all protocols in the sample and weights the regression by the protocol's average 2022 TVL. "Avg. TVL" row provides the average total value lock of the protocols in the given sample. Constant omitted. t-statistics are reported in parentheses using robust standard errors, where * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	USDT	DAI
	ΔEFFR_t	ΔEFFR_t
$\Delta R_{i,t}$	-0.007	0.000
	(0.87)	(0.99)
N	486	450

Table A.3: Correlation of FTX Lending Rates and Fed Funds Rate. Table presents the correlation of FTX lending rates for stablecoin i, $R_{i,t}$, with the effective federal funds rate where * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	USDT			USDT and DAI		
	1	2	3	4	5	6
$\Delta \ln(s_{i,t})$	-2.65^{**}	-3.65^{**}	-4.42^{***}	-1.03^{*}	-1.23^{**}	-1.33^{**}
	(-2.57)	(-2.55)	(-3.00)	(-1.89)	(-2.07)	(-2.18)
Bitcoin Implied Volatility$_t$			-10.66			-9.25
			(-1.42)			(-1.25)
$\Delta \ln(s_{i,t-1})$			1.01			-0.55
			(0.69)			(-1.22)
$\ln(s_{i,t-1})$			-4761.72^{***}			-806.44^{**}
			(-2.69)			(-2.28)
N	704	704	704	1,353	1,353	1,353
R^2	0.01	0.02	0.04	0.00	0.01	0.01
Month FE	No	Yes	Yes	No	Yes	Yes
Coin FE	n/a	n/a	n/a	No	Yes	Yes

Table A.4: Outside Option Return and Stablecoin Volume. Table presents regression $\Delta\rho_t = \alpha + \beta_1 \Delta \ln(s_{i,t}) + \gamma' X + a_i + b_t + \varepsilon_{i,t}$ where $\Delta\rho_t$ is the change in the outside option ρ_t, $\Delta \ln(s_{i,t})$ is the change in the log change in the face value of stablecoin i (either USDT or USDT and DAI), X is a set of controls, a_i is a stablecoin fixed effect, and b_t is a time fixed effect. We define the outside option $\rho_t = y_t - (1-m)R_t$ where y_t is proxied by the future funding rate, R_t is the FTX lending rate for the given stablecoin, and we assume $m = 0.2$. t-statistics are reported in parentheses using robust standard errors and clustered by week, where * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	BTC/USDT Binance	ETH/USDT Binance	BTC/BUSD Binance	DOGE/BUSD Binance	BTC/USD FTX	ETH/USD FTX	$\mathbb{E}[R^{BTC}]$ CME	$\mathbb{E}[R^{ETH}]$ CME
BTC/USDT, Binance	1.00							
ETH/USDT, Binance	0.89***	1.00						
BTC/BUSD, Binance	0.81***	0.70***	1.00					
DOGE/BUSD, Binance	0.64***	0.59***	0.65***	1.00				
BTC/USD, FTX	0.83***	0.79***	0.76***	0.59***	1.00			
ETH/USD, FTX	0.75***	0.87***	0.65***	0.51***	0.80***	1.00		
$\mathbb{E}[R^{BTC}]$	0.65***	0.62***	0.55***	0.50***	0.66***	0.61***	1.00	
$\mathbb{E}[R^{ETH}]$	0.65***	0.62***	0.57***	0.55***	0.64***	0.56***	0.83***	1.00

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.5: Correlation of Expected Return Proxies. Table presents the pairwise correlations of several perpetual futures funding rates and the expected return inferred using CME crypto futures. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	Bitcoin		Ether		Both	
	1	2	3	4	5	6
$\mathbb{E}[Ret^{BTC}]$	1.05***	0.51***			0.55***	0.64***
	(7.64)	(3.16)			(2.76)	(2.87)
Ret^{BTC}		0.23***				0.37***
		(2.86)				(3.01)
$\mathbb{E}[Ret^{ETH}]$			0.78***	0.15	0.45***	−0.14
			(8.10)	(0.94)	(4.06)	(−0.73)
Ret^{ETH}				0.09		−0.15
				(1.35)		(−1.52)
$\mathbb{E}[Ret^{S\&P}]$						0.05
						(0.60)
N	924	924	868	868	868	868
R^2	0.35	0.51	0.35	0.50	0.38	0.52
Month FE	No	Yes	No	Yes	No	Yes
Coin FE	No	Yes	No	Yes	No	Yes

