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Research article

Impact of U.S. quantitative easing on international financial markets: evidence from a GVAR model

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Abstract: The high degree of interconnectedness and interdependence within the global financial system implies that cross-border spillovers from monetary policy propagate through complex transmission channels. This study uses a global vector autoregression (GVAR) model, using monthly data from 17 G20 economies over the period 2008–2023, to systematically investigate how US quantitative easing (QE) monetary policy, proxied by two key spread measures, affects global financial markets. The first proxy, the term spread, is defined as the yield on 30-year US Treasury securities minus that on 10-year Treasury securities; the second, the mortgage spread, is defined as the 30-year fixed mortgage rate minus the 10-year Treasury yield. A negative shock to either spread (that is, a narrowing) captures the interest rate compression typically induced by QE. The empirical results reveal that a 1% decline in the 30-year Treasury yield is associated with an increase of up to 5% in 10-year government bond yields in advanced economies, while the most pronounced effects in emerging markets occur in foreign exchange markets, where exchange rate responses reach as high as 23%. Moreover, the mortgage spread exerts a stronger influence across regional financial markets than the term spread, consistently generating more significant spillover effects. The Chicago Board Options Exchange volatility index (VIX) and monetary policy uncertainty (MPU) emerge as the two dominant transmission channels. Our analysis highlights substantial heterogeneity in cross-country responses, particularly in foreign exchange markets. Furthermore, the study examines the moderating roles of financial leverage and commodity exposure, showing that these factors significantly shape the magnitude and persistence of spillover effects.

Keywords: quantitative easing; financial market stability; financial leverage; commodity prices; spillover effects

JEL Codes: E52, G15, F42, C32

1. Introduction

After the collapse of Lehman Brothers in September 2008 triggered a global financial crisis, traditional monetary policy tools, such as short-term interest rate adjustments, have faced limitations in effectiveness due to the near-zero lower bound. In this context, the US Federal Reserve (the Fed) adopted a series of unconventional monetary policy measures to promote economic recovery, among which quantitative easing (QE) emerged as a key instrument. By purchasing large quantities of long-term bonds in open market operations, the Fed aimed to stimulate economic growth. Over the past decade or so, the Fed has implemented multiple rounds of QE, each reflecting its policy responses under distinct economic conditions. Today, QE remains one of the primary tools the Fed uses to address economic crises. However, as a major player in the global economy, the Fed's policies extend far beyond US borders. These policies exert significant spillover effects on global financial markets through complex transmission channels, placing upward pressure on asset prices and increasing financial market fragility (Tsai, 2014) With technological advancements over recent decades driving financial innovation and cross-border capital flows, global economic and financial integration has accelerated, further amplifying the role of US monetary policy in global financial stability. Therefore, a deeper understanding of how US QE affects international financial markets, particularly through its spillover effects, is crucial for comprehending global financial dynamics (Hou et al., 2025). While the existing literature has extensively examined the interplay between the US QE policies and international financial markets (Tillmann et al., 2019; Ha, 2021), much of this research has focused on individual countries or differences across economies, with relatively less attention given to specific transmission channels and external influencing factors. A more comprehensive understanding of these complex interactions requires further investigation into these underexplored dimensions.

Blinder's (2010) analytical framework on the US QE policies has spurred significant debate within the economics community regarding their effects on international financial markets. Among the earliest empirical studies, Duca et al. (2016) examined how QE policies transmit across borders, offering critical insights into the mechanisms of unconventional monetary policy spillovers. Subsequent research has identified three primary transmission channels through which the Fed's QE policies impact global financial markets: The signaling channel, the liquidity channel, the portfolio balance channel, and the risk-taking channel (Diamond and Rajan, 2006; Christensen and Rudebusch, 2012; D'Amico and King, 2013; Abbate and Thaler, 2019. Of these, the risk-taking channel—a relatively recent addition to the literature—provides a novel perspective on how QE influences markets' behavior. To deepen the analysis of this channel, we incorporate the Chicago Board Options Exchange volatility index (VIX) and the US Monetary Policy Uncertainty (MPU) index as key metrics, offering a more precise assessment of its efficacy.

The VIX index is an indicator of risk aversion in the financial market. According to Whaley (2000), the VIX index reflects the market's expectation of future volatility and can capture changes in investor sentiment. When the VIX index rises, it usually indicates an increase in market concerns about future risks, and investors tend to avoid risks; while when the VIX index falls, market sentiment becomes more optimistic, and investors may be more willing to take risks. In an environment of low

interest rates, QE policies have reduced the yield of risk-free assets, driving investors to shift towards higher-risk assets in search of higher returns (Belke, 2013). This behavioral pattern is influenced by market volatility because volatility directly affects investors' risk preferences, which, in turn, affects the prices of financial assets such as stocks, bonds, and foreign exchange (Bianconi et al., 2013; Chung and Chuwonganant, 2018; Shu and Chang, 2019; Habib et al., 2020).

MPU refers to the divergence in market expectations caused by ambiguity regarding the future direction of policy. Research by Baker et al. (2016) indicates that during periods of high uncertainty, investors tend to adopt risk-averse strategies and reduce their investments in high-risk assets. In contrast, during times of low uncertainty, investors are more willing to take on risk in pursuit of higher returns. Thus, MPU directly influences investors' risk-taking behavior (Bernanke and Kuttner, 2005 Luo et al., 2022). Incorporating MPU into the analytical framework helps reveal how QE affects investors' decisions by shaping their expectations about future policy paths, thereby influencing the prices of financial assets such as stocks, bonds, and foreign exchange. Specifically, when central banks implement asset purchase programs under QE, these measures can, in theory, operate by reducing the overall financial and economic uncertainty. If effective, such interventions can lower both the level and slope of the yield curve, thus reducing capital costs. As a result, QE may not only affect private-sector credit availability, risk premiums in financial markets, and asset prices through various channels, including the risk-taking channel, similar to conventional monetary policy, but it may also directly or indirectly mitigate the negative impacts associated with MPU.

Furthermore, the global spillover effects of the US QE policy, driven by changes in international investors' risk appetite, are influenced by leverage levels in financial futures markets and fluctuations in commodity prices.

