Designing Stable Coins

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Based on the paper by Yizhou Cao, Min Dai, Steven Kou, Lewei Li, and Chen Yang

Outline

Introduction

- Fintech is a new word. Fintech vs. Techfin
- "Fintech takes the original financial system and improves its technology. Techfin is to rebuild the system with technology." Jack Ma from Alibaba, *South China Morning Post*, Dec 2, 2016.
- Neither IT issues nor philosophical issues will be discussed.
- Fintech = Quantitative Finance 2.0?

A New Journal: Digital Finance

- To be published by Springer.
- Co-editors, Wolfgang Hardle from HU Berlin and myself
- Professors Min Dai and Ying Chen are in the editorial board.
- Subject fields:
    - Cryptocurrencies
    - Blockchain Technology
    - Robo Advising
    - Text Mining
    - P2P Financing
    - Financial Privacy Issues
    - Digital Banking
    - Internet Finance
    - Financial Inclusion

Background

- Bitcoin, ETH, and other cryptocurrencies—distributed payment systems
  - A peer-to-peer network: A payment from one user to another is processed without any intermediary.
  - Blockchain: All transaction records are stored by every user.
  - Anonymous payment: Anonymous transaction orders are recorded to Blockchain, after miners' verification, and updated to all users immediately.
- Benefits of using cryptocurrencies
  - Low cost without intermediary
  - Easy to maintain the ledger inside the Blockchain system
  - Privacy

The Need for Stable Coins

- Stable coins can be used within the Blockchain to settle payments.
- Stable coins can be used in crypto money market accounts.
- Stable coins can be used by miners, who may find that it is difficult to convert the mined coins into traditional currencies in some countries.
- The existing cryptocurrencies are too volatile to be served as stable coins.

ETH Coin

ETH/USD price data from 1 Oct 2017 to 28 Feb 2018.

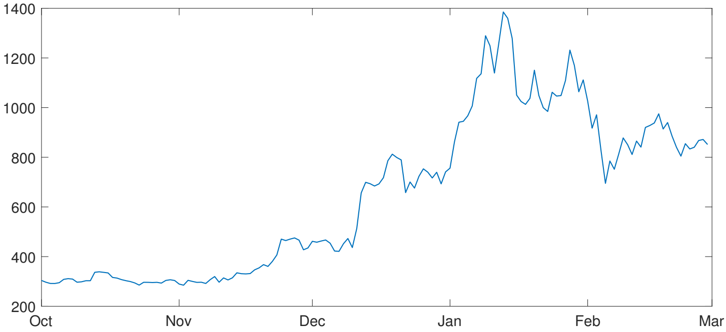

Figure: ETH/USD Price from 1 Oct 2017 to 28 Feb 2018

The Need for Stable Coins

- How to create stable coins?
- "The Holy Grail of Cryptocurrency" (Forbes, March 12, 2018, The Sydney Morning Herald, Feb 22, 2018, Yahoo Finance, Oct 14, 2017)
- There are at least 3 existing ways to issue stable coins in Blockchain networks.

Existing Stable Coins (1)

- Issuance backed by accounts in cash, gold, oil, etc.: One has certain assets and issues tokens that represent a claim on the underlying asset.
  - The most famous one is Tether, which 100% backed by USD. The conversion rate is 1 tether USDT equals 1 USD. Disadvantage: The total assets is about \$62.46 million, but the total liabilities is \$63.014 million, with a negative equity more than half million.
  - Tokens are claimed to link to gold, although it is difficult to verify the claims, e.g. Digix, GoldMint, Royal Mint Gold, OzCoinGold, ONEGRAM.
  - Petro, issued by Venezuela and backed by one barrel of oil.

Existing Stable Coins (2)

- Issuance backed by over-collateralized cryptocurrencies with automatic exogenous liquidation.
  - For example, one can generate \$100 worth of stable coins by depositing \$150 worth of Ether. The collateral will be sold automatically by the smart contract, if the Ether price reaches \$110.
  - Examples include token issued by BitShares and MakerDAO.

Existing Stable Coins (3)

- Automatic adjustment of the quantity of coin supply, called seigniorage shares.
  - When the price is too high, new coins are issued. When the price is too low, bonds are issued to remove coins from circulation.
  - Examples include Basecoin, etc.

Government-Backed Stable Coins

- Besides Venezuela, other countries are considering issuing cryptocurrencies, including Russia, China (Bloomberg news, Feb 13, 2018).
- CAD-coin: Canadian government also did "Project Japser", in which a Blockchain network is built for domestic interbank payments settlement.
- Fedcoin: There is a virtual currency working group under the Federal Reserve System in U.S. The Fedcoin is used internally.
- "The goal is to create a stable (less price volatility) and dependable cryptocurrency that delivers the practical advantages of Bitcoin even if this means involving the central government and abandoning the Libertarian principles that many believe underlay Bitcoins creation." Rod Garrett (2016).

