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Has US (Un)Conventional Monetary Policy Affected South African Financial Markets in the Aftermath of COVID-19? A Quantile–Frequency Connectedness Approach

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Abstract

The US has undertaken both unconventional and conventional monetary policy stances in response to the COVID-19 pandemic and the Ukraine–Russia conflict, and there has been much debate on the effects of these various monetary policies on global financial markets. Our study considers the debate in the context of South Africa and uses the quantile–frequency connectedness approach to examine static and dynamic systemic spillover between the US shadow short rate (SSR) and South African equity, bond and currency markets between 1 December 2019 and 2 March 2023. The findings from the static analysis reveal that systemic connectedness is concentrated at their tail-end quantile distributions and US monetary policy plays a dominant role in transmitting these systemic shocks, albeit these shocks are mainly high frequency with very short cycles. However, the dynamic estimates further reveal that US monetary policy exerts longer-lasting spillover shocks to South African financial markets during periods corresponding to FOMC announcements of quantitative 'easing' or 'tapering' policies. Overall, these findings are useful for evaluating the effectiveness of the Reserve Bank's macroprudential policies in ensuring market efficiency, as well as for enhancing investor decisions, portfolio allocation and risk management.

Keywords: unconventional monetary policies; shadow short rate; equity markets; debt markets; currency markets; quantile-frequency connectedness; South Africa

JEL Classification: C02; C58; G01; G15; N27

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1. Introduction

The adoption of UMP by the Federal Reserve Bank (FRB) in response to the COVID-19 pandemic was deemed necessary to restore stability in the US financial markets. US stock exchanges triggered their emergency 'circuit breaker' when the US indexes fell by more than 35% in March 2020 (Phiri et al., 2023). This was concerning since equity markets tend to reflect the health of an economy, and market crashes usually coincide with sharp economic downturns (Cepni et al., 2023). In response, the FRB implemented a round of quantitative easing (QE) consisting of large-scale asset purchases (LSAP) of Treasuries and mortgage-backed securities (MBS), which eventually accumulated into a USD 2 trillion expansion of the Federal Reserve's balance sheet in July 2020 (de Rezende & Ristiniemi, 2023). Remarkably, US equity markets recovered after these policy interventions, even reaching record highs in December 2020. Many commentators have cited these market recoveries as indicators of the success of UMP in recovering the US economy (Phan &

Narayan, 2021; Narayan et al., 2021). However, other authors are not so optimistic and have argued that spillovers from US UMP cause sharp fluctuations in capital flows to and from non-industrialized economies, which then destabilizes financial and economic cycles (Anaya et al., 2017; Papadamou et al., 2019; Tumala et al., 2021; Choi et al., 2024).

Whilst most African financial markets are considered to be underdeveloped and exempt from global financial shocks (Anyikwa & Phiri, 2023), South African financial markets are known to be well developed and more integrated into the global economy (Iyke & Ho, 2021). In particular, South Africa holds certain 'financial development' accolades, which makes the country an interesting case for investigating US UMP spillovers into the African continent. For instance, South Africa has the most developed equity and debt markets in the continent; it is the only African country with market capitalization greater than its GDP; it boasts the most listings of any African country on US Stock exchanges; and it has the most traded African currency, as well as the largest reserves of foreign currency (Kabundi et al., 2020; Phiri, 2015, 2020). However, South Africa is also classified as a 'fragile emerging economy' whose domestic financial markets are more susceptible to being recipients of cross-border spillover effects via the portfolio rebalancing and/or risk-taking transmission channels (Bhattarai et al., 2021; Maurer & Nitschka, 2023). Furthermore, Huertas (2022) has documented that inflation-targeters in emerging economies, like South Africa, have responded closely to UMP announcements by the Federal Reserve, hence suggesting a strong degree of monetary policy coordination amongst these countries. Therefore, US monetary policy decisions can spill over into the South African financial markets through the 'signalling' and/or 'foreign interest rate' channel of transmission. Moreover, spillovers from the US UMP to South African markets can also affect other African countries, particularly those whose financial systems are closely linked with South Africa via common monetary areas (CMAs) (Qabhobho et al., 2020; Mkhombo & Phiri, 2022, 2023).

For these reasons, South Africa has received more empirical attention from researchers investigating the impact of US UMP on financial market activity compared to other African countries (Lavigne et al., 2014; Bowman et al., 2015; Anaya et al., 2017; Gupta et al., 2017; Naape & Masoga, 2019; Kabundi et al., 2020; Kalu et al., 2020; Meszaros & Olson, 2020; Lubys & Panda, 2021; Wei & Han, 2021; Yildirim & Ivrendi, 2021; Ntshangase et al., 2023; Cui et al., 2024). Nonetheless, we identify certain empirical gaps that motivate us to advance this group of studies (see Appendix A for a comprehensive summary of previous literature). For starters, previous South African-based studies have focused on the impact of QE1 to QE3 on different financial markets, and notably, these QE programs only capture UMP practiced in response to the global financial crisis. Our study extends the scope of this previous research and seeks to examine the impacts of US UMP on South African financial markets in the aftermath of the COVID-19 pandemic. To this end, we formulate the following hypothesis:

H01. *The impact of US UMP conducted in response to the COVID-19 pandemic had a significant impact on South African financial markets.*

We also methodologically differ from previous South African studies that have mainly used conventional econometric methods, such as event studies (Lavigne et al., 2014; Aizenman et al., 2016; Estrada et al., 2016; Gupta et al., 2017; Naape & Masoga, 2019; Lubys & Panda, 2021; Wei & Han, 2021) and/or VAR-type models (Bowman et al., 2015; Anaya et al., 2017; Kabundi et al., 2020; Meszaros & Olson, 2020; Ono, 2020; Bhattarai et al., 2021; Yildirim & Ivrendi, 2021; Ntshangase et al., 2023; Cui et al., 2024). These conventional estimators have been criticized for being unable to account for time variation, which is crucial for detecting bubble-build-up and contagion effects (Rigobon, 2019). An alterna-

tive approach popularized in recent studies is the dynamic connectedness framework of Diebold and Yilmaz (2009, 2014), which not only measures the system-wide connectedness amongst financial markets but can further investigate spillovers at a market-specific level. An appealing feature of the framework is its ability to distinguish between net receivers and transmitters within a system of financial markets, whilst the rolling window analysis further reveals dynamic spillover and connectedness effects in a time-varying fashion. Various extensions of the D-Y framework have been proposed in the financial literature (Diebold & Yilmaz, 2023).

Our study uses the quantile–frequency framework of Chatziantoniou et al. (2021), which is a fusion of the quantile–frequency connectedness approach of Ando et al. (2022) and the frequency connectedness method of Baruník and Křehlík (2018). On one hand, the quantile connectedness model examines systemic spillover between financial assets at different quantiles of distribution, and this is useful for examining spillovers at different states of financial markets, which hold information on 'bad' and 'good' news. On the other hand, the frequency connectedness model measures systemic spillovers at different cyclical components and is useful for capturing differences in the behaviors of investors and policymakers in financial markets over different horizon periods. The quantile–frequency connectedness method disintegrates systemic spillovers within quantile distributions into different frequency spectrums, which allows one to observe both the short-run and long-run cycles of systemic connectedness, hence capturing the heterogeneous behavior of investors and policymakers at different states of the market and across various time periods (Chatziantoniou et al., 2021). We therefore use the quantile–frequency spillover framework to test the following hypothesis:

H02. *The impact of UMP on South African financial markets in the post-COVID-19 period varies across different time, quantile and frequency distributions.*

Our study also employs the shadow short rate (SSR) of de Rezende and Ristiniemi (2023) as a more precise measure of UMP compared to asset purchases (Lavigne et al., 2014; Naape & Masoga, 2019; Kabundi et al., 2020; Bhattarai et al., 2021), FOMC announcements (Bowman et al., 2015; Aizenman et al., 2016; Lubys & Panda, 2021; Wei & Han, 2021), quantitative 'easing' and 'tapering' dummy variables (Estrada et al., 2016; Ntshangase et al., 2023), Federal Reserve balance sheet (Anaya et al., 2017; Apostolou & Beirne, 2019), Treasury yield (Gupta et al., 2017; Kalu et al., 2020) and US term spread (Yildirim & Ivrendi, 2021) proxies used in previous South African-based studies. Notably, the SSR captures UMP as a time series measure of a hypothetical negative interest rate below the zero-lower bound. Moreover, during normalization periods, the SSR converges to the Federal Fund Rate (FFR). We therefore use the SSR in conjunction with the dynamic quantile–frequency connectedness framework to segregate the spillover effects of US conventional and unconventional monetary practices on South African financial markets in a time-varying fashion. This then allows us to test the following hypothesis:

H03. *The impact of US monetary policy on South African markets differs between UMP and 'normalization' periods.*

Altogether, our study uses the quantile–connectedness framework to examine the spillovers and connectedness between the US SSR and three classes of financial markets (equity, debt and currency) in South Africa between 1 January 2019 and 2 March 2023. The main objective of our research is to quantify the impact of US (un)conventional monetary policy on equity, debt and currency markets in the aftermath of COVID-19 and the Ukraine–Russia conflict. The main research question that our paper answers is whether there are

differences in transmission effects of US conventional and unconventional monetary policy to South Africa's equity, debt and currency markets across different time periods, quantiles and frequencies under these 'Black Swan' episodes.