Leverage is a key indicator influencing the stability and risk-bearing capacity of the financial system (Cincinelli et al., 2021; Ellis et al., 2022). In recent years, as the unconventional monetary policies (particularly QE) implemented by major global economies have generated widespread and profound spillover effects on international financial markets, the moderating role of leverage in this process has increasingly drawn scholarly attention. The US QE programs typically reshape market expectations and the investment environment by depressing short-term interest rates and boosting long-term asset prices (Fawley and Neely, 2013). Against this backdrop, investors seeking higher returns tend to increase their allocations to risky assets such as equities, corporate bonds, and derivatives, thereby driving up overall market leverage levels. Moreover, QE facilitates greater credit supply and risk asset allocation by reducing the financing costs and improving collateral values, thus relaxing both the explicit and implicit leverage constraints faced by financial institutions (Geanakoplos and Wang, 2020). However, this monetary policy-driven expansion of leverage also harbors potential systemic risks. In the event of an external shock, such as a credit crunch or sharp market volatility, financial intermediaries may face liquidity strains and pressures on capital adequacy ratios, prompting them to rapidly deleverage and reduce credit provision (Pacces and Heremans 2012). At such times, the spread between expected asset returns and the risk-free rate widens significantly, highlighting the critical role that leverage plays in modulating market participants' risk appetite and the resilience of the financial system.

The financialization of commodity markets, including those for precious metals, energy, and agricultural products, has deepened the connections between these markets and traditional capital markets, exposing capital markets to price and volatility spillover effects, thereby amplifying market fluctuations (Sadorsky, 2014; Antonakakis et al., 2018). Under the spillover effects of the US QE

policies, price volatility in gold, oil, and agricultural products has become a crucial mechanism for regulating international financial markets. Gold, as a safe-haven asset, provides investors with a refuge during periods of increased market uncertainty, helping to alleviate panic in financial markets (Triki and Maatoug, 2021; Yeniley, 2025). Changes in oil prices influence stock markets' performance by affecting future cash flows and discount rates, both directly and indirectly (Basher et al., 2012; Liu et al., 2019; Perifanis and Dagoumas, 2021; Zhang and Wong, 2023). Meanwhile, fluctuations in agricultural commodity prices reflect changes in global terms of trade and are transmitted to the broader economy through their impact on the costs and revenues of related industries (De Winne and Peersman, 2021; Baffes and Kabundi, 2023; Ginn, 2023, 2024). It is evident that commodity prices not only serve as risk management tools for investors but also play a regulatory role in adjusting investors' risk preferences.

This study utilizes a global vector autoregression (GVAR) model to empirically investigate the transmission mechanisms and heterogeneous effects of the US QE on international financial markets, based on a dataset of G20 countries covering the period from 2008 to 2023. Over the past two decades, global financial markets have become highly integrated. In this context, using a single-country vector autoregression (VAR) model risks omitting significant international influences. Although existing studies have widely documented that the cross-border effects of US monetary policy shocks exhibit pronounced time-varying characteristics (Kishor and Marfatia, 2013; Lastauskas and Nguyen, 2023), much of the literature relies on single-country or bilateral models, which are ill-suited to capture the networked nature of interactions within the global financial system. While standard the GVAR models internalize cross-country linkages, they often use fixed trade weights that fail to reflect the dynamic evolution of globalization. To address this limitation, this paper constructs a time-varying trade-weight matrix based on 3-year rolling averages, allowing the strength of intercountry connections to adjust in line with evolving real-world trade and economic relationships. Furthermore, although extensions such as the GVAR-Stochastic Volatility (SV) model can accommodate time-varying volatility (Marfatia et al., 2017), our analysis focuses specifically on the transmission mechanisms through which QE, operating via yield spread channels, affects mean-level variables such as asset prices and financial leverage, rather than volatility dynamics per se. Therefore, this study adopts the GVAR model, incorporating exogenous variables to capture these global spillover effects. The primary focus is on empirically analyzing how the QE of the US transmits to international financial markets, identifying which operations have more substantial impacts, and exploring the factors influencing these effects. A key objective is to compare the resilience of financial markets between emerging and advanced economies (AEs) and to identify and develop strategies and mechanisms to enhance the global financial system's resistance to external shocks.

The innovations of this study are the following aspects.

1. This study is the first to systematically investigate the spillover effects of the US QE policies on the financial markets of emerging market economies (EMEs) and AEs through specific risk-taking channels, namely the VIX index and US MPU. By using the GVAR model, this approach provides a unique analytical framework that not only considers changes in investor sentiment but also evaluates the dynamic evolution of policy expectations. Consequently, it offers a comprehensive understanding of how different transmission mechanisms of US QE operations distinctly impact the financial markets of various economies. This innovative methodological contribution fills a gap in the existing literature regarding the cross-country impacts of QE policies and lays the groundwork for further exploration into the mechanisms through which external shocks affect the international financial system.

2. This study innovatively constructs a GVAR model that encompasses stock, bond, and foreign exchange futures markets, systematically examining the moderating role of leverage ratios across these markets in response to shocks from the US QE policies. The empirical findings reveal that leverage in financial futures markets exhibits a dual nature, functioning simultaneously as both a risk amplifier and a hedging instrument. This insight not only deepens the understanding of the mechanisms through which leverage influences financial stability but also provides crucial empirical support for regulators in formulating differentiated risk control policies. From a methodological perspective, this study is the first to integrate multimarket leverage measures into a unified GVAR framework, developing a more comprehensive tool for systemic risk analysis. This approach extends the boundaries of existing research and offers a practical pathway toward enhancing the resilience of financial regulatory systems.

3. This study focuses on the dual-impact mechanisms of commodity price volatility on global financial stability. From a market function perspective, commodities often exhibit safe-haven properties during economic downturns, effectively hedging systemic risks. However, their nonlinear price fluctuations can also heighten market fragility and even trigger cross-market risk contagion. Building on this framework, the paper also uses a comparative analysis approach to examine differences in the transmission effects of prices across various commodity categories, such as energy, metals, and agricultural products, to identify key sources of risk. This research not only deepens the theoretical understanding of the financial attributes of commodities but also provides empirical support for the development of differentiated risk warning and prevention systems in financial markets.