Government Backed Stable Coins

There are several advantages of issuing stable coins by governments

- They are cheaper to produce than the cash in bills or coins, and stable coins are never worn out.
- They can be tracked and taxed automatically by the Blockchain technology.
- They can facilitate statistical works, such as GDP calculation and collecting consumer data.
- They cannot be forged (at least in theory).
- They can simplify legal money transfers inside and outside Blockchains.

The first countries that adapt stable coins will likely see the inflow of money from people who want stable currencies on Blockchains.

Our Contribution

- Inspired by the dual purpose funds popular in the US and China, we design, for the first time to our best knowledge, several dual-class structures that offer entitlements to either fixed income stable coins (class A coins) pegged to a traditional currency or leveraged investment opportunities (class B coins).
- Due to downward resets, a vanilla A coin behaves like a corporate bond with the collateral amount being reset automatically.
- The vanilla A coin can be further split into additional coins, A' and B' or A0 and A1, to reduce volatility.
- Unlike traditional currencies, these new class A coins record all transactions on a blockchain without centralized counter parties.
- By using the option pricing theory, we show that proposed stable coins indeed have very low volatility; indeed the volatility of A' and A0 are similar to that of the short term U.S. treasury bonds.

Practical Usages

- The design of stable coins can be used alone in most cases, except in the case of Black Swan events, when the underlying cryptocurrency suddenly drops close to zero within an extremely short time period.
- This is like the top tranche of a CDO contract. If the correlation of all firms covered within the CDO are close to 1, then one firm defaults leads to almost all other firms default.
- To be truly stable, stable coins need a guarantee in the Black Swan events.
- When combined with insurance from a government, similar to FDIC insurance, the design can also serve as a basis for issuing a sovereign cryptocurrency via a private-public partnership.
- By doing so, the government can let the private sector do the job of issuing stable coins, except to provide insurance in rare cases, saving government human and financial resources.

Vanilla A Coin, Overview

- The dual-purpose funds with dividend payments in U.S. were investigated both theoretically and empirically in Ingersoll (1976), Jarrow and O'Hara (1989), and Adams and Clunie (2006).
  - Finite time horizon, no resets.
  - Standard Black-Scholes PDE.
- China dual-purpose funds with fixed income payments, A and B shares (Dai, Kou, Yang and Ye (2017)).
  - Infinite time horizon, upward and downward resets cause changes of the prices of the underlying asset, but not the exchange ratio of the shares.
  - Periodic PDE with nonlocal terminal and boundary conditions, time dependent lower boundary and time independent upper boundary.
- Our vanilla A and B coins:
  - Infinite time horizon, upward and downward resets cause changes of the exchange ratio of the shares, but not the prices of the underlying asset.
  - Periodic PDE with nonlocal terminal and boundary conditions, time dependent lower boundary and time *dependent* upper boundary.

Vanilla A Coin, Initial Split

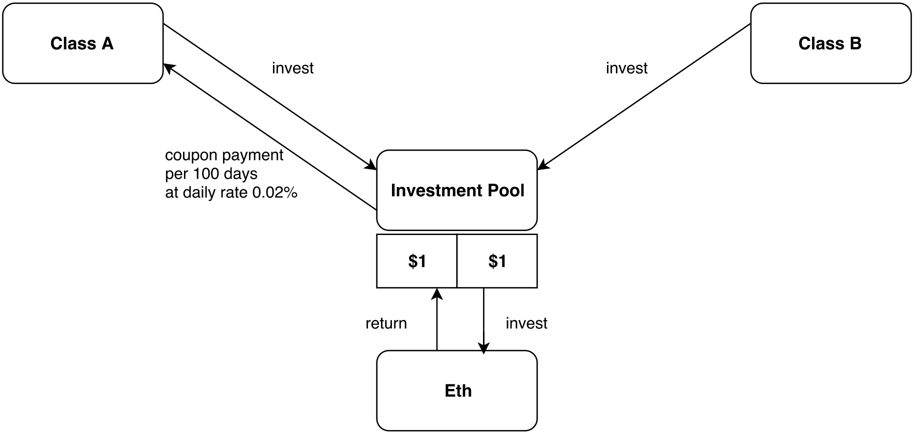

Figure: Initial Split. At the beginning, one share of Class A and B each invests $1 in Eth. The Eth price is $500, so two shares of Eth correspond to 500 shares of Class A coins and 500 shares of Class B coins. $\beta = 1$.