The overall contribution of our paper is three-fold. Firstly, our study presents a premiere in documenting spillovers of US UMP to South African financial markets in the aftermath of COVID-19. Secondly, our study is the first to make use of the SSR to capture the impact of US (un)conventional monetary policy on South African financial markets. We particularly make use of the SSR estimates of de Rezende and Ristiniemi (2023), which are not sensitive to the assumed numerical value of the lower bound and have more up-to-date coverage in comparison to the traditional SSR estimates of Krippner (2013, 2019) and Wu and Xia (2016, 2020). These features enhance the precision in capturing US UMP dynamics. Lastly, we demonstrated the usefulness of quantile frequency as a methodological approach to examine spillovers and connectedness in financial markets at different frequencies across different quantiles of distribution. The closest studies to ours those which used the traditional Diebold–Yilmaz connectedness framework to demonstrate that the US SSR is a main transmitter of systemic shocks to agricultural commodity futures (Umar et al., 2023) as well as Islamic and advanced equity markets (Choi et al., 2024) during crisis periods such as the sub-prime crisis, Brexit and the COVID-19 pandemic. We complement these studies by using a more advanced connectedness framework and focusing on South African financial assets for more recent data covering the Ukraine–Russia conflict.

Our study has important implications for different stakeholders. For instance, investors and fund managers who hold South African equity, debt and currency instruments in their portfolios would be interested in knowing which financial markets are more susceptible to systemic shocks. Our findings can thus be used by market participants to improve the risk profiles of portfolio holdings across different market states and investment horizons. Our study also has implications for South African monetary authorities who would be more interested in knowing the system-wide spillovers from US monetary policy to domestic financial markets. This is particularly interesting considering that the SARB has relied on macroprudential policies to protect South African financial markets from external shocks, and hence, our findings can be used to evaluate how effective these macroprudential policies have been under different market conditions and cyclical frequencies.

The rest of the study is structured as follows. Our data and empirical methodology are outlined in the next section. We then present our empirical results in Section 3 and provide a further discussion of these results in Section 4. Section 5 concludes the paper.

2. Data and Methods

2.1. Data

Our study uses daily data of 7 time series collected from 1 December 2019 to 30 March 2023. On one hand, we use the US SSR measure of de Rezende and Ristiniemi (2023) to capture unconventional and conventional monetary practices. On the other hand, South Africa's financial sector is represented by three stock indices (JSE All-Share Index; FTSE SA Index; iShares MSCI index), two bond indices (S&P South African Sovereign Bond; 10-year South African Bond) and the USD/ZAR exchange rate, which are all transformed to daily returns using the continuous compounding technique as $r_t = 100 \times ln\left(\frac{P_t}{P_{t-1}}\right)$. The methodological approach to modeling spillovers and connectedness amongst these time series is outlined in the next subsection.

2.2. Methods

We use the quantile–frequency connectedness approach of Chatziantoniou et al. (2021) to investigate systemic spillover effects between US UMP and the South African financial market. Recent application of this methodology is found in studies examining connectedness between cryptocurrency and energy markets (Le, 2023), policy uncertainty and oil markets (Nong & Liu, 2023), nonferrous metal (Wei et al., 2022), clean energy, cryptocurrencies and conventional financial markets (Zhao & Park, 2024), dirty and clean cryptocurrencies (Marco et al., 2023), cryptocurrencies, energy tokens and renewable energy markets (Wang et al., 2024) and geopolitical risk (Hong-Vo & Dang, 2024). To the best of our knowledge, our study is the first to use the methodology to examine the systemic spillovers between US monetary policy and financial markets. In describing the methodology, we begin with the breakdown of the quantile connectedness framework and thereafter incorporate the frequency components within each quantile.

2.2.1. Quantile Connectedness Component

We firstly present our baseline QVAR(p) model:

$$Z_t = V(\tau) + \sum_{i=0}^{\rho} \varphi_J(\tau) Z_{t-J} + \epsilon_t(\tau) \tag{1}$$

where Z_t and Z_{t-j}, are N × 1 vectors of endogenous variables, τ is the quantile (τ ∈ 0,1), p is the lag length, V(τ) is a N × 1 dimensional conditional mean vector, $\phi_j(\tau)$ is an N × N vector of QVAR coefficients and ε_t is a N × 1 vector of autocorrelated disturbance terms. An infinite order moving average representation of the QVAR model (i.e., QVAR(∞)) can be written as

$$Z_t = V(\tau) + \sum_{i=0}^{\infty} A_i(\tau) \epsilon_{t-i} \tag{2}$$

With A(τ) representing the moving average lag coefficient matrix. The H-step ahead generalized forecast error variance decomposition (GFVED) matrix $\Theta^H = [\Theta^H_{ij,(\tau)}]$ can be computed at any quantile (τ) as

$$\Theta^H_{ij,(\tau)} = \frac{\sum \tau_{ij}^{-1} \sum_{h=0}^{H-1} \left(w_i A_h(\tau) \sum(\tau) e_j\right)^2}{\sum_{h=0}^{H-1} \left(w_i A_h(\tau) \sum(\tau) e_j\right)} \tag{3}$$

where $\sum$ is the variance matrix of the error vector ϵ; and $\boldsymbol{e}_i$ is an n × 1 selection vector with 1 as the *ith* element and zero if otherwise. Thereafter, individual elements of the variance decomposition matrix are normalized by the row sum as

$$\hat{\Theta}^H_{ij,(\tau)} = \frac{\Theta^H_{ij,(\tau)}}{\sum_{j=1}^{n} \Theta^H_{ij,(\tau)}} \tag{4}$$

where $\sum_{j=1}^{n} \hat{\Theta}^H_{ij,(\tau)} = 1$, and $\sum_{i,j=1}^{n} \hat{\Theta}^H_{ij,(\tau)} = n$.

2.2.2. Frequency Connectedness Component

In introducing the frequency component within the connectedness framework, we follow Stiassny (1996) and Baruník and Křehlík (2018), who use a spectral decomposition approach to induce frequency dynamics within the VAR model. The method is based on the following frequency response function:

$$\Psi\left(e^{-i\omega}\right) = \sum_{h=0}^{\infty} e^{-i\omega h} \Psi_h, \tag{5}$$

where $i = \sqrt{-1}$ and where ω represents the frequency. The spectral density of $\boldsymbol{x}_t$ at frequency ω can be defined as an infinite Fourier transformation of an infinite order moving average (i.e., FVAR(∞)):

$$S_x(\omega) = \sum_{h=-\infty}^{\infty} E(\boldsymbol{x}_t \boldsymbol{x}'_{t-h}) e^{-i\omega h} = \Psi\left(e^{-i\omega h}\right) = \sum_t \Psi'\left(e^{-i\omega h}\right) \tag{6}$$

where $S_x(\omega)$ is the power spectrum and $\mathrm{E}\left(\boldsymbol{x}_t \boldsymbol{x}'_{t-h}\right) = \int_{-\pi}^{\pi} S_y(\omega) e^{-i\omega h} d\omega$ is the covariance in the frequency domain. Notably, the frequency GFEVD is the combination of spectral density and the GFEVD, which can be normalized as

$$\Theta_{ij}(\omega) = \frac{\sum_{ij}^{-1} \left| \sum_{h=0}^{\infty} \left(\boldsymbol{\Psi}\left(e^{-i\omega h}\right) \sum \right)_{ij} \right|^2}{\sum_{h=0}^{\infty} \left(\boldsymbol{\Psi}\left(e^{-i\omega h}\right) \sum \boldsymbol{\Psi}\left(e^{-i\omega h}\right) \right)_{ij}} \tag{7}$$

And incorporating the frequency GFVED within a quantile framework yields

$$\Theta_{ij,(\tau)}(\omega) = \frac{\sum \tau_{ij}^{-1} \left| \sum_{h=0}^{\infty} \left(\boldsymbol{\Psi}(\tau)\left(e^{-i\omega h}\right) \sum(\tau) \right)_{ij} \right|^2}{\sum_{h=0}^{\infty} \left(\boldsymbol{\Psi}\left(e^{-i\omega h}\right) \sum(\tau) \boldsymbol{\Psi}(\tau) \left(e^{-i\omega h}\right) \right)_{ij}} \tag{8}$$

$$\hat{\Theta}_{ij,(\tau)}(\omega) = \frac{\Theta_{ij,(\tau)}(\omega)}{\sum_{k=1}^{n} \Theta_{ij,(\tau)}(\omega)} \tag{9}$$

where $\hat{\Theta}_{ij,(\tau)}(\omega)$ represents the portion of the spectrum of the ith series at a given frequency ω that can be attributed to a shock in the jth series at the τ^{th} quantile. To assess short-term and long-term connectedness, we aggregate all frequencies within a specific range, $d = (a, b) : a, b \in (-\pi, \pi),\ a < b$:

$$\hat{\Theta}_{ij,(\tau)}(d) = \int_a^b \hat{\Theta}_{ij,(\tau)}(\omega) d\omega \tag{10}$$