The rest of this paper is organized as follows. Section 2 provides a literature review related to the research topic. Section 3 presents the research hypotheses. Section 4 introduces the data and econometric model used in the study. Section 5 reports the empirical results and associated analysis. Section 6 presents robustness checks and further analysis. Finally, Section 7 concludes the paper and offers relevant policy implications.

2. Literature review

2.1. Spillovers of US QE policy on international financial markets

Since the launch of the QE program in the US, there has been a growing body of research examining the impact of QE on international financial markets, particularly within the context of the financial crisis. Diebold and Yilmaz (2012) noted that cross-market volatility spillovers significantly intensified following the collapse of Lehman Brothers in September 2008. Fornari and Stracca (2012) emphasized the importance of financial shocks during the crisis period. Berge and Cao (2014) explored the global effects of US monetary policy, highlighting the distinctive characteristics of unconventional policies. Lavigne et al. (2014) found that the QE implemented by developed countries had substantial impacts on the fundamentals of developing countries and emerging economies. Bowman et al. (2015) analyzed how nontraditional US monetary policies were transmitted to EMEs. Tillmann (2016) also discussed the spillover effects of unconventional monetary policies on emerging markets. Georgiadis (2016) identified key factors influencing the global spillover effects of US monetary policy.

A commonly used approach in the existing literature to measure the US unconventional monetary policy is the shadow interest rate proposed by Wu and Xia (2016) and Krippner (2020). This indicator reflects the target interest rate the Fed aims to achieve through bond transactions and is highly correlated with the assets held during QE periods (Wu and Xia, 2020). However, recent studies have

increasingly adopted more direct measures to assess the international spillover effects of QE, such as using the stock of mortgage-backed securities (MBS) and treasury securities on the Federal Reserve's balance sheet, or interest rate spreads, as proxy variables for QE activities (Chudik and Fratzscher, 2011; Gambacorta et al., 2014; Bhattarai et al., 2021). This study deliberately avoids indirect proxies for US QE, such as shadow rates, and instead uses spread-based variables that directly reflect the asset purchase operations of the Federal Reserve. This approach mitigates potential estimation biases arising from indirect measurements, thereby enhancing the reliability of our empirical findings.

Specifically, the term spread (TS) is defined as the difference between the yields on 30-year and 10-year US Treasury securities, diverging from the more commonly used spreads between 10-year and 2-year or 10-year and 3-month Treasury securities in the literature. This design is grounded in a clear policy rationale: The Federal Reserve's large-scale asset purchase (LSAP) programs primarily targeted long- and ultra-long-term government bonds with the explicit objective of compressing ultra-long-term interest rates to stimulate housing investment and long-horizon capital expenditures (d'Amico et al., 2012). Consequently, the 30–10-year Treasury spread more effectively captures the QE-induced compression of the ultra-long-end term premium. In contrast, conventional short-end spreads predominantly reflect market expectations about the future path of the federal funds rate and are thus susceptible to confounding signals from conventional monetary policy. Notably, during our sample period (2008–2023), short-term rates repeatedly hit the zero lower bound (ZLB), substantially diminishing the informational content of short-end spreads, whereas long-end spreads remained sensitive to unconventional monetary policy actions.

Correspondingly, the mortgage spread (MS) is defined as the difference between the 30-year fixed-rate mortgage rate and the 10-year US Treasury yield. This specification is also firmly rooted in the operational mechanics of QE: Across multiple rounds of asset purchases, the Fed acquired large quantities of MBS with the primary aim of lowering mortgage rates to repair the housing market, strengthen household balance sheets, and stimulate consumption (Krishnamurthy and Vissing-Jørgensen, 2011; Gertler and Karadi, 2015). Given that 30-year MBS constituted the dominant component of the Fed's MBS purchase program, and that the 10-year Treasury yield serves as a widely accepted pricing benchmark for MBS, due to its comparable duration and high liquidity, the spread between these two rates directly reflects the actual reduction in housing credit costs induced by QE. Compared with alternatives such as using AAA-rated MBS yields or simplifying the measure to the spread between the 10-year Treasury yields and the federal funds rate (which conflates long-term credit effects with short-term policy expectations), our chosen MS variable offers both clearer policy correspondence and greater precision in isolating the credit channel of QE. Crucially, under ZLB conditions, this spread exhibits pronounced sensitivity to QE announcements and balance sheet expansions, making it an ideal proxy for capturing the transmission of QE through housing finance conditions.

In summary, this paper jointly uses TS and MS, which respectively correspond to the two pillars of the Federal Reserve's QE operations, namely, purchases of long-term Treasury securities and MBS. More importantly, these two spreads directly capture the two key financial variables most immediately affected by QE: Ultra-long-term interest rates and housing credit costs. This dual-spread design enables a clearer identification of QE's unconventional transmission mechanisms while effectively disentangling them from the effects driven by conventional monetary policy, particularly market expectations about short-term policy rates. Furthermore, as part of our robustness checks, we complement our baseline analysis by using the stock of MBS and Treasury securities held on the Federal Reserve's balance sheet as alternative proxies for QE. This approach provides a more direct

measure of the credit channel through which QE operates, thereby strengthening both the empirical credibility and policy relevance of our findings.

2.2. Channels of US QE

The spillover channels of US QE to international financial markets can be broadly categorized into the signaling channel, the liquidity channel, the portfolio balance channel, and the risk-taking channel. The signaling channel refers to the transmission of pessimistic signals regarding the economic outlook through the US QE, prompting global investors to reassess the value of risky assets and reduce their appetite for safe-haven investments (Eggertsson et al., 2003; Bernanke et al., 2004). For instance, QE policies signal a prolonged period of accommodative monetary policy, influencing market expectations and risk preferences. The liquidity channel operates through the injection of substantial US dollar liquidity into financial markets, which lowers borrowing costs and drives capital flows into high-yield emerging markets (He et al., 2021). The resulting excess liquidity reduces risk premiums, encouraging investors to pursue limited high-return assets and intensifying risk-taking behavior. The portfolio balance channel arises as unconventional monetary policy depresses yields on safe assets such as US Treasury securities, compelling investors to seek higher returns by reallocating capital toward riskier assets like equities and foreign bonds. This cross-border capital reallocation drives up asset prices, further compresses risk premiums, and creates a self-reinforcing cycle of "low returns–high risk-taking".