Vanilla A Coin, Regular Payout

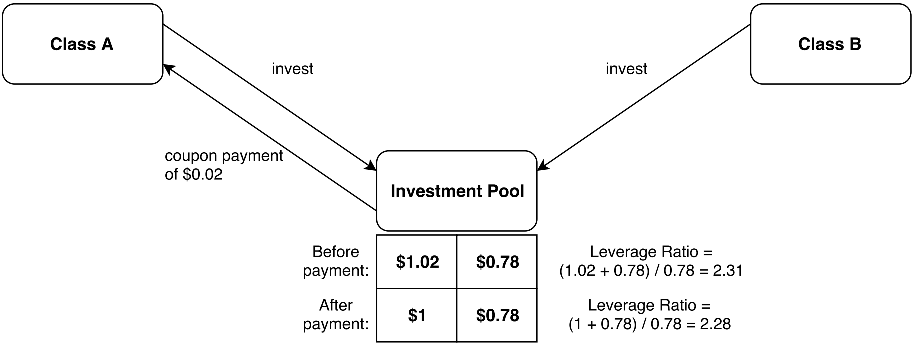

Figure: Regular payout. After 100 days, the Eth price drops to \$450, so that total investment of one Class A coin and one Class B coin becomes \$1.8, within which \$1.02 belongs to Class A. A regular payout takes place, and Class A receives \$0.02 coupon payment. New exchange ratio: 2 shares of Eth now correspond to 505.62 $\left(= 500 \times \frac{2\times 450}{2\times 450 - 500 * 0.02}\right)$ shares of Class A and 505.62 shares of Class B, yielding $\beta = 1.01$.

Vanilla A Coin, Upward Reset

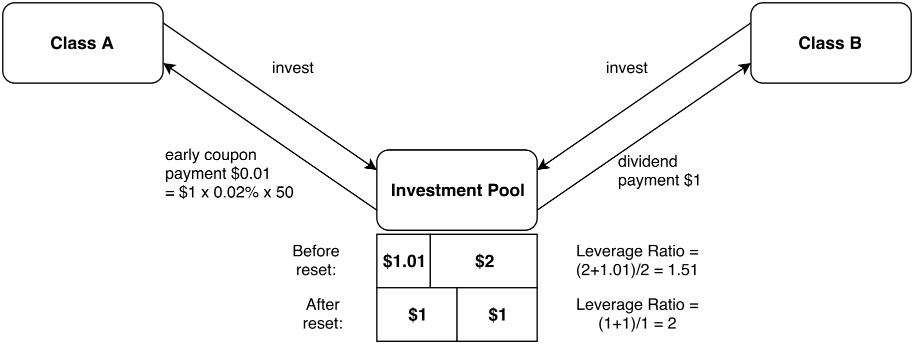

Figure: Upward Reset. After 50 days, the Eth price grows to \$760.95, and Class B NAV grows to \$2, triggering an upward reset. Class A NAV equals \$1.01, where \$0.01 is half-year accrued coupon. On this date, Class A receives \$0.01 coupon payment, and Class B receives \$1 dividend payment. New exchange ratio: 2 shares of Eth now correspond to 760.95 shares of Class A and 760.95 shares of Class B, yielding $\beta = 1$.

Vanilla A Coin, Downward Reset

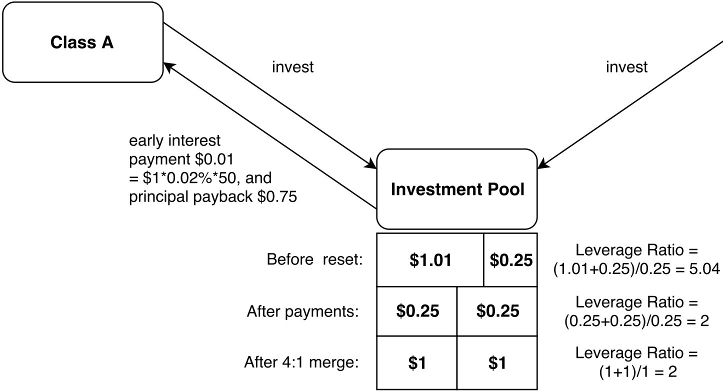

Figure: Downward Reset. After another 50 days, the Eth price drops to $479.40, and Class B NAV drops to $0.25, triggering an downward reset. Again, Class A NAV equals $1.01, where $0.01 is half-year accrued coupon. On this date, Class A receives $0.01 coupon payment, as well as $0.75 principal payback. Then, Class A and B each undergo a 4:1 merger, so that both have NAV equal to $1. New exchange ratio: 2 shares of Eth now correspond to 479.40 shares of Class A and 479.40 shares of Class B, yielding $\beta = 1$.

Remarks

- No arbitrage implies that

$$W_A^t + W_B^t = 2P_t/(\beta_t P_0),$$

  where P_t is the price of the underlying cryptocurrency, W_A and W_B are the price of the Class A and B coins, and β_t is the conversion ratio, initially equal to 1, and will be changed on regular reset.
- Coin A behaves like a corporate bond.
  - Although Class A has a fixed coupon rate and its coupon payment is periodic and protected by the resets, its value is still volatile on non-coupon dates.
  - The main risk of Class A is not credit risk, but the risk of a downward reset. On a downward reset, a portion of Class A coin will be liquidated, so the investor will lose the value of future coupons that would be generated from this portion.
  - Therefore, a downward reset will reduce the value of Class A.
- We propose two classes of more stable coins, the class of A' and B' coins and the class of A0 and A1 coins.

