HONG KONG MONETARY AUTHORITY

**Research Memorandum 07/2022**

**21 November 2022**

# AN ASSESSMENT OF THE VOLATILITY SPILLOVER FROM CRYPTO TO TRADITIONAL FINANCIAL ASSETS: THE ROLE OF ASSET-BACKED STABLECOINS

***Key points:***

- *The rapid growth of the crypto ecosystem and its increasing connection with the traditional financial system have raised questions on whether and how the volatility of crypto assets could spillover to the traditional financial system. With a perceived stable value offered by the backing of traditional financial assets, asset-backed stablecoins play a pivotal role in the crypto ecosystem. However, these stablecoins bear liquidity mismatch risks similar to money market funds, which may expose them to a fire-sale of reserve assets in times of crypto ecosystem instability and in turn increase the volatility of these reserve assets.*

- *Focusing on Tether, the largest asset-backed stablecoin, this study shows that its reserve adjustment magnifies the volatility spillover from crypto assets to money market instruments. This could be a channel through which risks borne by crypto assets could spillover to the traditional financial system. In extreme circumstances, failures of stablecoins or other crypto assets could result in large-scale redemptions of asset-backed stablecoins and a fire-sale of their reserve assets, potentially posing material impacts on the traditional financial system such as the money market identified in this study.*

- *As the crypto ecosystem continues to expand and is increasingly exposed to the financial sector, the linkages between crypto and traditional financial assets are likely to become stronger, potentially increasing the risk spillover discussed above. Importantly, the crypto ecosystem remains largely outside the oversight of regulators, with large data gaps impeding their assessments of the spillover risk. Given that the international regulatory community is considering putting in place appropriate regimes to regulate stablecoins, this study concludes with two suggestions that regulators may consider:*

1. *Requiring standardised and regular disclosures by the issuers of asset-backed stablecoins on their reserve assets holdings which could help regulators assess and compare their liquidity condition and potential liquidity mismatch risk. This could enable regulators to consider, in a more timely manner, taking appropriate measures to reduce the spillover risk in times of market disruption, and;*

2. *Strengthening the asset-backed stablecoins' liquidity management, possibly by imposing restrictions on the composition of reserve assets and requiring well-defined redemption rights, which may also help reduce the spillover risk.*

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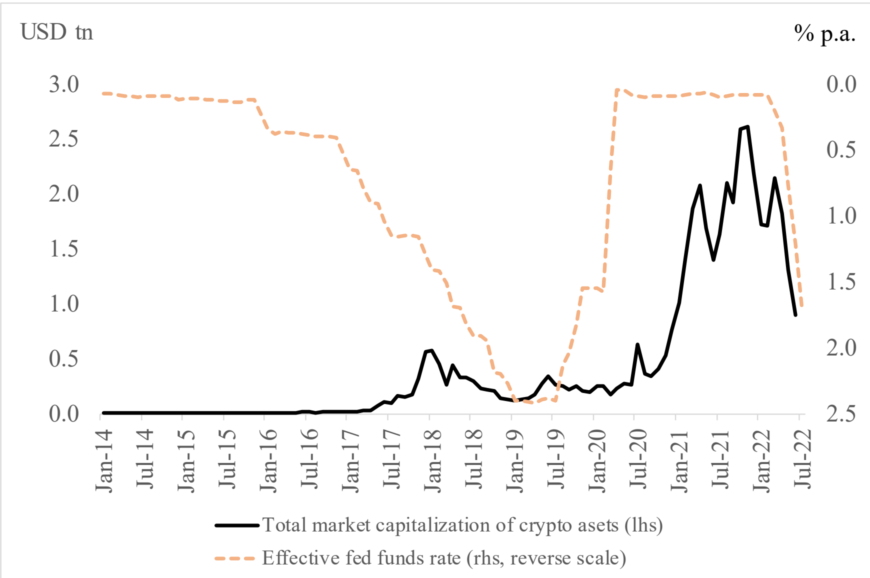
*The authors would like to thank Eric Wong and colleagues from the Monetary Management Department of the HKMA for their helpful comments and suggestions.

## I. INTRODUCTION

Since the introduction of Bitcoin in 2009, the crypto-asset ecosystem (the "crypto ecosystem") has opened perceived possibilities for cheaper, faster and more accessible financial services. Prospects of quick and large gains from investing in crypto assets have also made them attractive alternatives to traditional financial assets. These possibilities have contributed to a rapid growth of the crypto ecosystem, especially since the onset of the COVID-19 pandemic where major central banks injected ample liquidity to the financial system (Chart 1).[1] The ecosystem has grown in both size and the variety of asset types to the meet growing needs for alternative investments and financial services (Annex A). While presenting perceived possibilities for more financial innovations, **the increased complexity and interconnection of crypto assets have made the crypto ecosystem more vulnerable to systematic shocks** (Ferroni, 2022).[2]

Chart 1: Total market capitalization of crypto assets




Notes (1) End of month figures. (2) The figures cover the total market capitalization of all crypto assets covered by source, including unbacked cryptocurrencies, stablecoins and tokens.
Source: CoinMarketCap and St. Louis Fed

**The vulnerabilities associated with the fast rising crypto ecosystem could have stability implications for the traditional financial system.**

[1] The decline in total market capitalisation of crypto assets from the peak in November 2021 could be largely attributed to the valuation effect, in particular for Bitcoin and Ethereum that account for more than half of the total market capitalisation.

[2] Applying the dynamic interconnectedness measure proposed by Diebold and Yilmaz (2012) on 19 crypto assets, Ferroni (2022) finds that 86% to 94% (based on different specifications and sample sizes) of crypto assets price uncertainty is due to shocks to other cryptocurrencies.

On the one hand, financial institutions are increasingly exposed to crypto assets, both directly by investing in these assets and indirectly by investing in financial vehicles holding these assets or providing financial services to crypto market participants. These exposures could subject these financial intuitions to the large swings in the price of crypto assets and result in losses for them. On the other hand, crypto and traditional financial assets are found to be more correlated over time (Iyer, 2022), suggesting that any abrupt developments in the crypto space could have knock-on effects on traditional financial assets.