The three aforementioned channels ultimately converge into the risk-taking channel. The mechanism through which US unconventional monetary policy spills over to international financial markets hinges on two core characteristics: First, its immediate impact on global currency values, particularly the US dollar exchange rate, which represents a key source of global financial risk (Bauer et al., 2023); second, its significant influence on global risk aversion in financial markets, thereby reshaping investors' overall risk appetite. These two features jointly shape global financial conditions and play a decisive role in determining capital flows. Specifically, the signaling channel alters investors' expectations regarding future economic conditions (Goldstein, 2023), the liquidity channel increases the availability of funds for investment, and the portfolio balance channel incentivizes investors to seek higher-yielding assets. Collectively, these mechanisms enhance investors' capacity and willingness to take on risk in pursuit of higher returns. However, existing academic research on the spillover effects of US QE has largely focused on how changes in international investors' risk preferences generate global spillovers, with limited attention paid to the specific transmission pathways through which foreign asset prices are affected.

The risk-taking channel represents a relatively new transmission mechanism, which illustrates how US monetary policy can influence global financial stability by altering market participants' risk preferences and risk-taking behaviors (Miranda-Agrippino and Rey, 2020). When investors exhibit higher risk tolerance, they tend to allocate more capital to high-risk, high-return assets, thereby affecting global capital flows and asset prices. Notably, in empirical research, the risk-taking channel is inherently difficult to observe directly. The existing literature typically identifies the causal effects of QE using high-frequency event studies, such as yield surprises around LSAP announcement windows, or estimates of term premia (Gagnon et al., 2011). However, within a cross-country macro-panel framework, such high-frequency identification strategies face significant constraints in terms of data frequency and country coverage. To address this challenge, this paper follows the approach

adopted in recent studies on international spillovers (Miranda-Agrippino and Nenova, 2022) and operationalizes the risk-taking channel through the dynamic market responses to shifts in risk sentiment and policy uncertainty. Specifically, we infer the transmission of QE via the risk-taking channel by examining the impulse responses of financial variables to shocks in the VIX and US MPU, two widely used proxies for global risk appetite and policy-related ambiguity, respectively. In contrast to studies focusing on the global financial cycle, this paper is the first to explicitly incorporate the risk-taking channel, as proxied by VIX and MPU, into a GVAR framework, thereby offering a more nuanced assessment of how QE transmits across borders through investors' risk behavior and uncertainty-driven portfolio reallocations.

The VIX index, widely recognized as a leading indicator of uncertainty in the US stock market, serves as a key measure of global financial market instability and investor expectations regarding future market conditions (Smales, 2022). The level of the VIX directly reflects market participants' expectations of future volatility: Higher values indicate greater anticipated uncertainty and heightened investor anxiety. Building on the VIX index, Bekaert et al. (2013) found that the US accommodative monetary policy can reduce both risk aversion and uncertainty, with a more pronounced effect on the former. However, due to cross-country differences in factors such as trade openness, financial integration, political risk, and debt ratios, international investors exhibit significant heterogeneity in their risk aversion coefficients across different types of economies. Furthermore, Nave and Ruiz (2015) argued that in the short term, an expansionary monetary policy may actually increase the risk aversion of domestic representative investors.

In addition, existing studies have examined the impact of US QE on MPU, confirming that Federal Reserve announcements of unconventional monetary policy significantly reduced the implied volatility in foreign exchange options markets, indicating that policy interventions effectively alleviated market uncertainty regarding future exchange rate fluctuations (Fassas et al., 2021). The Fed's shifts between "conventional" and "unconventional" monetary policy instruments are constrained by economic agents' expectations about the effectiveness of new policies, which in turn substantially increases US MPU (Husted et al., 2020). Research by Inoue and Okimoto (2022) further confirms that the Fed's MPU has profound effects on global financial markets. For instance, Chiang (2020) found that QE exerts a significant negative influence on global stock prices. When MPU rises sharply, investors may face heightened risks compared with normal periods (Gospodinov and Jamali, 2018). Sen and Rajan (2024) showed that changes in US MPU meaningfully affect financial stress levels in AEs. Moreover, evidence suggests that US QE generates spillover effects on the real economic activity and financial markets of emerging economies such as China through various channels, including exchange rates, interest rates, trade, and capital flows. However, research examining MPU as an international transmission channel of US QE remains notably scarce.

In summary, this study selects the VIX index and the US MPU index as key indicators to measure global risk appetite. This approach not only enriches the existing theoretical understanding of the spillover channels of US QE into international financial markets but also offers a more comprehensive explanation by capturing both market sentiment, reflected in the VIX index, and policy expectations, as captured by the MPU index.

3. Research hypotheses

Although QE is primarily designed to achieve domestic macroeconomic objectives, it exerts profound spillover effects on global financial markets through multiple channels, including interest rate adjustments, portfolio rebalancing, and shifts in risk-taking behavior. While the literature widely acknowledges that QE compresses long-term yields and stimulates cross-border capital flows, systematic evidence remains scarce regarding (i) the differential transmission efficacy of alternative spread-based proxies for QE, (ii) the structural heterogeneity in market responses across countries, and (iii) how key macroeconomic conditions moderate the intensity of these spillovers. To address this gap, this paper integrates insights from the global financial cycle framework (Rey, 2015) and the risk-taking channel literature (Brunnermeier and Sannikov, 2015), leveraging the cross-country dynamic structure of the GVAR model to formulate four falsifiable hypotheses.