2.2.3. Connectedness and Spillover Effects in Quantile–Frequency Framework

Finally, we compute similar connectedness measures to those presented in Diebold and Yilmaz (2009, 2012, 2014) within a quantile–frequency framework. In particular, Chatziantoniou et al. (2021) propose that total directional connectedness from other (FROM), total connectedness to others (TO), the net spillover effects (NET) and the total connectedness index (TCI) can be estimated as

$$TO_{ij,(\tau)\leftarrow *}(H) = \frac{\sum_{j=1}^{N} \hat{\theta}_{ij,(\tau)}^{h}}{\sum_{i,\, j=1}^{N} \hat{\theta}_{ij,(\tau)}^{h}} \times 100 \quad j \neq 1 \tag{11}$$

$$FROM_{ij,(\tau)\rightarrow *}(H) = \frac{\sum_{j=1}^{N} \hat{\theta}_{ij,(\tau)}^{h}}{\sum_{i,\, j=1}^{N} \hat{\theta}_{ij,(\tau)}^{h}} \times 100 \quad j \neq 1 \tag{12}$$

$$Net_{ij,(\tau)}(H) = S_{i\rightarrow *,(\tau)}(H) - S_{i\leftarrow *,(\tau)}(H) \tag{13}$$

$$TCI_{(\tau)}(H) = \frac{\sum_{i,j,(\tau)=1, i\neq j}^{n} \hat{\theta}_{ij,(\tau)}^{h}}{\sum_{i,\, j,(\tau)=1}^{N} \hat{\theta}_{ij,(\tau)}^{h}} \times 100 \tag{14}$$

3. Empirical Analysis

3.1. Descriptive Statistics of Time Series

The summary statistics presented in Table 1 provide some stylized facts on the data. For instance, the US SSR averages close-to-zero values, which highlight the fact that 'quantitative easing' practices have been dominant over our sample period. Moreover, the returns and yields on South African financial assets is positive on average, although the relatively high standard deviations show that the series are quite volatile. The JB statistic further shows that the variables are not normally distributed, mainly due to fat tails in the data, and this provides motivation for using the quantile–frequency connectedness approach to capture tail-end spillover dynamics. Lastly, the ADF and PP unit root tests show that, with the exception of the US SSR, all remaining series are levels stationary. Since the quantile–frequency connectedness approach is only compatible with I(0) variables, we follow Antonakakis et al. (2019) and use the first differences of the US SSR in our analysis.

Table 1. Descriptive statistics.

Series	Mean	Std Dev	Skew	Kurt	JB (prob)	ADF	PP
US SSR	0.74	2.17	0.21	2.10	0.00	−0.369	−0.285
All Share Index	0.032	1.28	−0.82	11.01	0.00	−32.98 ***	−32.99 ***
FTSE SA Index	0.018	1.35	−0.86	11.81	0.00	−32.78 ***	−32.79 ***
iShares MSCI Index	−0.017	2.12	−0.94	11.63	0.00	−36.72 ***	−36.63 ***
S&P SA Sovereign Bond	0.029	0.06	−0.52	15.59	0.00	−11.55 ***	−28.69 ***
TR SA 10 yr Gov. Bond	0.033	0.62	−0.46	14.78	0.00	−29.27 ***	−29.47 ***
USD/ZAR Exchange Rate	0.022	0.94	0.30	3.62	0.00	−34.04 ***	−34.04 ***

Notes: '***' denotes the 1% critical levels, respectively.

3.2. Overview of Empirical Analysis

Our empirical analysis seeks to examine the extent to which US UMP is systemically connected with South African equity, debt and exchange rate markets. We also aim to identify which of these financial markets is resilient or vulnerable to systemic shocks. The connectedness tables presented in Appendices B–F report the GFVED estimates for the quantile-VAR, frequency-VAR and quantile-frequency VAR and form the basis of our analysis. Each connectedness table reports the raw 10-day forecast GFVED estimates obtained at different frequencies and/or quantiles, and this captures the 'input-output' spillovers in a square matrix. The diagonal elements of the connectedness matrix measure the 'self-shocks or idiosyncratic shocks', whilst the non-diagonal elements capture 'spillover shocks' TO and FROM all possible pairs of the time series. Diebold and Yilmaz (2009) initially proposed that the sum of non-diagonal elements in proportion to the sum of all elements (both diagonal and non-diagonal) measures the extent to which cross-market spillovers are dominant in the matrix system, i.e., the total connectedness index (TCI). Moreover, the market-specific net spillover effects reported in the last row of each connectedness table segregate the net transmitters (i.e., markets with positive net spillovers) from net receivers (i.e., markets with negative net spillovers) of systemic shocks.

It should be clear that our interest is in obtaining the TCI estimates and identifying market-specific net spillovers of systemic shocks across different quantiles and/or frequencies. We induce dynamism in our analysis by estimating rolling regressions with a window

size of 100 days on the QVAR, FVAR and QFVAR models and summarize the time-varying TCI and net spillovers derived from the GFVED estimates in time-series plots. Diebold and Yilmaz (2012, 2014) consider this important for identifying periods of heightened spillover effects, which are more prevalent during periods of crisis. Ando et al. (2022) find that these heightened spillovers experienced during crisis periods are most prominent at the tail-end distributions of the connectedness, and hence, the mean-based connectedness estimates of Diebold and Yilmaz (2009, 2012, 2014) undermine the severity of contagion effects. Moreover, Baruník and Křehlík (2018) find that connectedness created in high-frequency spectrums captures periods when information is absorbed rapidly by markets, and systemic shocks dissipate in short-term cycles, whereas connectedness observed at low frequency captures longer-lasting systemic shocks, which may reflect fundamental changes in the behavior of financial market participants (Strohsal et al., 2019).

We present our empirical findings as follows: Section 3.3 presents the traditional D-Y and frequency connectedness results; Section 3.4 presents the quantile connectedness results; and Section 3.5 presents the quantile–frequency results. Note that through Sections 3.3–3.5, we discuss the results of the static and dynamic estimates of each connectedness model. Further bearing in mind that the full empirical results for the static analysis are voluminous, we summarize the key findings of the connectedness tables in these sections and present the full empirical results as Appendices B–F.

3.3. Frequency Connectedness Analysis

We begin by presenting the findings from the D-Y and frequency connectedness analysis. Following Chatziantoniou et al. (2023), we make use of two frequency bands at 1–5 days (high frequency) and 5-infinity (low frequency) day cycles, whilst the total frequency corresponds to the D-Y estimates. The TCI estimates summarized in Table 2 indicate that 24.46% of the total forecast error variance comes from cross-market spillovers. In further decomposing the cross-market spillovers along a frequency spectrum, we find high-frequency components accounting for about 71% (i.e., 17.32/24.46) of total connectedness, whilst the remaining 29% (i.e., 7.12/24.46) is attributed to long-frequency components. The net spillover effects summarized in Table 2 further indicate that US monetary policy is a transmitter of systemic shocks at high frequencies, with all financial markets (with the exception of the MSCI SA index and USD-ZAR) being net receivers of these shocks. Conversely, at lower frequencies, US monetary policy and sovereign bonds are net receivers of systemic shocks, whilst the remaining financial markets are net transmitters.

Table 2. Summary of static TCI and net spillover effects at different frequencies.

	Receivers	Transmitters	TCI
Total frequency	US SSR, FTSE SA index, S&P sovereign bond, 10-year gov bond	JSE all share, MSCI SA index, USD-ZAR	24.46
High frequency	JSE all share, FTSE SA index, S&P sovereign bond, 10-year gov bond	US SSR, MSCI SA index, USD-ZAR	17.34
Low frequency	US SSR, S&P sovereign bond	JSE all share, MSCI SA index, FTSE SA index, 10-year gov bond, USD-ZAR	7.12

The rolling regression estimates of the TCI index reported in Figure 1 adhere to those from the static analysis by showing that high-frequency connectedness is more dominant than lower-frequency spillovers at all time periods. The dynamic estimates also show that the TCI has varied over time, and systemic connectedness is heightened around three main periods. Firstly, the TCI values are largest between March 2020 and May 2020, and notably, this period corresponds to the FOMC announcement of the 'quantitative easing' in response to COVID-19. Secondly, the TCI values were slightly heightened between the implementation of 'quantitative tapering' in November 2021 to the start of the Ukraine–Russia conflict in February 2022. Lastly, systemic risk began to build up from May 2022, when the Federal Reserve concluded its 'quantitative tapering' and began to aggressively increase interest rates in response to inflation pressures arising from the Ukraine–Russia conflict.

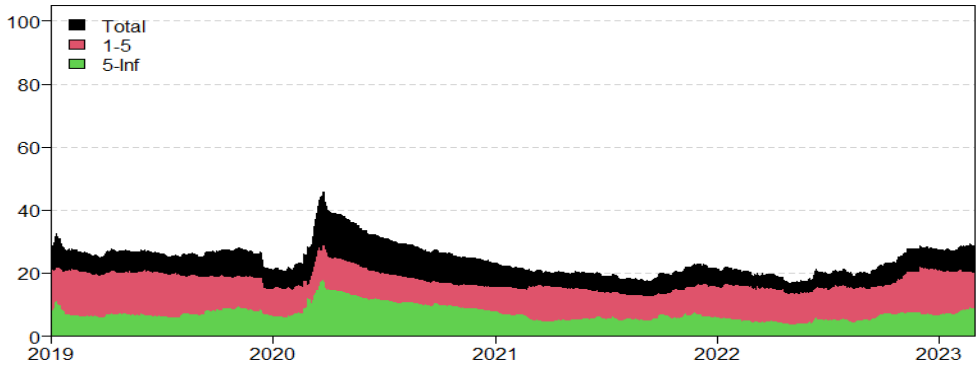


Figure 1. Dynamic TCI at total, high and low frequencies. Note: Black, red and green color contours represent the total and high- and low-frequency spillovers, respectively.