To broaden the understanding of the "knock-on" effects, **this study examines the channels through which volatility in crypto assets could spillover to traditional financial assets.** In particular, we focus on the role of asset-backed stablecoins. First created in 2014, stablecoins are crypto assets that generally maintain a stable value with reference to fiat currency. One way to do so is to back the stablecoins issued with a portfolio of traditional financial assets with stable values and may offer a promise or expectation that the coins can be redeemed at par on request (referred to as "asset-backed" stablecoins), similar to money market funds (MMFs, Chart 2).[3]

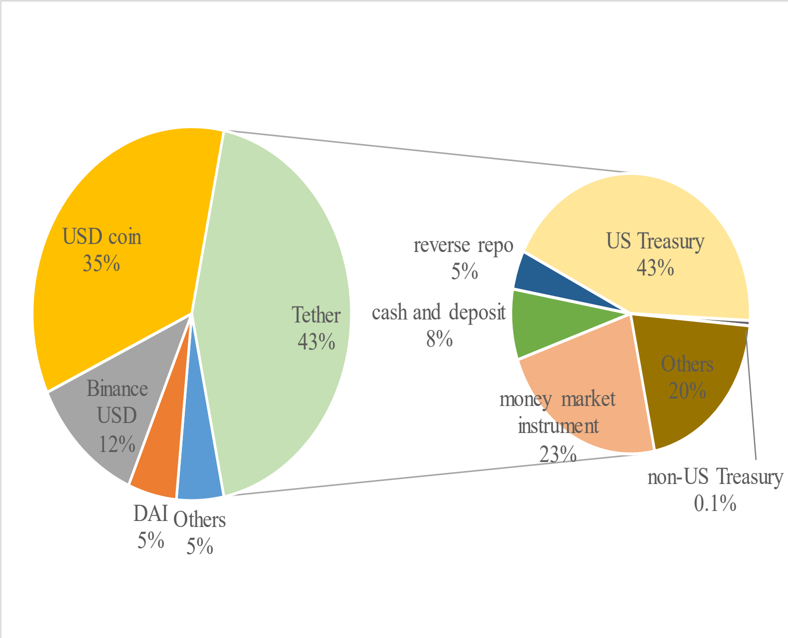
With the perceived price stability and ease of moving across crypto exchanges compared to that of fiat currency, stablecoins have been used as a bridge between fiat currencies and the more volatile "non-backed" crypto assets and also as a "parking space" for crypto volatility. The use of stablecoins for yields earning and liquidity provision in the fast-rising decentralised finance (DeFi) segment have further stimulated the growth of stablecoins.[4] In fact, the size of Tether, the largest stablecoin by market capitalisation that is "pegged" to the US dollar at 1 to 1 ratio and claimed to be backed by cash and equivalent assets, was equivalent to 7.7% of all U.S. prime MMFs at the end of June 2022. The ratio was just 0.4% before the COVID-19 pandemic.[5]

[3] There are also stablecoins that are not backed by real assets. Instead, these stablecoins maintain a stable value by linking to another crypto asset and use algorithms to adjust their price based on the supply and demand of stablecoins by market participants.

[4] DeFi offers access to basic financial services (e.g. borrowing and lending) without the need for a financial intermediary. Crypto asset holders can earn a higher interest (than say, traditional bank deposits) by placing their crypto assets in a Defi lending protocol. Placing stablecoins instead of "un-backed" crypto assets in the Defi lending protocol allows Defi market participants to enjoy the high yield without being affected by the volatility in the crypto markets. Another typical usage of stablecoins in Defi is to form a liquidity pool for facilitating the trades between stablecoins and crypto, where holders of stablecoins receive transaction fees in return.

[5] At the end of June 2022, the total market capitalisation of Tether was USD 66 billion according to CoinMarketCap while the outstanding size of US prime MMFs was USD 859 billion according to the Office of Financial Research.

Chart 2: Distribution of stablecoins and Tether's reserve asset compositions




Notes: 1. Money market instruments include commercial papers, certificate of deposits and money market funds. 2. Sizes of different stablecoins as at 11 August 2022 while the reserve compositions of Tether are positions at 30 June 2022. 3. "Others" reserve assets held by Tether include secured loans, corporate bonds, precious metals and other investments such as digital tokens. Source: CoinGecko and Tether Limited

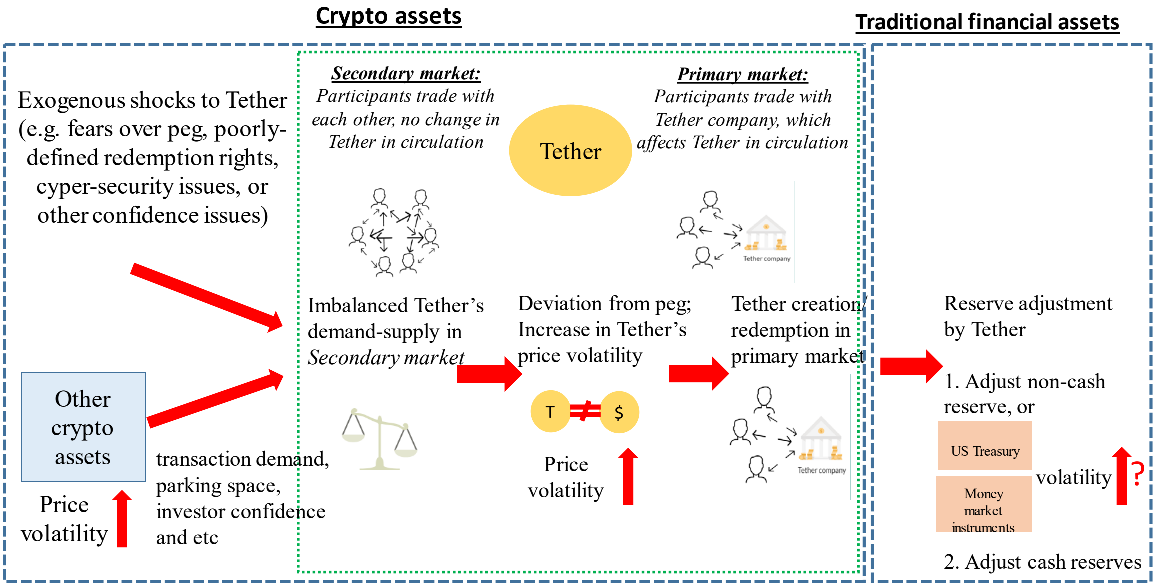
**The growing size of asset-backed stablecoins, together with their inherent risks, could make asset-backed stablecoins a potential magnifier of the volatility spillover from crypto to traditional financial assets**. Similar to MMFs, creations and redemptions of the asset-backed stablecoins involve adjustment in holdings of their reserve assets (Chart 2). These stablecoins are thus exposed to liquidity mismatch risks similar to MMFs, where large volatilities in crypto assets may trigger redemption of stablecoins, resulting in a fire-sale of reserve assets and in turn increasing volatilities in these reserve assets. This study attempts to offer evidence of this spillover channel.