First, concerning the precision of policy signal identification and its implications for transmission efficacy, we distinguish between TS and MS as proxies for QE, grounded in their fundamentally distinct policy interpretations and economic meanings. The TS primarily reflects market expectations about long-run growth and inflation. Under the ZLB constraint, a narrowing of this spread often stems not from active monetary easing but from deteriorating growth prospects or heightened deflationary concerns (Bauer and Rudebusch, 2016). In such cases, the spread compression is a passive outcome of adverse macroeconomic news, which tends to dampen investors' risk appetite, thereby elevating the VIX. Simultaneously, policymakers face heightened data dependence, leading to ambiguity about the appropriate policy response and a temporary rise in MPU. However, if the central bank subsequently responds by intensifying QE, MPU may decline in later periods, generating a characteristic hump-shaped dynamic, where MPU initially rises before falling. In contrast, MS directly captures household borrowing costs. Its compression typically results from the Federal Reserve's deliberate purchases of MBS and ultra-long-term Treasury securities (Hancock and Passmore, 2015), representing an endogenous, unambiguous signal of accommodative policy. Such operations not only lower housing finance costs but also trigger portfolio rebalancing toward riskier assets, thereby bolstering global investor confidence. Consequently, a narrowing of the MS leads to a sustained and pronounced decline in the VIX, while MPU falls concurrently due to greater clarity in the policy trajectory. Thus, although both spreads may narrow, the underlying drivers differ sharply: TS compression is often recession-driven and passive, whereas MS compression is policy-driven and intentional. These differences imply divergent and even opposing impacts on global risk-taking behavior in both their direction and persistence. This reasoning leads to our first hypothesis.

H1: Conditional on an equivalent negative shock, a contraction in the MS exerts a stronger and more persistent dampening effect on both the VIX and MPU, whereas a contraction in the TS may initially trigger risk aversion and induce a rising then -falling dynamic in MPU.

Second, differences in institutional endowments and market structures across economies shape their capacity to absorb external shocks. According to the modern reinterpretation of the impossible trinity, EMEs face a more acute trade-off among capital mobility, exchange rate flexibility, and monetary policy independence. In theory, this should render them more vulnerable to cross-border capital flow volatility. However, empirical evidence suggests that during periods of QE, many EMEs exhibited notable resilience in equity and bond markets. This resilience stemmed from relatively stronger growth prospects and valuation advantages, which attracted substantial search-for-yield capital inflows (Aizenman et al., 2016; Fratzscher et al., 2018. In contrast, AEs benefit from deep

foreign exchange markets, well-developed dealer intermediation capacity, and ample pools of dollar liquidity, features that dampen the sensitivity of their exchange rates to global liquidity shocks. This asymmetry implies that vulnerability to QE-induced spillovers is not uniformly distributed across asset classes. Specifically, EMEs may display greater resilience in domestically denominated equities and long-term sovereign bonds, yet remain more susceptible to exchange rate volatility. Conversely, AEs tend to exhibit greater stability in their nominal effective exchange rates but may experience more pronounced asset price adjustments in certain contexts. Building on this reasoning, we formulate our second hypothesis.

H2: In response to a narrowing of US yield spreads, EMEs exhibit greater price resilience in equity returns and 10-year government bond yields, manifested as smaller stock market drawdowns and smaller increases in bond yields, whereas AEs demonstrate higher exchange rate stability, reflected in lower standard deviations of the nominal effective exchange rate and weaker depreciation pressures.

Third, the role of financial leverage in the cross-border transmission of monetary policy is not determined solely by its aggregate stock but instead hinges critically on the institutional and market frictions within which it operates. The procyclical feedback loop among leverage, risk-taking, and asset prices is particularly pronounced in highly integrated, low-friction financial systems. In such environments, accommodative monetary policy lifts asset prices, improves financial institutions' balance sheets, and thereby incentivizes rapid leverage expansion through derivatives markets to chase yield. By contrast, in economies with shallow derivatives markets, capital flow restrictions, or stringent margin requirements, even high levels of existing leverage may not translate into dynamic portfolio adjustments. Institutional constraints impede investors' ability to scale their positions flexibly, thereby substantially dampening the procyclical feedback mechanism. In today's global financial architecture, equity index futures, long-dated sovereign bond futures, and foreign exchange derivatives serve as essential instruments for institutional investors to manage the duration of exposure, hedge currency risk, and execute cross-market arbitrage. Countries endowed with liquid derivatives markets, low margin requirements, central clearing infrastructure, and open capital accounts enable market participants to respond swiftly, often with amplification, to US monetary policy signals, such as shifts in the TS or MS. For instance, when the Federal Reserve implements QE, compressing the key spreads, investors in AEs can immediately increase leverage to take long positions in risk assets, driving domestic bond yields lower (or reversing rapidly upon exit signals) and appreciating the local currency. Conversely, during policy normalization, equally efficient deleveraging mechanisms can accelerate asset sell-offs, exacerbating medium-term volatility. In contrast, in emerging markets with tighter institutional constraints, leverage adjustments tend to be sluggish and muted, even when nominal leverage (e.g., open interest in futures contracts) appears high. This "high stock–low elasticity" characteristic attenuates the procyclical feedback, resulting in more subdued responses of financial variables to external shocks. Thus, it is not the absolute level of leverage but its sensitivity and adjustability within a given institutional setting that drives cross-border amplification effects. This leads to our third hypothesis.

H3: The amplification effect of financial leverage on US yield spread shocks is significantly stronger in countries with more developed derivatives markets and lower trading frictions, indicating that the cross-border transmission of leverage is governed by institutional flexibility rather than by leverage levels per se.

Finally, commodities are not merely passive recipients of monetary policy spillovers but act as endogenous structural moderators whose influence varies by asset class and shock type. Gold, as a

canonical nonyielding safe-haven asset, tends to appreciate significantly during episodes of elevated market volatility (VIX) or heightened MPU (Baur and Lucey, 2010). Its price response reflects not only increased demand for safety but also its role as a highly liquid, globally tradable hedge that absorbs panic-driven selling pressure, thereby attenuating contagion across financial markets. In parallel, real commodities, such as crude oil and agricultural products, while potentially vulnerable to short-term risk-off dynamics, serve a distinct stabilizing function due to their close ties to real economic activity and inflation expectations. Under QE-induced accommodative conditions, stable or rising commodity prices can act as an expectational anchor, alleviating market concerns about runaway long-run inflation or abrupt policy normalization (Choi and Hammoudeh, 2010) This anchoring effect helps temper overreactions to monetary policy signals. The moderating role of commodities is especially pronounced in EMEs. The presence of significant commodity exposure can redirect capital flows: Instead of fleeing entirely to traditional safe havens, a portion of yield-seeking or hedging capital may be reallocated toward resource-rich EMEs, offering relatively high returns. This reallocation mitigates downward pressure on the local currencies and eases the transfer of foreign monetary shocks into domestic interest rates. In essence, gold functions primarily as tail-risk insurance that reduces systemic fragility, whereas real commodities stabilize macroeconomic expectations and curb excessive interpretation of policy signals. Building on this distinction, we formulate our fourth hypothesis.