Overview of A' and B'

- This second extension splits Class A into two sub-classes: Class A' and B'.
- Class A' and B' invest in Class A coin.
- At any time, two Class A coins can be split into one Class A' and one Class B' coin. Conversely, one Class A' and B' coin can be merged into 2 Class A coins.
- Class B' borrow money from Class A' at the rate R' to invest in Class A.
- R' is set to close to the risk-free rate r, where the rate R for Class A is generally much higher.
- Class A' and B' resets *when and only when* Class A resets and Class A gets regular payout.
- A' behaves like cash, except in extreme case, when the underlying asset suddenly jumps (not smooth transit) to close to zero.

A' Coin, Regular Payout

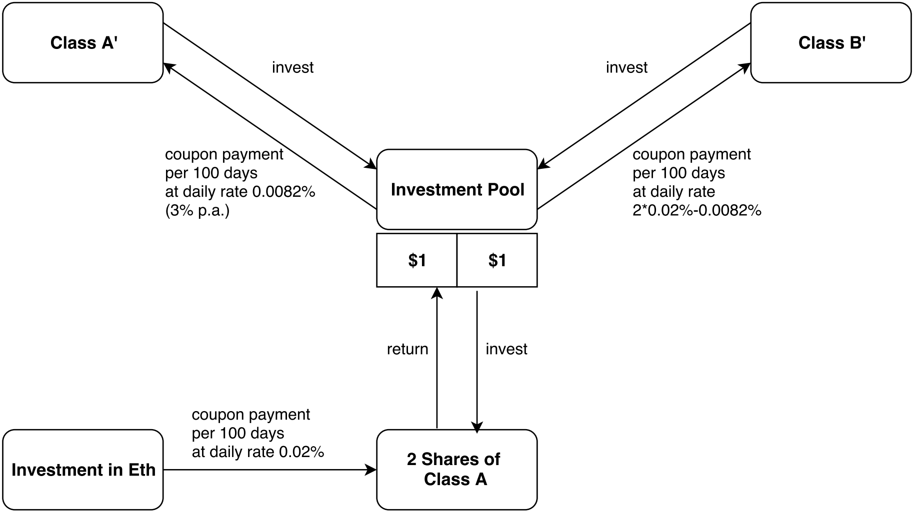

Figure: What happens to A' on a regular payout date of A. On regular payout dates for A (per 100 days), 2 shares of A receives coupon payment $0.04, i.e. at daily rate 0.02%.

A' Coin, Upward Reset

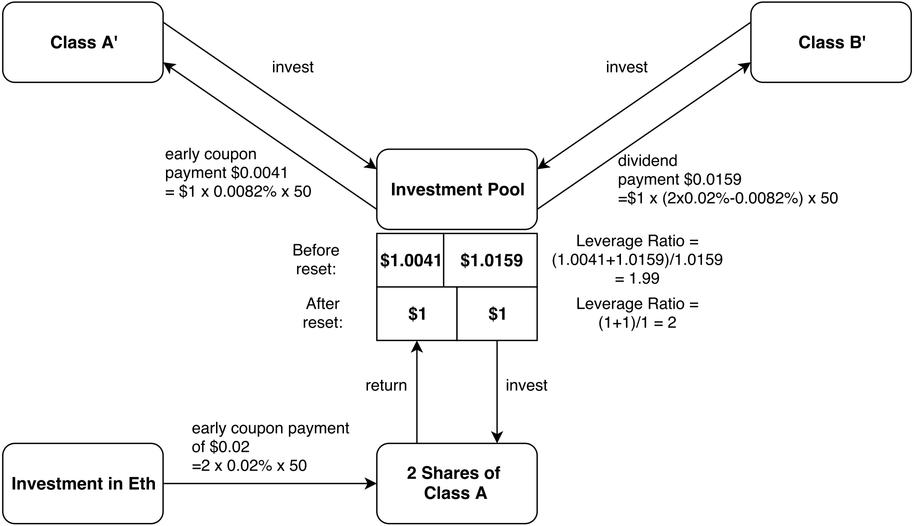

Figure: Upward Reset of Class A′. After 50 days, Class B's NAV grows to $2, triggering an upward reset.