This study is organised as follows. The next section elaborates the potential spillover channel and develops our hypothesis. Section 3 presents the empirical set-up and reports the findings. The final section concludes.

## II. HOW COULD ASSET-BACKED STABLECOINS MAGNIFY THE VOLATILITY SPILLOVER FROM CRYPTO TO TRADITIONAL FINANCIAL ASSETS?

Chart 3 illustrates how Tether's market participants ("participants") could obtain or redeem Tether, in both the primary or secondary market, and how such mechanism may make cause volatility of crypto assets to spillover to traditional financial assets.

Chart 3: Illustration of Tether's transaction mechanism and spillover channel from crypto to traditional financial assets




**Participants can transact Tether in either the primary or the secondary market.** In the primary market, participants trade directly with Tether Limited, the issuer of Tether. Participants who want to obtain Tether will first transfer an equivalent amount of US dollars into the bank account of Tether Limited. Tether Limited will then issue new Tether tokens in return and credit them to the registered e-wallet of participants. The US dollar received by Tether will be either injected directly into its reserve asset portfolio or converted to non-cash assets. Conversely, participants who want to redeem their Tether tokens would transfer them to Tether and Tether Limited will then remove the tokens from circulation and transfer an equivalent amount of US dollars to participants' registered bank accounts, either by drawing down its cash reserves or liquidating its non-cash reserve assets. As can be seen, both creation and redemption of Tether in the primary market involve adjustment of Tether's reserve asset portfolio.

Participants could also obtain and redeem Tether tokens by transacting with other participants in the secondary market. These transactions only involve changing hands on Tether tokens and do not change the amount of Tether in circulation. Nevertheless, imbalances in the secondary market could end up with transactions in the primary market. Specifically, when the secondary market price of Tether token rises above (falls below) one US dollar due to excess demand (supply), participants could arbitrage the deviations by purchasing (redeeming) Tether tokens in primary market at 1 to 1 peg before (after) selling (purchasing) the tokens in the secondary market at the market price. This leads to the creation or redemption of Tether in the primary market and thus, reserve adjustment by Tether.

The above suggests that fluctuations in the price of asset-backed stablecoins could result in reserve adjustment by stablecoins. Stablecoins' own development, which may affect participants' confidence, thus the demand for and supply of stablecoins, could obviously trigger volatility of their price. Meanwhile, the wide use of stablecoins as a medium to trade for other crypto asset types means that volatilities in these assets could also affect the demand and supply, and hence, the price stability of asset-backed stablecoins.[6]

[6] For instance, large volatility in Bitcoin's prices may incentivize crypto markets participants to shift to stablecoins, while large selling pressures on stablecoins may occur if Bitcoin's volatility dampen crypto market participants' confidence on the broader crypto ecosystem. By investigating the volatility process of crypto assets, Grobys et al (2021) find that Bitcoin volatility is a fundamental factor that drives the volatility of stablecoins.

## III. EMPIRICAL SETTINGS AND FINDINGS

In this section, we test empirically the channel of volatility spillover laid out in the previous section. **Specifically, we test whether volatilities in crypto asset' prices would have a larger impact on the volatility of stablecoins' reserve assets when there is a larger reserve adjustment**. Our baseline analysis focuses on Tether, which compared to other asset-backed stablecoins, is more likely to magnify volatility spillover from crypto to traditional financial assets given its sheer size.

In addition to Tether, our analysis also covers four other asset types that are summarized in Table 1. The sample period covers from January 2020 to June 2022, as Iyer (2022) finds that there is a noticeable increase in volatility spillover from crypto and equity markets since 2020.[7]

Table 1: Summary of assets types covered in the analysis

| Asset type | Reasons to include |
|---|---|
| Stablecoins | Represented by Tether, the largest asset-backed stablecoins with a size comparable to large prime MMFs. Volatility of Tether's price may lead to reserve adjustment by Tether and increase the volatilities in its reserve assets. |
| Non-stablecoin crypto assets | Represented by Bitcoin, the largest crypto asset. Stablecoins are closely connected with other crypto assets such that volatilities in crypto assets like Bitcoin may spillover to traditional financial assets through increasing volatility of stablecoins' prices. |
| Equity | Represented by S&P 500 index. Equity market is an integral part of the traditional financial system. It is closely connected with crypto assets as well as other traditional financial assets. Therefore, it is necessary to control for the dynamics between equity market and these assets. The inclusion of equity market can also act as a "counter" test as equity does not constitute Tether's reserve assets, such that Tether' reserve adjustment is unlikely to magnify the volatility spillover from crypto assets to the equity market. |