H4: The inclusion of major commodities (gold, crude oil, and agricultural products) significantly dampens the transmission intensity of VIX- and MPU-mediated spillovers from negative TS or MS shocks to global financial markets. This buffering effect is particularly strong in emerging economies and can even induce directional reversals in key variables such as exchange rates, indicating that commodities act as endogenous stabilizers within the global financial system rather than mere price takers.

4. Data and methodology

4.1. The GVAR model

To examine the spillover effects of US QE on international financial markets, this study uses a novel time series model, namely the GVAR model (Pesaran et al., 2004; Pesaran and Smith, 2006).

4.1.1. Constructing the GVAR model

At the core of the GVAR modeling framework lies a set of individual vector autoregressive with exogeneity (VARX)* models, combined in such a way to give rise to the global VAR model. We start with a general VARX*(p_i,q_i) model for each country

$$x_{it} = a_{i0} + \sum_{l=1}^{p_i} \Phi_{il}\, x_{i,t-l} + \sum_{l=0}^{q_i} \Lambda_{il}\, x^*_{i,t-l} + u_{it} \tag{1}$$

where x_{it} is a $k_i \times 1$ vector of domestic variables, x^*_{it} is a $k^*_i \times 1$ vector of foreign variables, a_{i0} is a constant, t is a linear trend, u_{it} is a $k_i \times 1$ vector of serially uncorrelated innovations, $u_{it} \sim iid(0, \sum_{u,i})$, and Φ_{il} and Λ_{il} are coefficient matrices. The lag orders p_i and q_i of the domestic and foreign variables, respectively, can be selected using the Akaike information criterion (AIC). In the robustness test, p_i and q_i are chosen according to the Schwarz Bayesian criterion (SBC).

$$x_{it}^{*} = \sum_{j=1}^{N} w_{ij}\, x_{jt}, \text{ with } w_{ii} = 0 \tag{2}$$

where w_{ij}, j=1,...,N, is a set of weights such that $\sum_{j=1}^{N} w_{ij} = 1$ and w_{ij} is the share of country j in the trade (exports plus imports) of country i. This ratio specifically reflects a country's degree of trade dependence on a particular partner country, relative to its overall trade volume. In contrast to approaches that use fixed trade weights based on a single benchmark year, this paper constructs a time-varying trade weight matrix derived from 3-year rolling averages.

4.1.2. Solving the GVAR model

Starting from the estimated country-specific VARX*(p_i,q_i) models

$$x_{it} = a_{i0} + a_{i1}t + \Phi_{i1}x_{i,t-1} + \ldots + \Phi_{ip_i}x_{i,t-p_i} + \Lambda_{i0}x_{it}^{*} + \Lambda_{i0}x_{i,t-1}^{*} + \ldots + \Lambda_{i0}x_{i,t-q_i}^{*} + u_{it}, \tag{3}$$

We define z_{it} by

$$z_{it} = \begin{pmatrix} x_{it} \\ x_{it}^{*} \end{pmatrix}. \tag{4}$$

Assuming that $p_i = q_i$ for ease of exposition, rewrite Eq (3) for each economy as follows:

$$A_{i0}z_{it} = a_{i0} + a_{i1}t + A_{i1}z_{i,t-1} + \ldots + A_{ip_i}z_{i,t-p_i} + u_{it}, \tag{5}$$

where $A_{i0} = (I_{ki}, -\Lambda_{i0})$ and $A_{i1} = (\Phi_{ij}, -\Lambda_{ij})$ for j=1,...,p_i.
We can then use the so-called link matrices w_i, defined by the trade weights w_{ij}, to obtain the identity

$$z_{it} = W_i x_t \tag{6}$$

where $x_t = (x_{it}', \ldots, x_{Nt}')$ is the k × 1 vector which collects all the endogenous variables of the system, and W_i is a $(k_i + k_i^{*}) \times k$ matrix.

The country-specific weights are computed by dividing the purchasing power parity (PPP) -gross domestic product (GDP) figure of each country by the total sum across countries, such that the weights add up to one across the countries. These are used for the computation of global shocks (i.e., shocks to a variable across all countries) in impulse response analysis and forecast error decompositions.

Using the identity given by (5), it follows that

$$A_{i0}W_i z_{it} = a_{i0} + a_{i1}t + A_{i1}W_i z_{i,t-1} + \ldots + A_{ip_i}W_i z_{i,t-p_i} + u_{it} \tag{7}$$

These individual models are then stacked to yield the model for x_t given by

$$G_0 x_t = a_0 + a_1 t + G_1 x_{t-1} + \ldots + G_p x_{t-p} + u_t, \tag{8}$$

where $a_t = \begin{pmatrix} a_{10} \\ \cdots \\ a_{N0} \end{pmatrix}$, $G_j = \begin{pmatrix} A_{1j}W_1 \\ \cdots \\ A_{Nj}W_N \end{pmatrix}$, $u_t = \begin{pmatrix} u_{1t} \\ \cdots \\ u_{Nt} \end{pmatrix}$, j=1, ...p, and $p = \max p_i$ across all values of i. In general, $p = (\max p_i, \max q_i)$.

Since G_0 is a known nonsingular matrix that depends on the trade weights and parameter estimates, premultiplying Eq (8) by G_{10}, the GVAR(p) model is obtained as follows:

$$x_t = b_0 + b_1 t + F_1 x_{t-1} + \ldots + F_p x_{t-p} + \varepsilon_t, \tag{9}$$

where $b_0 = G_0^{-1}a_0$, $b_1 = G_0^{-1}a_1$, $F_1 = G_j$, and ε_t=$G_0^{-1}u_t$.