A' Coin, Downward Reset

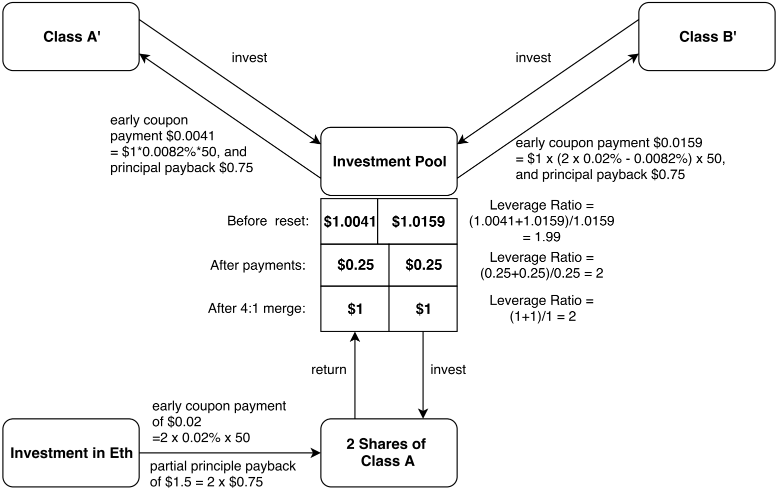

Figure: After another 50 days, Class B NAV drops to $0.25, triggering an downward reset.

Overview of A0 and A1

- Each Class A coin is split into one Class A0 coin and one Class A1 coin.
- On the next coupon payment date or reset date t, Class A1 receives the coupon payment for Class A, and then Class A1 is terminated.
- Class A0 is then split into Class A0 coin and Class A1 coin, until the next reset when Class A1 receives payment and A0 is split again, so on and so forth.
- At any time, the quantity of Class A0 and A1 maintains 1:1.
- At any time, the value of Class A1 equals the expected discounted value of Class A's next payment on the next reset or coupon payment date.
- The value of Class A0 equals the difference between values of Class A and A1.

A0 Coin, Regular Payout

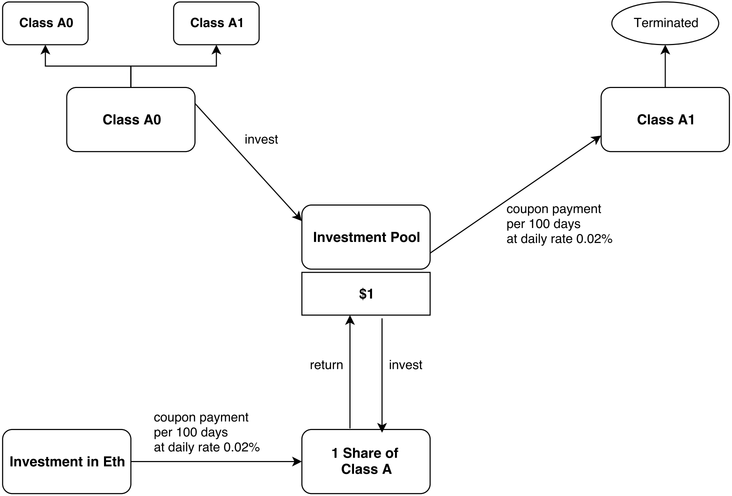

Figure: Class A0 receives no coupon. Class A1 receives all the coupon payment. After the coupon payment, Class A1 is terminated, and 1 Class A0 is split into 1 new Class A0 and Class A1.

A0 Coin, Upward Reset

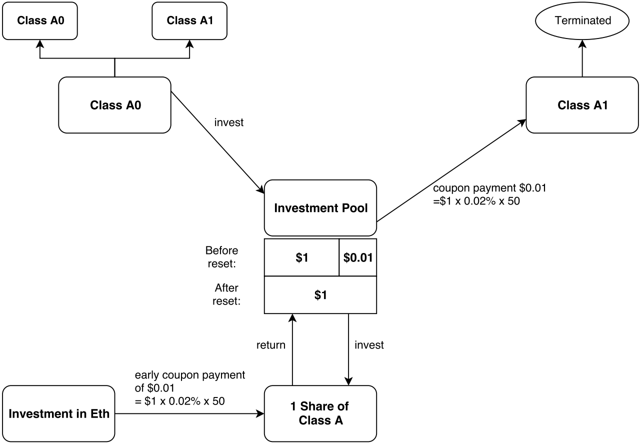

Figure: Upward Reset of Class A0. After 50 days, Class B NAV grows to \$2, triggering an upward reset.

A0 Coin, Downward Reset

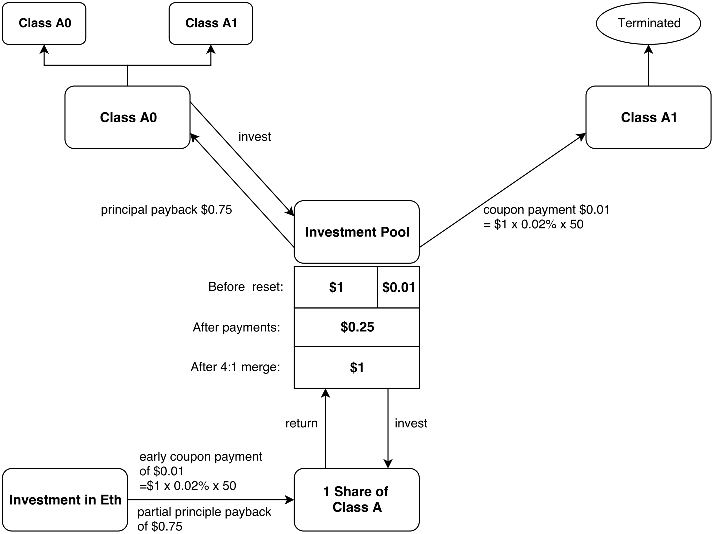

Figure: After another 50 days, Class B NAV drops to $0.25, triggering a downward reset.