[7] Using a linear vector autoregressive model that consists of Bitcoin, Tether, S&P500 and Russell 2000 indices, Iyer (2022) finds that spillover from price volatility of Bitcoin to that of the S&P 500 index has increased from one percentage point (ppt) between 2017 and 2019 to 17 ppts between 2020 and 2021. The volatility spillover from Tether to S&P 500 has also increased from 0 ppts between 2017 and 2019 to 6.1 ppts between 2020 and 2021.

| | |
|---|---|
| US Treasury | Represented by iShares Short Treasury Bond ETF, which tracks the investment results of an index composed of U.S. Treasury bonds with remaining maturities one year or less. The US treasury is an important reserve asset for Tether such that volatilities in crypto assets could spillover to the US treasury through triggering reserve adjustments by Tether. |
| Money market instruments | Represented by JPMorgan Ultra-Short Income ETF, which invests mainly in short-term investment-grade, US dollar-denominated fixed, variable and floating-rate debt. [8] Money market instruments are another important component of Tether's reserve assets such that volatility of crypto assets could spillover to money market instruments through triggering reserve adjustments by Tether. |

## PRELIMINARY ASSESSMENT

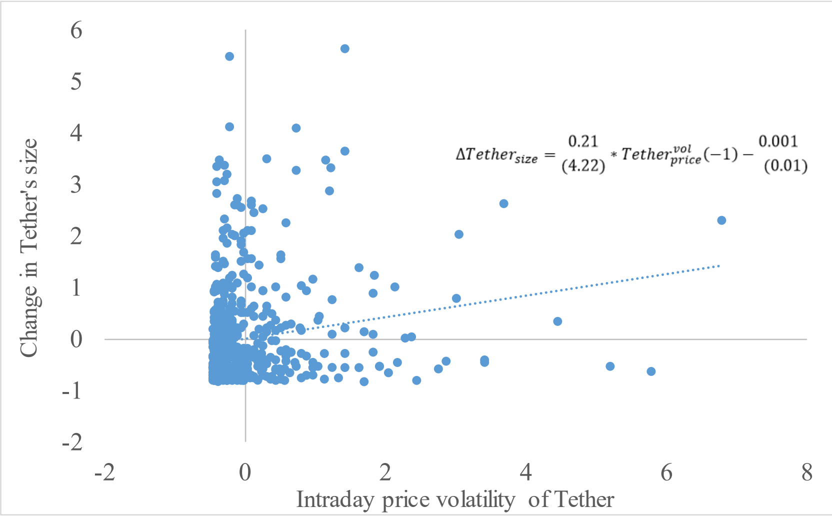
To empirically examine the aforementioned spillover channel, we will first verify whether a larger price volatility of Tether leads to a larger reserve adjustment. We measure the price volatility of Tether by its intraday high-low price differences.[9] This reflects fluctuations in an asset's daily price and is a commonly used measure in the analysis of assets' volatility spillover (e.g., Diebold and Yilmaz, 2012). The level of Tether's reserve adjustment is proxied by the absolute value of the daily percentage change in Tether's market capitalisation.[10] Chart 4 depicts a significant and positive relationship between our proxy for Tether's reserve adjustments and the intraday price volatility of Tether the previous day, consistent with the conjecture that larger volatility of Tether's price could result in a larger reserve adjustment by Tether.

[8] The daily high and low price are not available for the benchmark commercial paper rates. In addition, by trading continuously in a trading day, prices of related ETFs may better reflect the impacts of intraday market activities on US Treasury and money market instruments.

[9] The intraday day volatility is given by the formula: volatility = 0.361*((log(Day high) – log(Day low))^2)

[10] As creation (positive change in Tether's size) and redemption (negative change in Tether's size) of Tether both trigger reserve adjustment, taking the absolute value would ensure a larger (more positive) value always indicate a larger reserve adjustment undertaken by the Tether Limited. Meanwhile, taking the percentage change would make the figures comparable across time as Tether increased noticeably during the sample period. Changes in market capitalisation of Tether is a good proxy for changes in the amount of Tether in circulation (and therefore the amount of reserve adjustment involved) given that Tether's market price size largely stays around its 1:1 peg with the US dollar during the sample period. Our result holds qualitatively when we further adjust the proxy by the daily percentage in Tether's market price.

Chart 4: Scatter plot on tether price volatility against tether's size changes

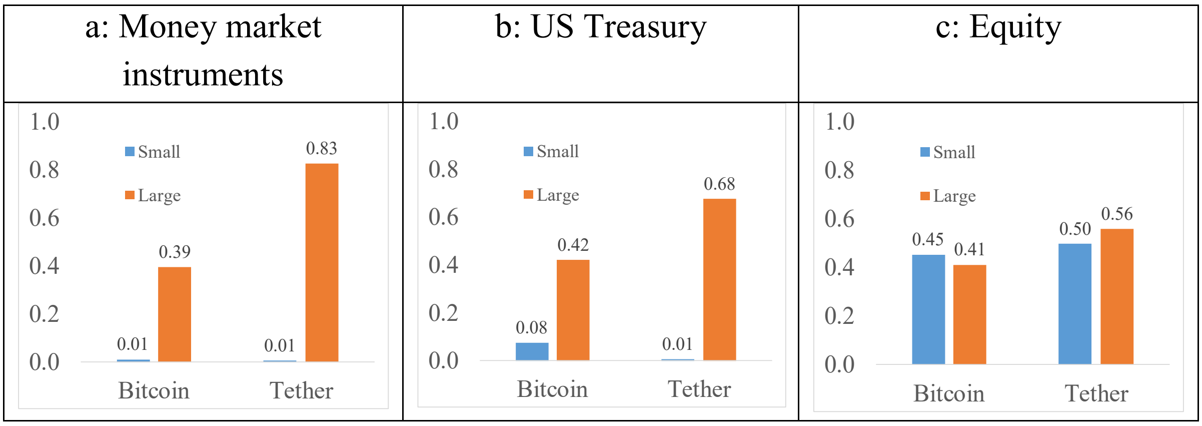



Notes: (1) Figures in parentheses denote the t-statistics of the regression coefficient. (2) Figures are normalized into zero mean and unity variance for presentation purpose. (3) Extreme outliers have been removed for depicting a clearer relationship.