At the market-specific level, the rolling regression estimates presented in Figure 2 show that net spillover effects are mainly affected by two events. Firstly, the largest net spillover effects for all markets at all frequencies are observed between early 2020 and early 2021 and correspond to a period stretching from the announcement of QE4 to the initial implementation of LSAP. Secondly, we also observe periods of heightened net spillover effects for equities and currency markets corresponding to the end of the 'quantitative tapering' and the beginning of policy normalization from May 2022 onwards. During these two episodes, we observe (i) US monetary policy is a dominant transmitter (receiver) of shocks at higher (lower) frequencies, while (ii) South African financial markets are the main receiver (transmitter) of these shocks at the higher (lower) frequencies.

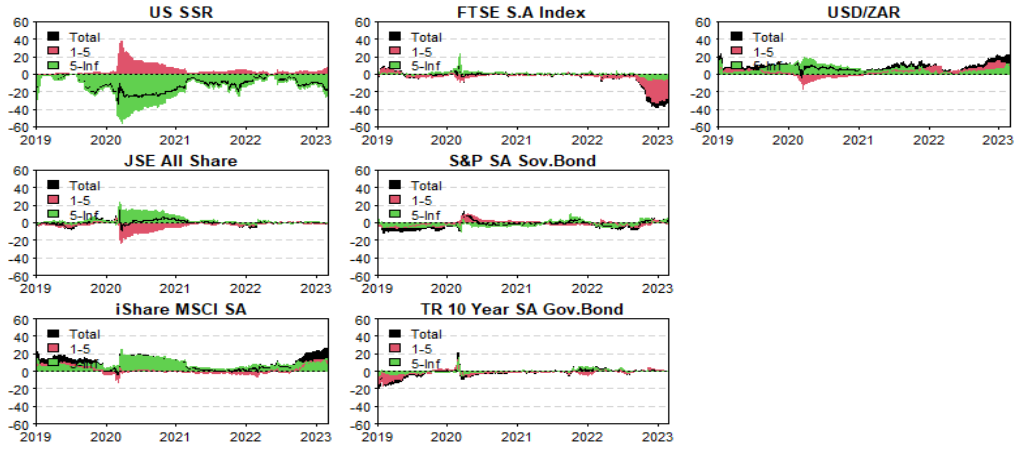


Figure 2. Net directional spillovers at total, high and low frequencies. Notes: Red and green color contours represent high- and low-frequency spillovers, respectively.

3.4. Quantile Connectedness Analysis

Next, we focus on the results obtained from the quantile connectedness analysis. Following Ando et al. (2022), we use the 5th, 50th and 95th quantiles to represent the bear, normal and bull markets, respectively. This is important to do since our sample period covers the COVID-19 pandemic and the Ukraine–Russia conflict, which many authors have categorized as being Black Swan events responsible for turmoil in global financial markets (Anyikwa & Phiri, 2023; Phiri et al., 2023). As discussed in Taleb (2007), during these rare events, the distribution of financial time series is concentrated at the extreme ends of their probability function. Therefore, mean-based estimates become ineffective in capturing these tail-end dynamics, hence creating the need to examine the spillovers amongst financial time series at different quantile distributions.

Table 3 summarizes the static TCI indexes and net transmitters/receivers of systemic shocks at the left-tailed, median and right-tailed quantile distributions. Interestingly, the TCI values corresponding to the 5th (77.63) and 95th (76.28) quantiles are more than three times as large compared to the estimates for the 50th (25.12) quantile. Furthermore, at the 5th and 50th quantiles (50th quantile), the US SSR and South African equity returns are net transmitters (receivers) of systemic shocks, whereas reverse dynamics are found for bond returns and exchange rates. Overall, these results suggest that systemic connectedness is stronger during extreme events when US monetary policy is the main transmitter of systemic shocks, and the bond/exchange rate markets (equity markets) are susceptible (resistant) to these shocks.

Table 3. Summary of static TCI and net spillover effects at different frequencies.

	Receivers	Transmitters	TCI
5th quantile	S&P sovereign bond, 10-year gov bond, USD-ZAR	US SSR, JSE all share, MSCI SA index, FTSE SA index.	77.63
50th quantile	US SSR, JSE all share, FTSE SA index	MSCI SA index, S&P sovereign bond, 10-year gov bond, USD-ZAR	25.12
95th quantile	FTSE SA index, S&P sovereign bond, 10-year gov bond, USD-ZAR	US SSR, JSE all share, MSCI SA index	76.28

The rolling regression estimates of the TCI values reported in Figure 3 provide further evidence of the systemic connectedness being larger (smaller) at the tail-end (median) distribution across the entire time window. Moreover, we find that connectedness patterns in the medium quantile correspond to those reported for the frequency connectedness, whereby the TCI indexes are heightened at periods corresponding to the start of COVID-19 in March 2020, the start of LSAP by the Federal Reserve in mid-2020, the start of the Ukraine–Russia conflict in early 2022 and the start of policy normalization from mid-2022. At the extreme quantiles, we observe that periods of heightened systemic connectedness are very 'sharp' during market slumps and booms. For instance, systemic spillovers are heightened at the left tail during the March 2020 stock market slump and April 2020 oil market crashes at the left tail and correspond to a period when the FOMC announced its intention to implement QE4. Similarly, heightened systemic spillovers at the right tail

exist during the market booms experienced (i) after the announcement of QE tapering in mid-2021 and (ii) after the end of QE tapering in mid-2021 onwards.

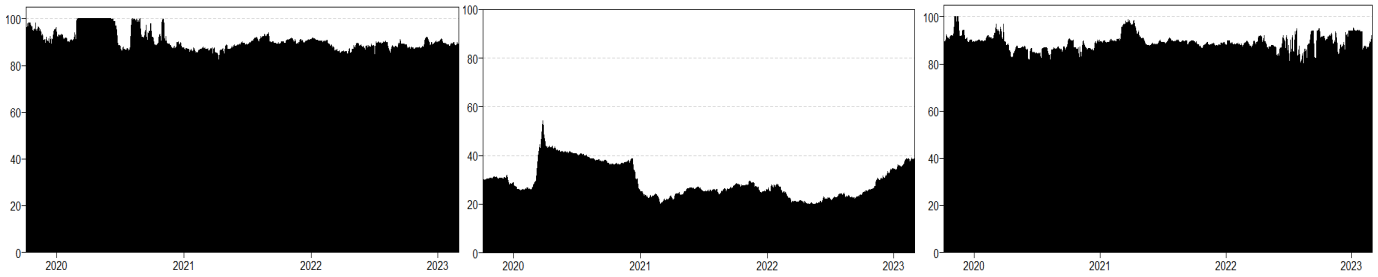


Figure 3. Dynamic TCI at 5th, 50th and 95th quantiles. Notes: The 5th, 50th and 95th quantiles are reported in the left, middle and right panels.

The rolling regression estimates of the market-specific net spillover effects are reported in Figures 4, 5 and 6 for the 5th, 50th and 95th quantiles, respectively. At the medial quantile, the US SSR is only a net transmitter at the start of COVID-19 in March 2020, and during this period, all financial markets (except JSE All Share and MSCI SA index) are susceptible to systemic shocks. However, at the tail-end distributions, the US SSR (most South African financial markets) is (are) a net transmitter (receivers) of shocks (i) from the announcement of QE4 and the start of the LSAP program experienced between early 2020 and mid-2020; (ii) from the announcement of quantitative tapering to the start of the Ukraine–Russia conflict; and (iii) during the period of policy normalization experienced from May 2022 onwards.

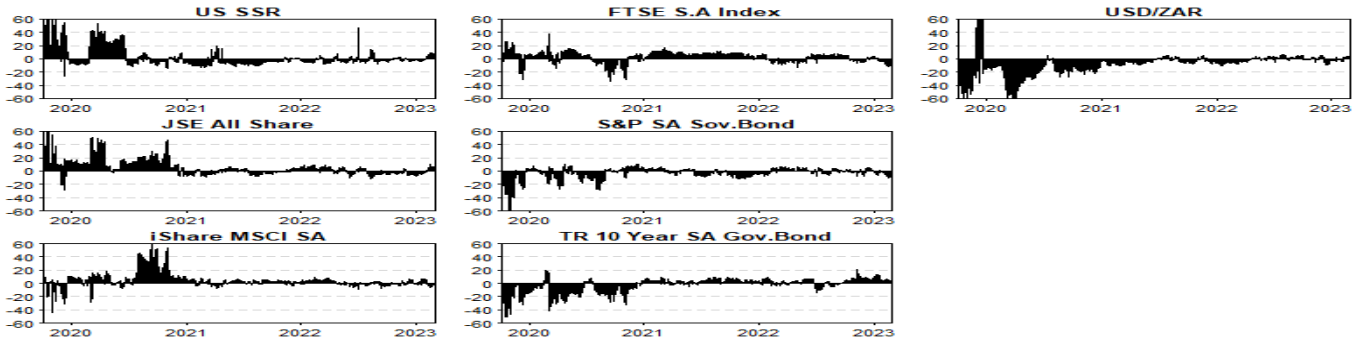


Figure 4. Net directional spillovers at 5th quantile.