The Vanilla A and B Coins, Overview

- Let the downward reset boundary be $H_d(t) = \frac{1}{2}(1 + Rt) + \frac{1}{2}\mathcal{H}_d$, and upward reset boundary $H_u(t) = \frac{1}{2}(1 + Rt) + \frac{1}{2}\mathcal{H}_u$.
- We have both stochastic representation and PDE for vanilla A and B coins.

The Vanilla A and B Coins, Stochastic Representation

- $W_A(t, S)$ denotes the market value of Class A coin with time from last interest payment $0 \le t \le T$, with $S_t = P_t/(\beta_t P_0)$, $H_d(t) \le S_t \le H_u(t)$.
- $W_A(t, S)$ is given recursively by

$$E_t \Bigg[\sum_{1 \le i < \tau \wedge \eta} e^{-r(i-t)} RT + e^{-r(\tau - t)}(R\tau + W_A(0,1)) \cdot \mathbf{1}_{\{\tau < \eta\}} + e^{-r(\eta - t)}(R\eta + 1 - |V_B^{\eta-}| + (V_B^{\eta-})^+ W_A(0,1)) \cdot \mathbf{1}_{\{\eta < \tau\}} \Bigg],$$

  where E_t is the expectation computed under the risk-neutral measure and under the initial condition $S_{t-} = S$,
- The random times ζ, τ and η represent the first regular payout, upward and downward reset date from t, respectively.
- Once we calculate W_A, the value of Class B coin can be calculated as $W_B = 2S - W_A$.

The Vanilla A and B Coins, PDE

We assume that P_t follows a geometric Brownian motion under the risk neutral measure:

$$dP_t = rP_t dt + \sigma P_t dW_t,$$

where W_t is a one-dimensional standard Brownian motion.
$W_A(t, S)$ is the unique solution of the following periodic PDE with nonlocal boundary and nonlocal terminal conditions,

$$-\frac{\partial W_A}{\partial t} = \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 W_A}{\partial S^2} + rS\frac{\partial W_A}{\partial S} - rW_A,$$
$$t \in [0, T),\ \ S \in (H_d(t), H_u(t))$$
$$W_A(T, S) = RT + W_A(0, S - \frac{1}{2}RT),$$
$$W_A(t, H_u(t)) = Rt + W_A(0, 1)$$
$$W_A(t, H_d(t)) = Rt + 1 - \mathcal{H}_d + \mathcal{H}_d W_A(0, 1).$$

The A' and B' Coins, Stochastic Representation

Under the risk-neutral pricing framework, the value $W_{A'}(t, S)$ of Class A' is given as

$$E_t \left[\sum_{1 \le i < \tau \wedge \eta} e^{-r(i-t)} R' T + e^{-r(\tau - t)} (R' \tau + W_{A'}(0,1)) \cdot \mathbf{1}_{\{\tau < \eta\}} \right.$$
$$\left. + e^{-r(\eta - t)} \left(\min\{ R'\eta + 1 - (V_B^{\eta-})^+, 2(R\eta + 1 + V_B^{\eta-})^+ \} + (V_B^{\eta-})^+ W_{A'}(0,1) \right) \cdot \mathbf{1}_{\{\eta < \tau\}} \right],$$

where τ and η are the first upward and downward reset of Class A (or equivalently, Class A' and B') after t, respectively. On downward reset, if $V_B^{\eta-} > 0$, A receives coupon $R'\eta$, $1 - V_B^{\eta-}$ shares of A is liquidated, and A receives the liquidation value; if $\frac{R'\eta - 1}{2} - R\eta \le V_B^{\eta-} \le 0$, A is fully liquidated, and still receives full NAV; otherwise, A is fully liquidated and takes a loss by receiving $2(1 + R\eta + V_B^{\eta-})^+$ which is smaller than the NAV $1 + R\eta$.