Next, we compute the pair-wise correlations between different pairs of crypto and traditional financial assets for a glimpse of whether changes in the size of Tether's reserve adjustment are likely to affect the relationship of their price volatilities. Chart 5 reports the results. In particular, the right part of panel a shows that the correlation between the intraday price volatility of Tether and money market instruments is 0.83 when the size of Tether's reserve adjustment is above the 90th percentile, and 0.01 vice versa. A similar pattern is observed for Bitcoin and the money marker instruments (left part of panel a), as well as between Tether/Bitcoin and US treasury (panel b).[11]

[11] The small differences in the correlation between crypto assets and equity across two periods of Tether's reserve adjustment (panel c) are in line with our conjecture that reserve adjustments by Tether would unlikely have direct associations with equity's price volatilities as equity is not part of Tether's reserve portfolio (Table 1).

Chart 5: Pairwise correlation of crypto and traditional financial assets' price volatility




Note: Small (Large) denotes the correlation of intraday price volatility between specified crypto and traditional financial assets, during sample period when the absolute percentage change in Tether's size is smaller (larger) than 90th percentile of the sample.

## SPILLOVER ANALYSIS

While the correlation analysis in the previous section provides a simple way to gauge the changes in the relationship of crypto and traditional financial assets' price volatility when the size of Tether's reserve adjustment varies, it may not be enough to conclude a larger volatility spillover as the lead-lag relationship is not considered. Furthermore, the pair-wise correlation does not capture the dynamics with other assets, which may also be an important factor to consider given the interlinkages between different asset types.

To take these aspects into account, we consider the following two-regimes Threshold Vector Autoregression model (TVAR);

$$y_t = \begin{cases} \alpha_1 + A_1(L)y_t + \varepsilon_{1t}, if\ 0 < dTether_{t-1} < V_1 \\ \alpha_2 + A_2(L)y_t + \varepsilon_{2t},\ if\ V1 \leq dTether_{t-1} \end{cases} \quad (1)$$

In the above model, $y_t$ is a vector of intraday price volatility of the five asset types given in Table 1. $dTether$ denotes the size of Tether's reserve adjustment. $V_1$ refers to the threshold value of Tether's reserve adjustment determined by the TVAR model. Accordingly, the model captures the differences in the relationships of different variables between regimes of large and small reserve adjustment by Tether.

With the estimated TVAR we compute the gross volatility spillover between different asset classes based on Diebold and Yilmaz (2009)'s spillover measure.[12] It defines the **gross spillover from variable A to variable B as the percentage of variation in B that can be explained by the shock originated in A**.[13] It should be noted that the Diebold and Yilmaz (2009)'s spillover measure is intended for conventional VAR model, such that we further apply Lanne and Nyberg (2016) algorithm to compute the spillover measure for a TVAR model.[14]

The network graphs in Chart 6 presents the results. Specifically, they depict the gross intraday price volatility spillover from crypto (i.e., Bitcoin and Tether, upper part of the chart) to traditional financial assets (i.e., equity, US treasury and money market instruments, lower part of the chart), with the thickness of the edges denoting the size of gross volatility spillover defined earlier. The left (right) panel shows the gross volatility in regimes of small (large) reserve adjustments by Tether, based on the pre-defined threshold value ($V_1$) determined by the TVAR model.

There are three observations from the charts. First, there is a larger gross volatility spillover from both Tether and Bitcoin to money market instruments when there is larger reserve adjustment by Tether. Specifically, shocks to Tether's price volatility explains 29.3% of the variations in the price volatility of money market instrument when there is a large reserve adjustment by Tether, compared to 18.7% in times of a small reserve adjustment (the rightmost red edge in both panels of Chart 6). In other words, the gross volatility spillover from Tether to money market instruments increases by about half when Tether undergoes a larger reserve adjustment. The relative increase in the volatility spillover from bitcoin to money market instruments is even larger (0.6% to 9.7%, a 15-times increase).[15]

[12] Two adjustments have been made to $y_t$ before TVAR estimation. First, we remove the effect of market volatility (by regressing each variable in $y_t$ against the VIX index and extract the resulting residual), as crypto assets tend to be more closely tied to wider financial markets in times of heightened risk aversion (ECB, 2022). Second, we winsorised all $y_t$ at 95% to remove the effect of outliers.

[13] In this regard, for each variable, the sum of spillover from all variables in the system (including the variable itself) would always equal to 100%.

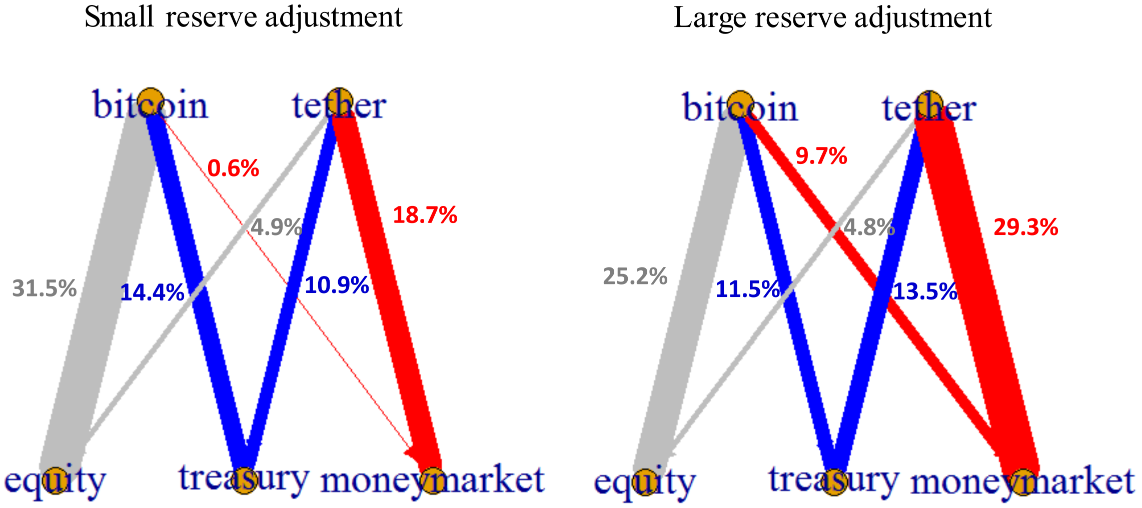
[14] Annex B provides the details of the computation algorithm.