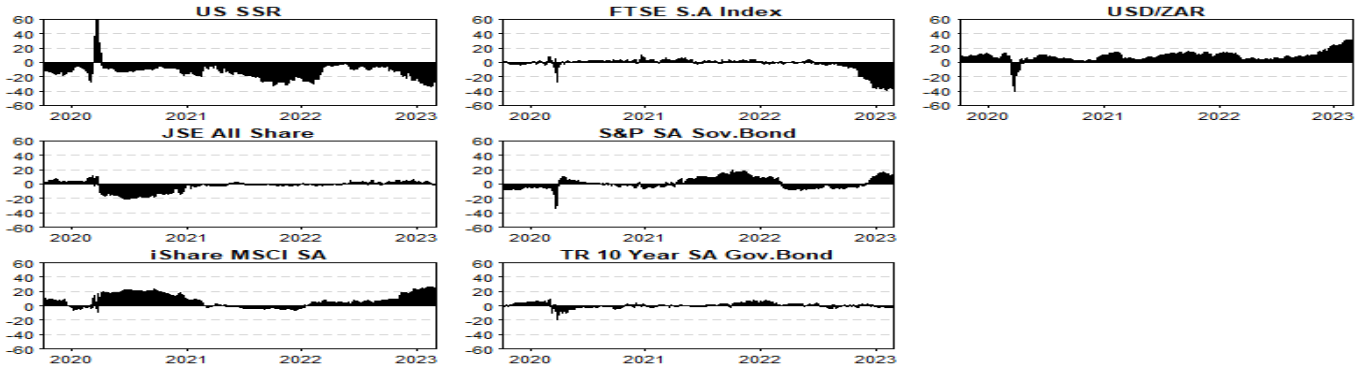


Figure 5. Net directional spillovers at 50th quantile.

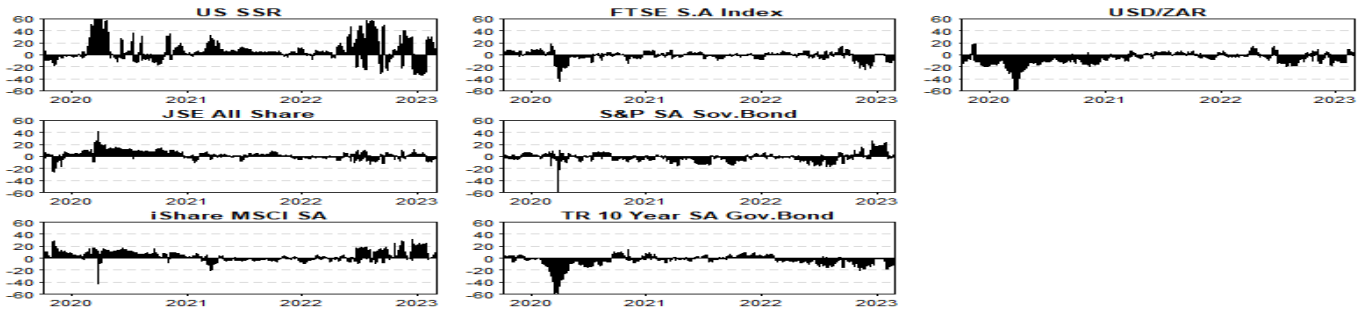


Figure 6. Net directional spillovers at 95th quantile.

3.5. Quantile–Frequency Connectedness Analysis

So far, we have examined systemic connectedness between US monetary policy and South African financial markets at different quantiles and frequencies. In general, we have found that spillover effects are more concentrated at higher frequencies and at the tail-end quantile distributions, whereby US UMP is a main transmitter of systemic shocks, whilst the bond and exchange rate markets are main receivers of these shocks. However, we have explored both quantile and frequency connectedness as separate phenomena, and now we present the best of both worlds by decomposing the quantile connectedness and spillover effects into their low- and high-frequency spectral components.

Notably, the summary of the static TCI indexes and net transmission spillovers presented in Table 4 harmonize the results obtained from the QVAR and FVAR estimates in the sense that (i) TCI indexes are largest at high-frequency levels of connectedness and also at the tail-end distributions; (ii) US monetary policy (South African financial markets) is (are) the main net transmitter (receivers) of systemic shocks at high frequency across all market states; and (iii) South African financial markets are the main net receivers of high-frequency systemic shocks experienced at different market states, with the exception of JSE All share at the 5th quantile and the exchange rate market at the 50th quantile. Therefore, from a static perspective, the insinuations drawn from the QFVAR connectedness model do not differ much from those obtained from the individual QVAR and FVAR connectedness approaches.

Table 4. Summary of static TCI and net spillover effects at different quantile frequencies.

	Receivers	**Transmitters**	**TCI**
Panel A: 5th quantile			
Low frequency	US SSR	JSE all share, MSCI SA index, FTSE SA index, S&P sovereign bond, 10-year gov bond, USD-ZAR.	31.49
High frequency	FTSE SA index, MSCI SA index, S&P sovereign bond, 10-year gov bond, USD-ZAR	US SSR, JSE all share	46.15
Panel B: 50th quantile			
Low frequency	US SSR	JSE all share, MSCI SA index, FTSE SA index, S&P sovereign bond, 10-year gov bond, USD-ZAR	7.73

Table 4. *Cont.*

	Receivers	Transmitters	TCI
High frequency	JSE all share, MSCI SA index, FTSE SA index, S&P sovereign bond, 10-year gov bond	US SSR, USD-ZAR	17.39
Panel C: 95th quantile			
Low frequency	US SSR	JSE all share, MSCI SA index, FTSE SA index, S&P sovereign bond, 10-year gov bond, USD-ZAR	27.10
High frequency	JSE all share, MSCI SA index, FTSE SA index, S&P sovereign bond, 10-year gov bond, USD-ZAR	US SSR	49.17

However, from a dynamic perspective, the time-varying TCI indexes (Figure 7) are much larger at the tail-end distributions across the entire time window, and yet the frequency decompositions within these quantiles show that there are some periods in which low-frequency connectedness is stronger than high-frequency connectedness, i.e., forward guidance and start of LSAP between early and mid-2020; the announcement of QE tapering in mid-2021; and the start of policy normalization in mid-2022. During these periods, systemic spillovers are considered to have longer-lasting effects, and Strohsal et al. (2019) note that such low-frequency spillover shocks are difficult to hedge against.

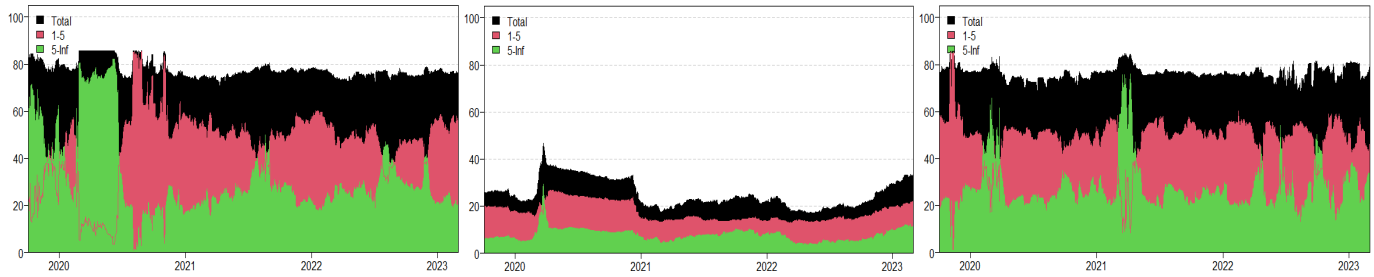


Figure 7. Dynamic TCI for total, low and high frequencies at 5th (left), 50th (middle) and 95th (right) quantiles. Notes: Black, red and green color contours represent the total and high- and low-frequency spillovers, respectively. The 5th, 50th and 95th quantiles are reported in the left, middle and right panels.

The dynamic net spillover effects at the market level further show that US monetary policy is a main transmitter of low-frequency systemic shocks during the announcements of (i) 'quantitative easing' in early 2020 at the 5th and 50th quantiles (Figures 8 and 9, respectively) and (ii) 'quantitative tapering' during the June 2021 period at the 95th quantile (Figure 10). We note that during these periods when US SSR is a transmitter of systemic shocks, most South African financial markets, particularly bond and exchange rate markets, are receivers of low-frequency net spillovers. In other periods, US SSR (South African financial markets) is (are) a net transmitter (receivers) of high-frequency systemic shocks, particularly at the tail-end distributions.

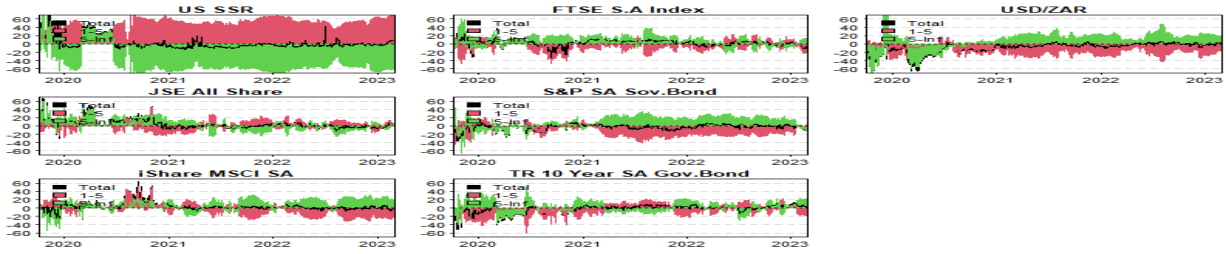


Figure 8. Net directional spillovers for total, low and high frequencies at 5th quantile. Notes: Black, red and green color contours represent the total and high- and low-frequency spillovers, respectively.