Table A.6: Stablecoin Interest Rates and Expected Returns. Table presents regression $R_{t,i} = \alpha + \beta_1 \mathbb{E}_t[Ret^i] + \beta_2 Ret^i + a_i + b_t + \varepsilon_{i,t}$ where $R_{t,i}$ is the lending rate for stablecoin i, either USDT or DAI, $\mathbb{E}_t[Ret^j]$ is the one-month/one-month expected returns for coin j—either Bitcoin and Ether—Ret^j is the contemporaneous price returns on Bitcoin and Ether, a_i is a stablecoin fixed effect, and b_t is a time fixed effect. Observations are daily; the Bitcoin-only sample in columns (1) and (2) runs from December 2020 to November 5, 2022, and the remaining columns with Ether run from February 2021 to November 5, 2022. t-statistics are reported in parentheses using robust standard errors and clustered by week, where * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	Lending Rate R_t					
	USDT			DAI		
	1 Day	1 Week	4 Weeks	1 Day	1 Week	4 Weeks
	1	2	3	4	5	6
Futures $\widehat{\text{Funding}}$ Rate$_t$	0.182	0.207	0.315	0.178	0.131**	−0.153
	(1.540)	(1.339)	(0.654)	(1.479)	(2.019)	(−0.710)
R_{t-1}	0.606***	0.519***	0.437	0.500***	0.556***	0.674***
	(4.761)	(2.992)	(1.005)	(6.712)	(7.221)	(4.719)
Bitcoin Implied Volatility$_t$	−0.033	−0.039	0.009	−0.060	−0.044	0.011
	(−0.733)	(−0.725)	(0.181)	(−1.193)	(−1.506)	(0.468)
$\Delta \ln(s_{i,t})$	−0.007*	−0.004	−0.005	−0.003	0.000	0.006
	(−1.773)	(−1.332)	(−0.569)	(−0.922)	(0.031)	(1.256)
N	258	258	258	258	258	258
F-stat	1.88	1.25	0.33	2.45	1.47	0.96
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Table A.7: Instrumental Variables Placebo Regression of Futures Funding Premia and Lending Rates. Instrumental variables regression using the mean household rating of MLB games on a given day in the future as an instrument to predict the perpetual futures funding premium. Table presents several placebo tests using viewership data from the future as the instrumental variable: either 1 day, 1 week, or 4 weeks in the future. Time FE indicates day of week, month of year, and year fixed effects. Kleibergen-Paap rk Wald F statistics reported. t-statistics are reported in parentheses using robust standard errors and clustered by week where * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Instrument: Household Rating × Championship Leverage Index				
	Lending Rate R_t			
	USDT		DAI	
	1	2	3	4
Futures $\widehat{\text{Funding}}$ Rate$_t$	0.342***	0.217***	0.252***	0.162***
	(10.872)	(3.280)	(4.019)	(3.660)
Bitcoin Implied Volatility$_t$	0.032	0.030	−0.028	−0.027
	(0.366)	(0.424)	(−0.597)	(−0.860)
$\Delta \ln(s_{i,t})$	−0.008	−0.005	−0.009***	−0.006**
	(−1.246)	(−1.149)	(−2.673)	(−2.331)
R_{t-1}		0.406*		0.512***
		(1.925)		(6.302)
N	245	245	245	245
F-stat	24.84	7.11	22.48	21.01
Time FE	Yes	Yes	Yes	Yes

Table A.8: Instrumental Variables Regression of Futures Funding Premia and Lending Rates with Championship Leverage Index. Instrumental variables regression using the mean household rating of MLB games on a given day as an instrument to predict the perpetual futures funding premium. Instrument is the product of the Household Rating and the Championship Leverage Index. The Championship Leverage Index (cLI) is a common sabermetrics estimate of the importance of a game to a team's chances of winning the World Series. cLI data provided by Baseball Reference for the regular season, and we manually calculate it for playoff games. The cLI is standardized so that its value is 1 for the average game. Time FE indicates day of week, month of year, and year fixed effects. Kleibergen-Paap rk Wald F statistics reported. t-statistics are reported in parentheses using robust standard errors and clustered by week where * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	BTC		ETH		DOGE	
	1	2	3	4	5	6
Rating	0.14	0.15	0.23	0.23	0.36*	0.40**
	(1.18)	(1.27)	(1.29)	(1.29)	(1.93)	(2.25)
Constant	−0.14	−0.13	−0.11	−0.01	−0.27	0.26
	(−0.56)	(−0.43)	(−0.34)	(−0.01)	(−0.81)	(0.34)
N	258	258	258	258	258	258
R^2	0.00	0.04	0.00	0.04	0.01	0.04
Day-of-Week FE	No	Yes	No	Yes	No	Yes

Table A.9: Speculative Returns and Household Rating. Table presents regression $Ret_{i,t} = \alpha + \beta \text{Household Rating}_t + b_t + \varepsilon_{i,t}$ where $Ret_{i,t}$ is the price return of coin i—where i is Bitcoin, Ether, or Dogecoin—Household Rating_t is the household rating of nationally televised MLB games on date t, and b_t are day of week fixed effects. Observations are daily. t-statistics are reported in parentheses using robust standard errors and clustered by week, where * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.