The A' and B' Coins, PDE

We assume that P_t follows a geometric Brownian motion.
$W_{A'}$ satisfies the following PDE, which is the same as that for W_A, except changing R to R' for the coupon payment:

$$-\frac{\partial W_{A'}}{\partial t} = \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 W_{A'}}{\partial S^2} + rS\frac{\partial W_{A'}}{\partial S} - rW_{A'},$$
$$t \in [0, T), \; S \in (H_d(t), H_u(t))$$
$$W_{A'}(T, S) = R'T + W_{A'}(0, S - \frac{1}{2}RT),$$
$$W_{A'}(t, H_u(t)) = R't + W_{A'}(0, 1)$$
$$W_{A'}(t, H_d(t)) = R't + 1 - \mathcal{H}_d + \mathcal{H}_d W_{A'}(0, 1).$$

The A0 and A1 Coins, Stochastic Representation

Under the risk-neutral pricing framework, the market value $W_{A1}(t, S)$ of Class A1 coin is given as

$$E_t \Bigg[e^{-r(\zeta - t)} RT \cdot \mathbf{1}_{\{\zeta \le \tau, \eta\}} + e^{-r(\tau - t)} R\tau \cdot \mathbf{1}_{\{\tau < \eta, \zeta\}} + e^{-r(\eta - t)} (R\eta - (V_B^{\eta-})^-)^+ \cdot \mathbf{1}_{\{\eta < \tau, \zeta\}} \Bigg],$$

where the first regular payout time ζ, the first upward reset time τ and the first downward reset time η are defined as before. On a downward reset, if $V_B^{\eta-} > 0$, A1 gets the coupon payment $R\eta$; if $V_B^{\eta-} \le 0$, A1 only gets a part of the coupon $(R\eta + V_B^{\eta-})^+ < R\eta$.

The A0 and A1 Coins, PDE

We assume that P_t follows a geometric Brownian motion.
W_{A1} is the unique solution of the following PDE

$$
\begin{aligned}
-\frac{\partial W_{A1}}{\partial t} &= \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 W_{A1}}{\partial S^2} + rS\frac{\partial W_{A1}}{\partial S} - rW_{A1}, \\
& \qquad t \in [0, T),\ S \in (H_d(t), H_u(t)) \\
W_{A1}(T, S) &= RT \\
W_{A1}(t, H_u(t)) &= Rt \\
W_{A1}(t, H_d(t)) &= Rt.
\end{aligned}
$$

Finally, the value of Class A0 coin is defined as $W_{A0} = W_A - W_{A1}$.

The Setting

For illustration, we hereby uses Ether (ETH) as the underlying coin and apply below parameter values:

$$
\begin{aligned}
R &= 0.02\% \text{ (7.3\% p.a.)} & R' &= 0.0082\% \text{ (3\% p.a.)} \\
\mathcal{H}_u &= 2 & \mathcal{H}_p &= 1.02 \\
\mathcal{H}_d &= 0.25 & T &= 100 \\
\sigma &= 0.0628 \text{ (120\% p.a.)} & r &= 0.0082\% \text{ (3\% p.a.)}.
\end{aligned}
$$

The following assumptions are used:

1. Price is monitored on daily basis
2. Resets are performed according to end-of-day prices
3. Reinvestment of ETH payout from resets is not considered

Class A, Simulated Market Values

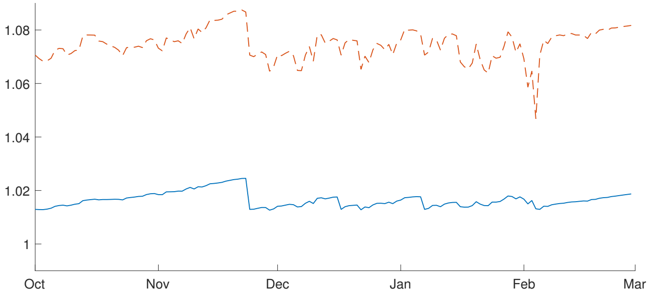

Figure: Simulated class A Market Value. Upward reset takes place on 24 Nov 2017, 17 Dec 2017, and 7 Jan 2018. Downward reset date takes place on 5 Feb 2018.

Class B, Simulated Market Values

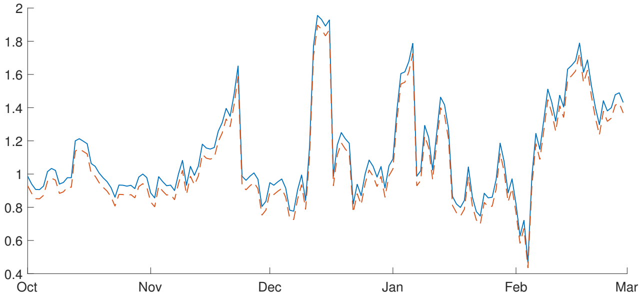

Figure: Class B Market Value. B has upward resets (on 24 Nov 2017, 17 Dec 2017, and 7 Jan 2018) with dividend payments \$1.0846, \$1.0467, and \$1.1106 and downward resets on 5 Feb, 2018.