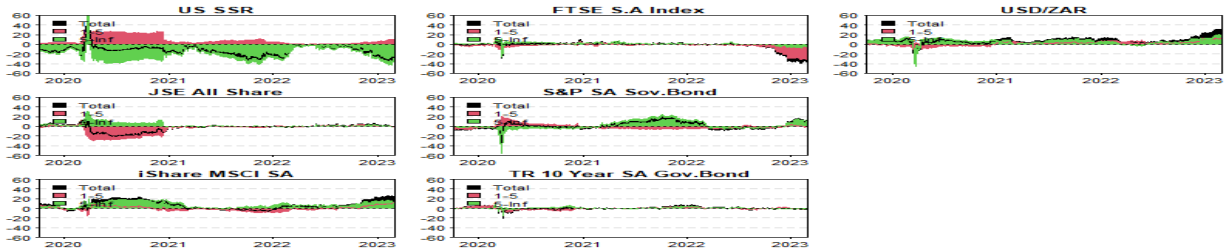


Figure 9. Net directional spillovers for total, low and high frequencies at 50th quantile. Notes: Black, red and green color contours represent the total and high- and low-frequency spillovers, respectively.

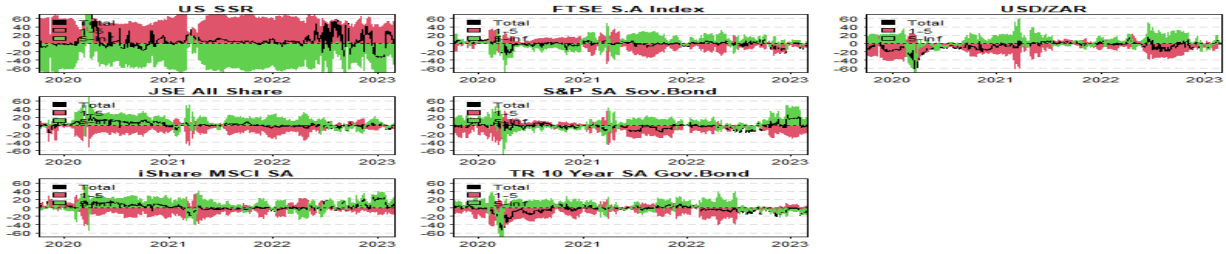


Figure 10. Net directional spillovers for total, low and high frequencies at 95th quantile. Notes: Black, red and green color contours represent the total and high- and low-frequency spillovers, respectively.

4. Further Discussion of Results

4.1. Comparison to Previous Literature

In examining how our findings align with and extend previous South African-based literature on U.S. monetary policy spillovers, we observe both continuity and important deviations. Previous studies, such as Gupta et al. (2017), Kalu et al. (2020) and Wei and Han (2021), emphasize significant spillovers from U.S. unconventional monetary policy (UMP) to South Africa's equity, bond and currency markets. However, many of these studies rely on mean-based VAR models, which, as our analysis shows, inadequately capture the complex transmission mechanisms of UMP, especially under extreme market conditions. By applying the quantile–frequency connectedness approach, our study not only confirms the existence of systemic spillovers but reveals that these effects are predominantly concentrated in the tail-end quantiles of the distribution—specifically during periods of heightened market volatility—and at higher-frequency spectrums.

Our results align with the broader literature that highlights the destabilizing effects of U.S. UMP on emerging markets. Anaya et al. (2017) and Tumala et al. (2021) suggest that increased liquidity in global markets leads investors to rebalance portfolios toward high-yield assets in emerging economies, only for these flows to reverse abruptly when U.S. monetary policy tightens, leading to sudden stops. Our findings corroborate these dynamics but show a unique distinction by demonstrating that these capital flow reversals and market disruptions in South Africa are primarily driven by high-frequency, short-lived

shocks. This stands in contrast to previous studies that argue for more persistent, long-term impacts (Lavigne et al., 2014; Bowman et al., 2015).

Furthermore, our rolling regression estimates show that the strongest spillover effects occur during FOMC announcements regarding 'quantitative easing,' 'quantitative tightening,' and 'interest rate hikes.' This observation contributes to the growing body of research emphasizing the importance of policy announcements themselves, rather than just the implementation of UMP, in influencing financial markets (Dedola et al., 2020; Bhattarai et al., 2021). Traditional studies that focus on the large-scale asset purchases (LSAP) miss this critical point, as they primarily account for the effects of UMP implementation—such as the actual purchase of U.S. Treasuries and mortgage-backed securities—but overlook the powerful forward guidance effects of FOMC announcements (Breitenlechner et al., 2021).

Our study also contributes to the debate on the transmission mechanisms of U.S. monetary policy. We provide evidence supporting the risk-taking channel, which Bhattarai et al. (2021) and Papadamou et al. (2019) describe as leading to heightened currency volatility and sovereign bond yields in emerging markets. Our analysis further shows that equity markets are more resilient to UMP-induced systemic shocks, particularly during bullish and bearish market conditions. This contradicts recent studies that find South African equity, bond, and currency markets equally susceptible to U.S. monetary policy shocks (Wei & Han, 2021; Yildirim & Ivrendi, 2021).

4.2. Implications of Findings

The implications of these findings extend beyond academic debate and speak directly to policymakers, regulators and investors. The South African Reserve Bank (SARB), which has implemented macroprudential policies to shield the financial system from external shocks, appears to have achieved some success in stabilizing equity markets. The resilience of equity markets against UMP shocks, particularly in extreme market conditions, suggests a level of informational efficiency, allowing investors to hedge their risks effectively and avoid exposure to high-frequency shocks. This underscores the effectiveness of macroprudential policies in strengthening market resilience, a finding consistent with theories of market signal transmission through portfolio rebalancing and investor expectations (Cepni et al., 2023; Gertler & Karadi, 2015).

However, the susceptibility of bond and currency markets to systemic spillovers, particularly during periods of FOMC policy announcements, points to vulnerabilities that need to be addressed. As Fausch and Sutter (2024) and Phan and Narayan (2021) suggest, financial cycles in emerging markets tend to become synchronized with U.S. monetary conditions during crisis periods. Our study reinforces this view, highlighting the need for SARB and other regulators to further develop macroprudential tools that can mitigate the impact of UMP announcements on bond and currency markets. Strengthening these areas will be essential for ensuring the broader financial stability of the South African economy.

For investors, our results provide valuable insights for portfolio allocation strategies. The relative resilience of equity markets to UMP shocks suggests that investors can reduce exposure to risk by placing lower portfolio weights on bonds and currencies during periods of heightened U.S. monetary activity. Moreover, our findings that UMP spillovers are largely short-lived provide opportunities for tactical asset allocation strategies aimed at hedging against short-term volatility spikes, a point that contrasts with the long-term shock assumptions in much of the existing literature (Aizenman et al., 2016; Choi et al., 2024).

5. Conclusions

Following the COVID-19 outbreak, US monetary authorities employed forward guidance and LSAP as UMP intended to stimulate the global economy and stabilize financial markets

at the lower zero bound. More recently, the US Federal Reserve has reverted back to 'normalization' policies and has aggressively adjusted policy rates to combat inflationary pressures arising from the Ukraine–Russia conflict. Since most emerging and developing countries have not employed similar unconventional monetary practices in response to the pandemic, there have been concerns over the effects of US UMP on the financial markets in these countries. This is more concerning for fragile emerging economies such as South Africa, which have extremely developed financial markets that are well integrated with global markets and are hence considered more susceptible to shocks from US monetary policy.

Against this background, we examine the impact of conventional and unconventional US monetary policies on South African financial markets between 1 January 2020 and 2 March 2023. We specifically use the SSR to capture both US unconventional and conventional monetary policy stances whilst employing the returns and yields from equities, bond and currency markets. We then use the quantile–frequency connectedness approach to examine static and dynamic systemic spillovers between the US SSR and South African financial asset returns across different market states and frequency spectrums.

Based on our empirical findings, our static analysis indicates that both system-wide connectedness and the net spillover effects of US monetary policy on financial markets exist only at tail-end quantile distributions and across high-frequency spillover cycles. Notably, the mean- and median-based connectedness estimates cannot capture these dynamics, hence implying that traditional estimators used in previous studies would not be able to capture these 'extreme event' dynamics. The time-varying estimates further indicate that these connectedness and spillover effects are most prominent during the FMOC announcements of 'quantitative easing' and 'quantitative tapering' experienced in the early 2020 and mid-2021 periods, respectively, and during these periods, the US acts as a net transmitter of low-frequency spillover shocks, and the US-based equity index and the bond and currency markets are mainly the net receivers of these shocks.

From an academic perspective, our study demonstrates the usefulness of the quantile–frequency framework in capturing tail-end spillover dynamics, which otherwise cannot be captured by mean-based connectedness models/estimates. Our results also have implications for market regulators and policymakers, as they indicate that bond and currency markets are particularly vulnerable to systemic shocks transmitted from US monetary policy announcements. Therefore, the current macroprudential policies adopted by the South African Reserve Bank (SARB) may not be sufficient to protect these markets from systemic shocks, and hence, additional policy measures may be required to safeguard the financial system during periods of market crisis. Investors can also benefit from our study in understanding that South African bond and currency markets are susceptible to US monetary policy announcements in 'extreme periods', hence creating a need to either hedge against these assets and/or adjust the portfolio weightings of these assets to reduce portfolio risk.