4.2. Sample and data

To comprehensively analyze the impact of QE on global financial markets since the outbreak of the global financial crisis, this study selects monthly frequency data ranging from January 2008 to December 2023 as the research sample. This time span covers the entire implementation period of QE, from its initial phase to the later stages when its effects gradually materialized.

To ensure sample representativeness, G20 members (excluding the European Union, the US, and Argentina) are selected as the focus of analysis. The European Union is excluded because most of its member states belong to the Eurozone, implying a high degree of synchronization in their foreign exchange market behaviors, which makes it difficult to isolate individual currency fluctuations. By excluding the US, the study can more precisely examine the external effects of Federal Reserve policies; that is, how these policies influence financial markets in other countries. Argentina is omitted due to the unavailability of key economic data, particularly the lack of a 10-year government bond yield series over the full sample period. The final sample includes 17 countries: Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, South Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, and the United Kingdom. These countries are further classified into two groups: Advanced markets and emerging markets. The AEs include Australia, Canada, France, Germany, Italy, Japan, South Korea, and the United Kingdom, while the remaining nine constitute the emerging market group.

This study incorporates three of the most influential financial submarkets (i.e., the stock market, government bond market, and foreign exchange market) using stock index returns, 10-year government bond yields, bilateral nominal exchange rates, and their corresponding leverage ratios as domestic variables, along with the respective foreign counterparts. As global variables, we use interest rate differentials, the VIX index, the US MPU index, and commodity prices, specifically gold, west texas intermediate (WTI) crude oil, and agricultural commodities (US soybeans).

In our empirical analysis, to gauge the intensity of each country's financial system exposure to key derivatives markets, we construct three aggregate leverage ratio indicators, namely equity index futures' leverage, long-term government bond futures' leverage, and foreign exchange futures' leverage, following the methodological approaches of Adrian and Shin (2010) and the Bank for International Settlements. Rather than relying on microlevel margin requirements or broker-specific leverage multiples, we use the notional amount of open interest in each derivative's segment as a proxy for national-level risk exposure. Specifically, equity futures' leverage is measured as the notional value of open interest in stock index futures divided by the total market capitalization of the domestic equity market; long-term bond futures' leverage is defined as the notional open interest in long-dated interest rate futures scaled by the outstanding stock of government bonds; and foreign exchange futures' leverage is calculated as the notional open interest in foreign exchange futures relative to either GDP or foreign exchange reserves, depending on the analytical context. This construction controls for differences in economic and financial scale across countries, ensuring meaningful cross-country comparability. More importantly, by linking derivative positions to fundamental macrofinancial aggregates, these indicators effectively capture the potential amplification effects of derivative markets on financial stability, thereby serving as a structural measure of institutional capacity to transmit and magnify external monetary shocks. The specific definitions of the above variables are shown in Table 1.

Table 1. Variable definitions and data sources.

Variable	Description	Data Source	Specification
stock	Stock market return	World development indicators (WDI)/Bloomberg	$\Delta\ln(P_t)$
y_{10}	10-year government bond yield	International Monetary Fund (IMF) International Financial Statistics (IFS)	Level
E	Nominal exchange rate (local currency per USD)	IMF IFS	$\ln(ER_t)$
VIX	Chicago board options exchange (CBOE) volatility index (global equity market volatility)	CBOE	$\ln(VIX_t)$
MPU	Monetary policy uncertainty index	www.policyuncertainty.com	$\ln(MPU_t)$
lev_{eq}	Equity futures' leverage ratio	Bank for international settlements (BIS)	$\frac{O_{Equity}}{Market\ Cap}$
lev_{bond}	Government bond futures' leverage ratio	BIS / IMF IFS	$\frac{O_{LTB}}{GovDebt}$
lev_{fx}	Foreign exchange futures' leverage ratio	BIS / WDI	$\frac{O_{FX}}{GDP}$
p_{gold}	Gold price (USD per troy ounce)	IMF IFS	$\ln(P_t)$
p_{oil}	Brent crude oil price (USD per barrel)	IMF IFS	$\ln(P_t)$
p_{soy}	Soybean price (USD per ton)	World Bank PPM	$\ln(P_t)$
TS	Term spread (30-year minus 10-year Treasury yield)	Federal Reserve H.15	r_{30y}-r_{10y}
MS	Mortgage spread (mortgage rate minus 10-year Treasury yield)	Federal Home Loan Mortgage Corporation/H.15	tr_{mort}-r_{10y}

Notes: $\Delta\ln(\cdot)$ denotes the first difference of the natural logarithm (approximating percentage changes). "Level" indicates that the variable is used in its original form; $\ln(\cdot)$ denotes the natural logarithm. p_{gold}: Gold price (USD per troy ounce); p_{oil}: Brent crude oil price (USD per barrel); p_{soy}: Soybean price (USD per metric ton). O_{Equity}: Total notional value of open interest in equity futures; Market Cap: Aggregate market capitalization of the equity market; O_{LTB}: Total notional value of open interest in long-term government bond futures; GovDebt: Total outstanding government debt; O_{FX}: Total notional value of open interest in foreign exchange futures; GDP: Country-level nominal gross domestic product. Ratios such as O_{Equity}/Market Cap, O_{LTB}/GovDebt, and O_{FX}/GDP are used to measure financial leverage in the equity, bond, and foreign exchange derivatives markets, respectively. All interest rates are expressed in percent per annum.