[15] Additional tests are conducted to validate the spillover channel. Details can be found in Annex C.

For the US treasury, another major component of Tether's reserve assets, the increase in gross volatility spillover is comparatively smaller when it shifts from small to large reserve adjustment regime. Specifically, the gross volatility spillover from Tether to US treasury increased only slightly from 10.9% in the small reserve adjustment regime to 13.5% in the large reserve adjustment regime (the rightmost blue edge in both panels of Chart 6). The little increase in gross volatility spillover may be explained by the fact that the US treasury market is much larger and deeper compared to the money markets, such that the transaction of the US treasury due to Tether's reserve adjustment may not pose a material impact on the US Treasury's price.

Lastly, despite having the largest gross spillover effect on average, the gross volatility spillover from Bitcoin to equity changes little across regimes (the leftmost grey edge, 31.5% and 25.2% in the small and large reserve adjustment regime respectively). The same applies for the gross volatility spillover from Tether to equity (4.9 and 4.8% in small and large regimes respectively). The insensitivity of the gross volatility spillover from crypto to equity to Tether's reserve adjustment is consistent with our expectation (Table 1).

Chart 6: Estimated gross volatility spillover from crypto to traditional financial assets

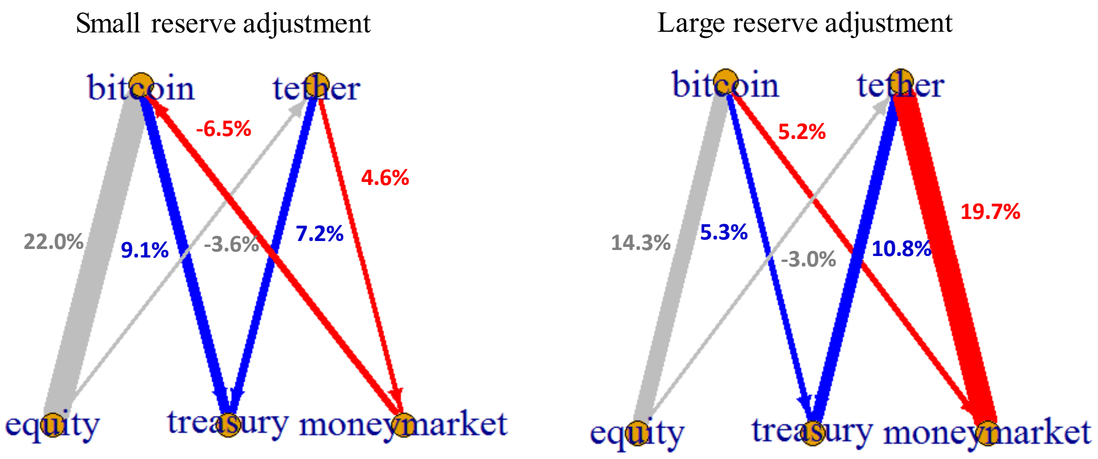



Notes: 1. The chart depicts the gross intraday price volatility spillover from crypto (upper part of the chart) to traditional financial assets (lower part of the chart), with the thickness of the edges denoting the size of gross volatility spillover. 2. Gross volatility spillover from one variable A to another variable B refers to the share of variation in B that can be explained by shocks originated in A.

The above observations largely hold when we consider the **net** volatility spillover from crypto to traditional financial assets. It is calculated as the gross volatility spillover from crypto to traditional financial assets (Chart 6) minus the gross volatility spillover in the opposite direction. Accordingly, a positive (negative) net spillover means a larger (smaller) gross volatility spillover from crypto to traditional financial assets than the other way round. By comparing the magnitude of gross volatility spillover in both directions, the net measure sheds further lights on the role of crypto assets as a volatility transmitter or receiver against traditional financial assets.

Chart 7 shows that Tether becomes a stronger volatility transmitter against money market instruments when it shifts from the small to large regime of Tether's reserve adjustment, with the net volatility spillover rising noticeably from **positive** 4.6% to **positive** 19.7%. The change in net volatility spillover from Bitcoin to money market instruments is even more drastic, from **negative** 6.5% to **positive** 5.2%. This implies that a larger reserve adjustment by Tether could change Bitcoin from a net volatility receiver to a net transmitter against money market instruments. For the US Treasury and equity, we do not find noticeable increases in the net spillover from crypto assets as it shifts to the large reserve adjustment regime, consistent with the observations in Chart 6.

Chart 7: Estimated net volatility spillover from crypto to traditional financial assets




Notes: (1) The chart depicts the net volatility spillover from crypto (upper part of the chart) to traditional financial assets (lower part of the chart), calculated as the gross volatility spillover from crypto to traditional financial assets minus the gross volatility spillover in the opposite direction. (2) A positive (negative) net spillover means crypto asset is a volatility transmitter (receiver) against traditional financial asset, as also reflected by an outgoing (incoming) edge. (3) Gross volatility spillover from one variable A to another variable B refers to the share of variation in B that can be explained by shocks originated in A.

## IV. DISCUSSION AND CONCLUSION

The rapid growth of the crypto ecosystem and its increasing connection with the traditional financial system have raised questions on whether and how instabilities of crypto assets could spillover to the traditional financial system. Focusing on Tether, the largest asset-backed stablecoin, this study finds that its reserve adjustment magnifies the volatility spillover from crypto to money market instruments.