Author Contributions: Conceptualization, A.P.; Software, M.N.; Formal analysis, M.N.; Investigation, M.N.; Data curation, A.P.; Writing—original draft, M.N. and A.P.; Writing—review and editing, A.P.; Visualization, A.P. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Author	Measure of UMP	Country	Period	Method	Result
Lavigne et al. (2014)	Asset purchase, and bond and equity inflows to EMEs	23 EMEs and 8 AE	2005–2013	Event study and dynamic stochastic general equilibrium mode	UMP as implemented by AE increases capital flow, and volatility in the financial market during the tapering period
Bowman et al. (2015)	Policy announcements, maturity extension program (MEP) and FOMC speeches	17 EMEs	2006:M01–2013:M12	VAR and event study	US UMP significantly affects the sovereign bond of EMEs. Lower US sovereign yields also lower sovereign yields in most EMEs.
Aizenman et al. (2016)	FOMC QE and tapering announcements	10 robust and 15 fragile emerging economies	27 November 2012 – 3 March 2013	Event study	Full sample: significant drop in stock indices during tapering
Estrada et al. (2016)	Taper tantrum dummy	22 developing countries	2013:M05–2013:M06	Regression analysis/event study	Taper tantrum had negative effect on South African equity prices
Anaya et al. (2017)	Fed balance sheet	19 EMEs	2008M01–2014M12	GVAR and event study	US UMP has increased capital flows from the US to EMEs for almost 6 months. This is accompanied by a persistent increase in real and financial variables (exchange rate).
Gupta et al. (2017)	FOMC announcements and 2/10-year Treasury yield	20 EMEs, including South Africa	1 October 2008–1 September 2016.	Event study and OLS	US UMP results in exchange rate appreciation, increase in equity prices and decrease in bond yields in EME. The spillover effects of other AE are weaker than US.
Apostolou and Beirne (2019)	Fed balance sheet	13EMEs	2003:M01–2018:M12	GARCH-in-mean	UMP has negative impact on equity, debt and exchange rate markets
Naape and Masoga (2019)	Asset Purchase	US and SA	25 November 2008–12 December 2012	Event study, AR and (CAR)	US UMP has a positive impact in the short run and a negative impact in the long run on treasury bonds
Kabundi et al. (2020)	FRED Policy Interest Rate (PIR) and Asset Purchase	US and SA	1990M01–2018M02	BVAR and event study	US CMP and UMP expansion has a positive impact on the SA financial market, except for industrial production and credit to the private sector, which respond differently.
Kalu et al. (2020)	US 10-year bond and Treasury Bill	6 African countries	01/05/2013–31/12/2018	FE, RE and PMG	US UMP has a negative effect on African equities
Meszaros and Olson (2020)	St. Louis Adjusted Monetary Base; and Divisia M4 measure of money	SA	1960:Q1–2008:Q3 and 2008:Q4–2018:Q3	VAR	US UMP, particularly the quantitative easing programs, had only slight overall effects on South Africa's economy

Author	Measure of UMP	Country	Period	Method	Result
Ono (2020)	SSR	SA	09/01/2004–29/12/2017	VARX	US UMP has negative impact on stock markets but positive on exchange rates
Bhattarai et al. (2021)	US Treasuries, debt and mortgage-backed securities	13EMEs	2008:M01–2014:M11	SVAR and PVAR	US UMP increases stock prices and yet weakens the exchange rates in the EMEs
Lubys and Panda (2021)	FOMC policy announcements	BRICS	1 January 2008–1 January 2017	Event study, AR, CAR and CAPM	US UMP announcements have a negative impact on the SA financial markets (stock and bond)
Wei and Han (2021)	FOMC policy announcements	37 countries	1 January 2011–30 January 2020	Event study	USP announcements have negative impact on equities and exchange rates and yet insignificant for bonds
Yildirim and Ivrendi (2021)	US Mortgage spread and US Term spread	20 EMEs and 20 AEs	1 June 2007–1 February 2013	SVAR	US UMP resulted in a decrease in country risk premiums and long-term yields. An upswing in stock prices and appreciation of local currencies across AEs, especially in EMEs.
Ntshangase et al. (2023)	Dummy variable as a proxy for United States' QE	12 EMEs	2000:Q1–2020:Q4	Panel VAR	US UMP increases volatility in exchange rate of EMEs, decreases interest rate and has no significant impact on stock prices
Cui et al. (2024)	SSR	33 emerging and advanced countries	2002:Q2–2021:Q4	TGVAR	EMEs are more vulnerable to spillover effects than AEs, and EMs are much more exposed to monetary policy shocks than AEs

Appendix B

	US SSR	JSE All Share	iShare MSCI SA Index	FTSE South Africa Index	S&P SA Sovereign Bond Index	TR SA 10 Years Gov. Bond Index	Exchange Rate USD/ZAR	FROM
Panel A: D-Y								
US SSR	82.15	3.92	4.46	1.73	2.70	0.67	4.36	17.85
JSE All Share	1.81	90.20	4.26	0.83	0.84	0.77	1.29	9.80
iShare MSCI SA Index	1.16	2.69	54.00	0.47	11.04	0.59	30.04	46.00
FTSE South Africa Index	0.47	1.09	2.63	89.83	3.05	1.12	1.81	10.17
S&P SA Sovereign Bond Index	0.59	0.55	14.34	1.50	65.38	1.01	16.63	34.62
TR SA 10 Years Gov. Bond Index	0.94	1.13	0.72	1.61	1.25	93.40	0.95	6.60
Exchange Rate USD/ZAR	1.00	0.61	29.81	0.71	13.17	0.87	53.83	46.17
TO	5.97	9.99	56.22	6.85	32.06	5.03	55.09	171.21
Inc.Own	88.12	100.19	110.22	96.68	97.44	98.43	108.93	
Net	−11.88	0.19	10.22	−3.32	−2.56	−1.57	8.93	
								TCI = 24.46
Panel B: High frequency								
US SSR	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.05
JSE All Share	1.52	71.57	3.20	0.74	0.71	0.63	1.00	7.80
iShare MSCI SA Index	0.97	1.94	44.76	0.35	9.33	0.53	25.22	38.34
FTSE South Africa Index	0.35	0.89	2.06	72.30	2.15	0.83	1.42	7.71
S&P SA Sovereign Bond Index	0.44	0.43	10.19	0.99	50.56	0.72	12.07	24.85
TR SA 10 Years Gov. Bond Index	0.70	0.79	0.54	1.39	0.89	72.63	0.70	5.00
Exchange Rate USD/ZAR	0.83	0.51	24.07	0.56	10.94	0.69	44.25	37.61
TO	4.81	4.57	40.07	4.02	24.03	3.41	40.43	121.35
Inc.Own	4.90	76.14	84.83	76.32	74.59	76.04	84.68	
Net	4.76	−3.22	1.73	−3.68	−0.81	−1.59	2.82	
								TCI = 17.34
Panel C: Low frequency								
US SSR	82.07	3.91	4.46	1.72	2.69	0.67	4.35	17.80
JSE All Share	0.29	18.63	1.06	0.10	0.13	0.14	0.29	2.00
iShare MSCI SA Index	0.19	0.75	9.24	0.12	1.71	0.06	4.82	7.66
FTSE South Africa Index	0.12	0.20	0.56	17.53	0.90	0.28	0.39	2.46
S&P SA Sovereign Bond Index	0.16	0.11	4.16	0.51	14.82	0.28	4.56	9.78
TR SA 10 Years Gov. Bond Index	0.24	0.34	0.18	0.22	0.36	20.78	0.25	1.60
Exchange Rate USD/ZAR	0.17	0.10	5.74	0.15	2.23	0.18	9.58	8.56
TO	1.16	5.41	16.15	2.82	8.03	1.61	14.67	49.86
Inc.Own	83.23	24.05	25.39	20.35	22.84	22.39	24.25	
Net	−16.63	3.41	8.49	0.36	−1.75	0.02	6.11	
								TCI = 7.12