Class A', Simulated Market Values

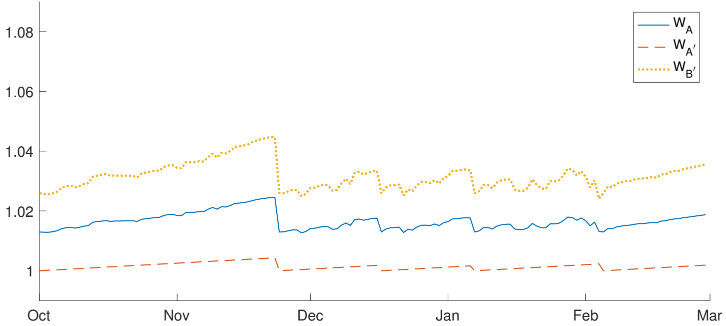

Figure: Market Value of Class A' (red) and B' (yellow), compared with Class A (blue).

Class A', Simulated Market Values

- The 4 downward jumps correspond to the coupon payment of Class A' on 1 downward and 3 upward reset dates of Class A.
- If we de-trend the value of Class A$'$ by its NAV and consider $W_{A'} - V_{A'}$, it has an annualized standard deviation of 5.4×10^{-5}, which is much smaller than that of $W_A - V_A$ (0.0178).

Class A0, Simulated Market Values, 1:1 Split

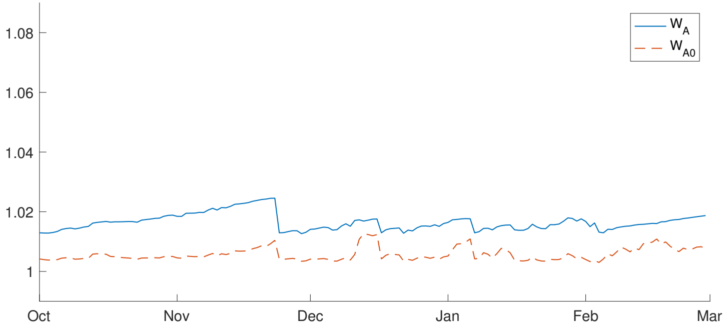

Figure: Market Value of Class A0 compared to Class A.

Class A0, Simulated Market Values, 2:1 Split

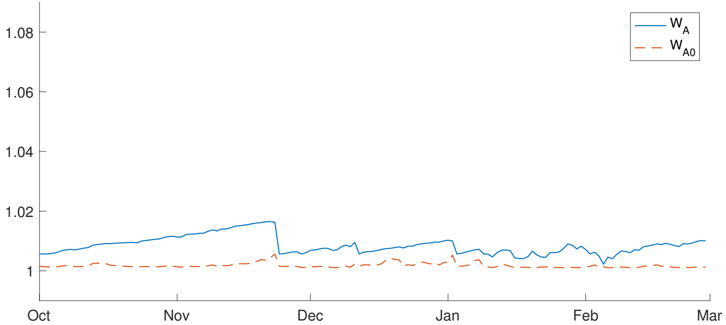

Figure: Market Value of Class A0 (principal only class) compared to Class A.

Class A0, Simulated Market Values

- The 4 downward jumps correspond to the coupon payment of Class A0 on 1 downward and 3 upward reset dates of Class A.
- A0 has an annualized standard deviation of 0.0413 for $\alpha = 1$, as compared to SD of W_A, which is 0.0530.
- A0 has an annualized standard deviation of 0.0156 for $\alpha = 2$, as compared to SD of W_A, which is 0.0571. Note that with $\alpha = 2$, the NAV of B is $3S_t - 2(1 + Rt)$, making B more sensitive to S_t.

Black Swan Events

- Let us assume that if an extreme event happens, then there is a 80% sudden drop in the Eth price.
- Assuming $\beta = 1$, $P_{t-} = P_0 = 500$ (so that the relative price $S_{t-} = 1$), and P suddenly drops to $P_t = 100$.
- Then the NAV of Class A coins $V_A^t = 2 \times S_{t-} \times (1 - 80\%) = 0.4$, while the NAV of Class A′ coins $V_{A'}^t = 2 \times V_A^t = 0.8$.
- Assuming that this kind of downward jump occurs in a jump diffusion model with a Poisson intensity 0.2 per year and constant jump size -80%, then we have at time 0, $W_A(0) = 0.888$ and $W_{A'}(0) = 0.962$; in contrast, if there is no jump risk (intensity equals 0), $W_A(0) = 1.013$, $W_{A'}(0) = 1.000$.
- Therefore, the presence of extreme jump risk has a smaller impact on Class A′ coins.

Conclusion

- Within the ecology system of Blockchains, stable coins are needed to settle transactions, to pay miners, and to do asset allocation.
- We design several classes of stable coins, A' and A0, based on vanilla A, which are inspired by the dual purpose funds in China and U.S.
- These stable coins can be used as a basis for sovereign stable coins, if a government can provide the insurance in extreme events.

Thank you.