Our finding reveals a channel through which risks borne by crypto assets could spillover to the traditional financial system and pose potential threat to financial stability. In extreme circumstances, failures of stablecoins or other crypto assets could result in large-scale redemptions of asset-backed stablecoins and a fire-sale of their reserve assets, potentially posing material impact on traditional financial markets such as the money market identified in this study. The mass redemptions in Tether in May-2022 amid the collapse of Terra USD has shown how vulnerable asset-backed stablecoins can be to abrupt developments in the crypto ecosystem.[16]

As the crypto ecosystem continues to grow and is increasingly exposed to the financial sector, the linkages between crypto and traditional financial assets are likely to become stronger, potentially increasing the risk spillover discussed above. Importantly, the crypto ecosystem remains largely outside the oversight of regulators, with large data gaps impeding regulators' assessments of the spillover risk. Given that the international regulatory community is considering putting in place appropriate regimes to regulate stablecoins, this study concludes with two suggestions that regulators may consider:

[16] Heightened volatility in money market instruments is observed at the same time as the intraday price volatility of Tether reached its recent peak on 12 May 2022, providing further evidence on volatility spillover from crypto to money market instrument found in this study. The outstanding Tether in circulation (price adjusted) declined by 13% in May 2022, the second largest month-to-month decline in its history.

1. Requiring standardised and regular disclosures by the issuers of asset-backed stablecoins on their reserve assets holdings[17], which could help regulators assess and compare their liquidity condition and potential liquidity mismatch risk. This could enable regulators to consider, in a more timely manner, taking appropriate measures to reduce the spillover risk in times of market disruption, and;

2. Strengthening the asset-backed stablecoins' liquidity management, possibly by imposing restrictions on the composition of reserve assets and requiring well-defined redemption rights,[18] which may also help reduce the spillover risk.

An effective implementation of the above would require internationally coordinated regulation and co-operative oversight given the borderless nature of the crypto ecosystem, as differing regulatory approaches across jurisdictions could lead to regulatory arbitrage and increase potential systemic risks (FSB, 2022).

[17] While largest asset-backed stablecoins such as Tether and USD Coin have been disclosing their reserve asset compositions, the information covered, format as well as the frequency of their disclosures are different to each other, making their comparison difficult.

[18] For instance, according to Tether's terms of service, Tether reserves the right to delay the redemption or withdrawal of Tether tokens if such delay is necessitated by the illiquidity or unavailability or loss of any Reserves held by Tether to back the Tether Tokens. Some issuers may even reserve the rights to suspend redemptions at any time (U.S. Department of The Treasury, 2021). Uncertainties in and variations of redemption rights across stablecoins could give rise to contagion risks when stablecoins were under stress. In fact, ensuring legal clarity to users on the nature and enforceability of any redemption rights and the process for redemption is also one of the high-level recommendations by the Financials Stability Board to address the regulatory, supervisory and oversight challenges raised by global stablecoins (FSB, 2020).

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ANNEX

## A. Six major types of Crypto assets

| Types | Description |
|---|---|
| Un-backed crypto currencies | Secured by cryptography, un-backed cryptocurrencies are digital currencies that act as a medium of exchange for buying products or services, as a store of value or as an investment asset. Un-backed cryptocurrencies have no inherent value; their perceived value is based largely on supply and demand in the market. Examples of un-backed cryptocurrencies include Bitcoin and Ethereum. |
| Stablecoins | A special type of cryptocurrencies, stablecoins aim to eliminate the price volatility of un-backed cryptocurrencies by tying their values to financial assets such as the fiat currencies or commodities. Examples of stablecoins include Tether, DAI and USD coins. |
| Utility tokens | A utility token uses a distributed ledger or blockchain platform to provide access rights to a specific product or service (potentially one that is still in development), or to be used to purchase specific products or services. The provider of the products or services typically issues the tokens, which can only be used within the issuer's network. |
| Security Tokens | Security tokens are often sold or auctioned in an Initial Coin Offering (ICO) or an Initial Token Offering (ITO) that allows businesses to raise money to fund an idea or business model. The business offers security tokens in exchange for fiat money or other crypto assets. The security token often comes with a stake in the project and additional benefits, such as voting rights, profit sharing or dividends, even though such projects may not always succeed. |
| Non-Fungible Tokens (NFTs) | Non-fungible tokens (NFTs) are tokens that exist on a distributed ledger or blockchain, which record ownership of a unique tangible or intangible object – such as a song, a digital image, a video, designer clothing, etc. Non-fungible means these tokens cannot be exchanged for one another; each one is unique. NFTs are relatively new, even for |

| | |
|---|---|
| | crypto assets, and the regulatory scheme and marketplace for NFTs are rapidly evolving. |
| Decentralised Finance (DeFi) Tokens | DeFi aims to make decentralised financial services accessible to anyone with an internet connection and uses smart contracts to provide them. DeFi platforms enable the decentralised exchange of tokens, lending and borrowing, as well as staking, yield farming and a multitude of other ways to earn passive income. Maker, Chainlink and Compound are some well-known DeFi tokens in respective DeFi platforms. |

Source: Canada Financial and Consumer Services Commission and Wirex

## B. Computation algorithm of the volatility spillover measure

1. Draw $N$ vectors of shocks for the $K$ endogeneous variables $(\delta_{t,1}, \delta_{t,2}, \ldots, \delta_{t,K})$ in the TVAR model from the residuals of the estimated TVAR model.