Appendix C

	US SSR	JSE All Share	iShare MSCI SA Index	FTSE South Africa Index	S&P SA Sovereign Bond Index	TR SA 10 Years Gov. Bond Index	Exchange Rate USD/ZAR	FROM
Panel A: 5th quantile								
US SSR	24.24	14.21	12.94	13.35	10.63	12.63	12.00	75.76
JSE All Share	13.05	21.08	14.66	12.83	13.20	12.80	12.39	78.92
iShare MSCI SA Index	13.08	14.21	22.64	13.52	15.37	12.71	8.47	77.36
FTSE South Africa Index	12.84	13.54	13.88	22.05	13.34	12.21	12.15	77.95
S&P SA Sovereign Bond Index	12.32	13.54	16.47	13.59	21.63	12.78	9.67	78.37
TR SA 10 Years Gov. Bond Index	12.94	14.11	13.69	13.07	12.56	20.90	12.74	79.10
Exchange Rate USD/ZAR	13.83	14.27	9.65	14.10	10.38	13.73	24.04	75.96
TO	78.08	83.87	81.27	80.46	75.49	76.86	67.41	543.43
Inc.Own	102.32	104.95	103.91	102.50	97.12	97.76	91.45	
Net	2.32	4.95	3.91	2.50	−2.88	−2.24	−8.55	
								TCI = 77.63
Panel B: 50th quantile								
US SSR	75.39	2.91	5.65	2.05	6.33	0.91	6.77	24.61
JSE All Share	2.90	88.95	3.30	1.18	1.60	0.89	1.17	11.05
iShare MSCI SA Index	2.03	2.13	54.99	0.63	9.93	1.24	29.05	45.01
FTSE South Africa Index	1.19	0.92	2.13	89.76	3.02	1.26	1.71	10.24
S&P SA Sovereign Bond Index	1.94	0.78	12.25	1.79	67.38	1.16	14.71	32.62
TR SA 10 Years Gov. Bond Index	1.42	1.05	0.89	1.13	0.98	93.62	0.91	6.38
Exchange Rate USD/ZAR	2.50	0.72	28.19	0.90	12.20	1.40	54.09	45.91
TO	11.99	8.52	52.40	7.68	34.06	6.86	54.32	175.83
Inc.Own	87.37	97.47	107.40	97.44	101.44	100.48	108.41	
Net	−12.63	−2.53	7.40	−2.56	1.44	0.48	8.41	
								TCI = 25.12
Panel C: 95th quantile								
US SSR	28.41	12.31	14.17	12.29	11.05	10.91	10.86	71.59
JSE All Share	13.22	23.30	13.93	12.26	12.55	12.28	12.46	76.70
iShare MSCI SA Index	12.96	13.57	23.71	12.72	16.40	12.17	8.48	76.29
FTSE South Africa Index	13.52	12.86	13.33	21.74	13.15	12.32	13.09	78.26
S&P SA Sovereign Bond Index	12.32	13.15	16.53	13.15	22.41	12.25	10.21	77.59
TR SA 10 Years Gov. Bond Index	12.56	13.40	12.80	13.00	12.44	21.93	13.88	78.07
Exchange Rate USD/ZAR	13.71	13.93	9.53	13.68	10.51	14.06	24.57	75.43
TO	78.28	79.22	80.29	77.10	76.08	73.99	68.97	533.93
Inc.Own	106.69	102.52	104.00	98.84	98.49	95.92	93.54	
Net	6.69	2.52	4.00	−1.16	−1.51	−4.08	−6.46	
								TCI = 76.28

Appendix D

	US SSR	JSE All Share	iShare MSCI SA Index	FTSE South Africa Index	S&P SA Sovereign Bond Index	TR SA 10 Years Gov. Bond Index	Exchange Rate USD/ZAR	FROM
Panel A: Low Frequency								
US SSR	23.59	13.56	12.26	12.84	10.17	12.19	11.58	72.59
JSE All Share	5.42	7.95	5.45	5.07	5.20	4.74	4.62	30.51
iShare MSCI SA Index	4.77	4.56	5.99	4.50	4.46	3.67	2.80	24.76
FTSE South Africa Index	4.60	4.55	4.53	6.87	4.40	3.66	3.42	25.17
S&P SA Sovereign Bond Index	3.96	3.83	4.20	3.69	5.00	2.88	2.29	20.85
TR SA 10 Years Gov. Bond Index	4.80	4.89	4.60	4.49	4.19	6.28	4.09	27.06
Exchange Rate USD/ZAR	3.95	3.56	2.66	3.48	2.68	3.14	4.80	19.46
TO	27.51	34.95	33.70	34.06	31.09	30.28	28.82	220.40
Inc.Own	51.10	42.90	39.69	40.93	36.09	36.55	33.62	
								TCI = 31.49
Net	−45.09	4.44	8.93	8.89	10.24	3.22	9.36	
Panel B: High Frequency								
US SSR	0.65	0.65	0.68	0.51	0.47	0.44	0.41	3.17
JSE All Share	7.64	13.12	9.21	7.75	8.00	8.05	7.77	48.42
iShare MSCI SA Index	8.31	9.65	16.65	9.02	10.92	9.04	5.66	52.60
FTSE South Africa Index	8.23	8.99	9.35	15.18	8.94	8.55	8.72	52.78
S&P SA Sovereign Bond Index	8.36	9.71	12.26	9.91	16.63	9.90	7.38	57.52
TR SA 10 Years Gov. Bond Index	8.14	9.22	9.09	8.58	8.37	14.62	8.65	52.04
Exchange Rate USD/ZAR	9.89	10.71	6.99	10.62	7.70	10.60	19.24	56.50
TO	50.57	48.93	47.57	46.39	44.40	46.58	38.59	323.03
Inc.Own	51.22	62.05	64.23	61.57	61.03	61.20	57.83	
Net	47.40	0.51	−5.02	−6.39	−13.13	−5.46	−17.91	
								TCI = 46.15

Appendix E

	US SSR	JSE All Share	iShare MSCI SA Index	FTSE South Africa Index	S&P SA Sovereign Bond Index	TR SA 10 Years Gov. Bond Index	Exchange Rate USD/ZAR	FROM
Panel A: Low Frequency								
US SSR	75.17	2.90	5.62	2.04	6.30	0.91	6.74	24.50
JSE All Share	0.52	17.56	0.37	0.20	0.14	0.14	0.17	1.54
iShare MSCI SA Index	0.34	0.52	9.60	0.11	1.61	0.19	4.41	7.18
FTSE South Africa Index	0.36	0.22	0.37	18.44	0.66	0.23	0.32	2.16
S&P SA Sovereign Bond Index	0.66	0.20	3.18	0.54	14.36	0.32	3.61	8.50
TR SA 10 Years Gov. Bond Index	0.35	0.34	0.15	0.14	0.24	20.47	0.20	1.42
Exchange Rate USD/ZAR	0.83	0.17	5.35	0.23	1.94	0.28	8.86	8.81
TO	3.07	4.35	15.04	3.26	10.89	2.07	15.44	54.12
Inc.Own	78.24	21.90	24.64	21.69	25.26	22.54	24.30	
Net	−21.43	2.81	7.86	1.09	2.39	0.65	6.63	
								TCI = 7.73
Panel B: High Frequency								
US SSR	0.21	0.02	0.02	0.01	0.03	0.01	0.03	0.11
JSE All Share	2.38	71.40	2.93	0.98	1.46	0.75	1.01	9.51

	US SSR	JSE All Share	iShare MSCI SA Index	FTSE South Africa Index	S&P SA Sovereign Bond Index	TR SA 10 Years Gov. Bond Index	Exchange Rate USD/ZAR	FROM
iShare MSCI SA Index	1.69	1.61	45.39	0.52	8.32	1.05	24.65	37.83
FTSE South Africa Index	0.83	0.70	1.76	71.32	2.37	1.03	1.38	8.07
S&P SA Sovereign Bond Index	1.28	0.58	9.07	1.24	53.02	0.84	11.10	24.12
TR SA 10 Years Gov. Bond Index	1.06	0.71	0.74	1.00	0.74	73.15	0.71	4.96
Exchange Rate USD/ZAR	1.67	0.55	22.84	0.68	10.26	1.11	45.23	37.11
TO	8.92	4.17	37.36	4.42	23.17	4.79	38.88	121.71
Inc.Own	9.13	75.56	82.76	75.75	76.18	77.94	84.11	
Net	8.80	−5.34	−0.47	−3.65	−0.95	−0.17	1.77	
								TCI = 17.39

Appendix F

	US SSR	JSE All Share	iShare MSCI SA Index	FTSE South Africa Index	S&P SA Sovereign Bond Index	TR SA 10 Years Gov. Bond Index	Exchange Rate USD/ZAR	FROM
Panel A: Low Frequency								
US SSR	27.97	11.90	13.68	11.89	10.62	10.53	10.46	69.08
JSE All Share	3.24	4.92	2.98	2.88	2.64	2.78	2.78	17.30
iShare MSCI SA Index	3.71	3.43	5.21	3.12	3.76	3.13	2.56	19.71
FTSE South Africa Index	4.81	4.20	4.30	6.18	4.21	3.88	3.82	25.22
S&P SA Sovereign Bond Index	3.71	3.52	4.15	3.34	5.03	2.96	2.55	20.24
TR SA 10 Years Gov. Bond Index	3.74	3.37	3.23	3.42	3.17	5.07	3.36	20.29
Exchange Rate USD/ZAR	3.65	3.36	2.21	3.05	2.38	3.23	5.14	17.88
TO	22.86	29.78	30.56	27.70	26.77	26.50	25.54	189.71
Inc.Own	50.83	34.71	35.76	33.89	31.80	31.57	30.68	
Net	−46.22	12.48	10.85	2.48	6.53	6.21	7.66	
								TCI = 27.10
Panel B: High Frequency								
US SSR	0.44	0.42	0.49	0.40	0.42	0.38	0.40	2.51
JSE All Share	9.98	18.37	10.95	9.38	9.91	9.51	9.67	59.41
iShare MSCI SA Index	9.24	10.14	18.51	9.60	12.64	9.04	5.93	56.58
FTSE South Africa Index	8.71	8.66	9.03	15.56	8.94	8.44	9.26	53.04
S&P SA Sovereign Bond Index	8.61	9.62	12.38	9.81	17.38	9.29	7.65	57.36
TR SA 10 Years Gov. Bond Index	8.81	10.03	9.57	9.58	9.27	16.86	10.52	57.78
Exchange Rate USD/ZAR	10.07	10.58	7.31	10.63	8.13	10.84	19.43	57.55
TO	55.41	49.44	49.73	49.40	49.31	47.49	43.43	344.22
Inc.Own	55.86	67.81	68.24	64.96	66.69	64.35	62.86	
Net	52.90	−9.97	−6.85	−3.64	−8.04	−10.28	−14.12	
								TCI = 49.17

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