2. Pick a history $\omega_{t-1,q}$ from among the set of all histories from certain regime $q$. Together with the shock vector in 1), compute the generalised impulse response function (GIRF) of $y_t$ to the shock $\delta_{t,K}$ at horizon $l$ as the differences in the expectation of $y_{t+l}$ conditional on history $\omega_{t-1,q}$ with and without shock $\delta_{t,K}$ imposed. The conditional expectations is obtained using the standard multistep forecasting methods. [19] Repeat for all $(\delta_{t,1}, \delta_{t,2}, \ldots, \delta_{t,K})$

$$\text{GIRF}(\text{l}, \delta_{t,K}, \omega_{t-1,q}) = E\left(y_{t+l} \middle| \varepsilon_{t,K} = \delta_{t,K}, \omega_{t-1,q}\right) - E\left(y_{t+l} \middle| \omega_{t-1,q}\right)$$

3. Plug in the GIRFs computed in Step 2 into the following equation to generate the generalized forecast error variance decomposition (GFEVD) at horizon $l$, for variable $i$ due to shock in variable $j$ $(\theta_{ij,\omega_{t-1}}(l))$

[19] In our application, we further assume the $dTether_{t-1}$ depends on intraday volatility of bitcoin and tether to enable regime switching in the multistep forecasting process. This is essential for generating the nonlinear GIRFs.

$$\theta_{ij,\omega_{t-1,q}}(l) = \frac{\sum_{l=0}^{l} \mathrm{GIRF}(\mathrm{l}, \delta_{t,K}, \omega_{t-1,q})_i^2}{\sum_{j=1}^{K} \sum_{l=0}^{l} \mathrm{GIRF}(\mathrm{l}, \delta_{t,K}, \omega_{t-1,q})_i^2}, i, j = 1, \dots, k$$

By construction, $\theta_{ij,\omega_{t-1,q}}(l)$ lies between 0 and 1, measuring the relative contribution of a shock to the *j*th equation in relation to the total impact of all
*K* shocks on the *i*th variable in $y_t$ after *l* periods, and these contributions sum to unity.

4. Repeat Steps 3 for all *N* vector of shocks.

5. Repeat Steps 2-4 for all the histories in regime q.

6. Compute the spillover measure from variable $j$ to variable $i$ in regime $q$ as the average of $\theta_{ij,\omega_{t-1,q}}(l)$, (*l* = 0,1,2…) over all the histories and shocks.

7. Repeat Steps 2-6 to compute the spillover measure for other regimes.

## C. Additional tests on spillover channel

This section reports results of various tests used to validate the spillover channel in Section 2. The tests can be broadly divided into two groups. First, two "positive" tests are conducted to verify whether our baseline results still hold when we slightly modify the empirical settings but the spillover channel is expected to remain. The second group contains three "negative" tests where we modify the empirical setting in a way that the spillover channel is not expected to exist anymore. Table C.1 summarizes these tests.

Table C.2 reports the test results. For brevity, we only report the estimated volatility spillover from crypto to money market instruments in these tests. For the two "positive" tests, where the spillover channel is expected to remain, we continue to find a larger volatility spillover from crypto assets (Tether and other crypto assets) to money market instruments with a large Tether reserve adjustment, while such patterns cannot be found consistently in all "negative" tests. These additional tests help validate our hypothesis that asset-backed stablecoins magnify the volatility spillover from crypto to traditional financial assets (in particular) through their reserve adjustment mechanism.

Table C.1: Descriptions of additional tests

| Test | | Details and expected results |
|---|---|---|
| **Positive** tests | Ethereum as non-stablecoin crypto assets | In this test we replace Bitcoin with Ethereum, the second largest non-stablecoin crypto assets. Similar to Bitcoin, volatilities in Ethereum' price could also affect the price volatilities of Tether and thus trigger its reserve adjustment, magnifying the volatility spillover from Ethereum to money market instruments. |
| | USD coin as non-stablecoin crypto assets | Similar to the above test, but we replace Bitcoin with USD coin, the second largest stablecoin behind Tether. Volatilities in USD coin could also spillover to Tether (e.g., confidence issue) and thus trigger Tether's reserve adjustment, magnifying the volatility spillover from USD coin to money market instruments. |
| **Negative** tests | Early history | The test setting is the same as the baseline except that the sample period is changed to 2018 to 2019. With a much smaller size during this period, Tether's reserve adjustment is unlikely to pose material impact on money market instruments, and thus the volatility spillover from crypto to money market instruments. |
| | Unrelated threshold variable | The test setting is the same as the baseline except that we use the size of USD coin's reserve adjustment (instead of Tether's) as the threshold variable. With little correlation between the reserve adjustment for USD coin and Tether (correlation coefficient = 0.01), it is unlikely to observe a larger volatility spillover from Bitcoin and Tether to money market instruments in times of larger reserve adjustment by USD coin. |
| | DAI as stablecoin | In this test we replace Tether with DAI as the stablecoin in test. An algorithmic stablecoin whose value is maintained by computer algorithm rather than reserve assets backing, changes in DAI's size would not involve reserve asset adjustment, such that larger changes in DAI's size would NOT magnify the volatility spillover from crypto (Bitcoin and DAI) to money market instruments. |

Table C.2: Estimated volatility spillover from crypto to money market instruments

| | Stablecoins → Money market instruments | | Other crypto assets → Money market instruments | |
|---|---|---|---|---|
| | Small reserve adjustment | Large reserve adjustment | Small reserve adjustment | Large reserve adjustment |

| | | | | | |
|---|---|---|---|---|---|
| **Positive** tests | Ethereum as other crypto assets | 0.65% | 1.55% | 5.54% | 8.21% |
| | USD coin as other crypto assets | 3.62% | 22.5% | 11.09% | 22.99% |
| **Negative** tests | Early history | 1.77% | 3.18% | 10.81% | 8.71% |
| | Unrelated threshold variable | 10.07% | 9.48% | 4.26% | 8.40% |
| | DAI as stablecoin | 7.86% | 7% | 3.69% | 2.15% |

Notes: 1. This table reports the estimated volatility spillover from crypto to money market instruments similar to baseline but with slightly different settings. 2. Figures in green under "large reserve adjustments' denote the estimated volatility spillover is larger than the estimated volatility spillover in the regime of small reserve adjustment.