5. Empirical results

5.1. The impact of TS and MS shocks

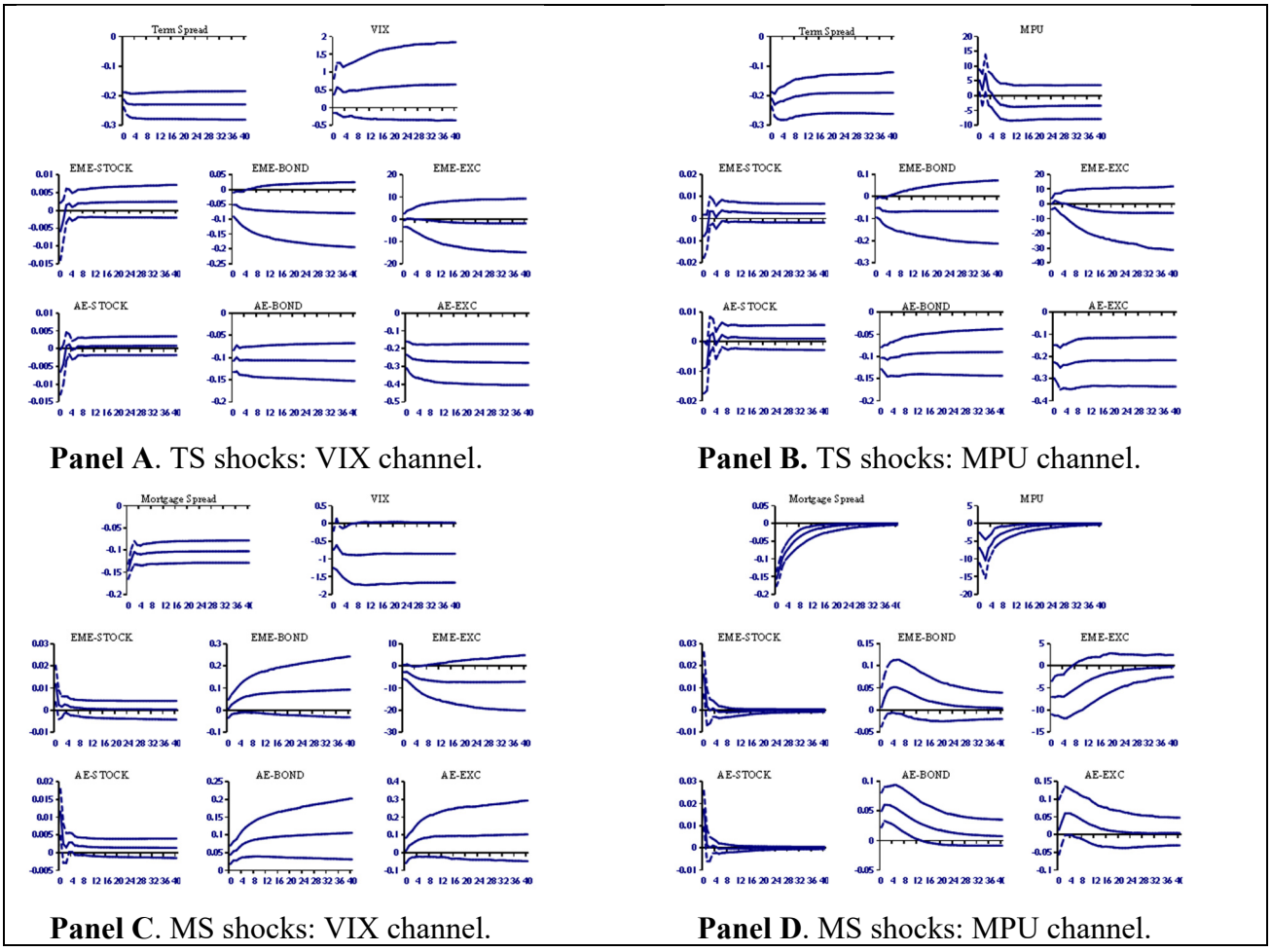
In the Appendix, we perform unit root tests, cointegration tests, and weak exogeneity tests to confirm that all variables satisfy the key requirements for GVAR framework. Specifically, to meet the structural assumptions of the GVAR model, we impose the condition that foreign variables and global common factors, collectively referred to as "external variables", are weakly exogenous in each country's individual VARX* model. This implies that while external variables may exert a unidirectional influence on domestic variables, they are not subject to long-run feedback from them (i.e., domestic and external variables are not cointegrated). To formally assess this assumption, we apply the *F*-test procedure proposed by Harbo et al. (1998), testing the null hypothesis that the external variables are weakly exogenous in each country's VARX model. The results, reported in Appendix

Tables C1–C4, show that in the vast majority of economies, the computed *F*-statistics fall below the critical value at the 5% significance level. Consequently, we fail to reject the null hypothesis of weak exogeneity across nearly all country models. This empirical validation confirms that the external variables satisfy the weak exogeneity requirement of the GVAR framework, thereby providing a sound theoretical and statistical foundation for model estimation and ensuring the reliability of our subsequent empirical analysis.

Subsequently, the generalized impulse response function (GIRF) approach is used to examine the impact of US interest rate spread shocks on the financial markets of both advanced and emerging economies. This paper imposes a negative one-standard-deviation shock on both TS and MS, thereby simulating a narrowing of these spreads, an approach consistent with Yildirim and Ivrendi (2021). The Federal Reserve compresses the TS by purchasing ultra-long-term Treasury securities, which lowers long-end yields, and narrows the MS through large-scale purchases of MBS, thereby reducing mortgage rates. Critically, in our identification strategy, this spread compression is interpreted not as a passive signal of economic distress but as an endogenous outcome of active QE operations. The shock thus represents an unexpected intensification of asset purchases, aligning with the theoretical expectations of QE expansion. Given their direct operational linkage to QE and the unambiguous policy interpretation of their negative movements, TS and MS serve as credible proxies for identifying the global spillovers of US unconventional monetary policy.

To trace the dynamic transmission of these shocks, we use GIRFs and assess the estimation's uncertainty by constructing 90% confidence intervals via a bootstrap procedure. Specifically, we draw 1000 random samples with replacement from the original dataset; for each bootstrap sample, we re-estimate the GVAR model and compute the corresponding impulse response paths. The 5th and 95th percentiles of the resulting empirical distribution of responses at each horizon are then used as the lower and upper bounds of the confidence interval. In all impulse response figures, the horizontal axis denotes time, divided into 40 equally spaced periods corresponding to 40 months. The vertical axis shows the GIRF of each economy's financial market variables to a one-standard-deviation negative shock in US yield spreads. The solid line represents the average cumulative response across bootstrap replications, while the upper and lower dashed lines indicate the 90% confidence bounds, providing a clear visualization of statistical uncertainty around the estimated impulse responses.

As shown in Panel A of Figure 1, the impulse response function analysis reveals that a one-standard-deviation negative shock to the US TS leads to a peak increase in the VIX index by 1.26% in the first month, indicating a slight decline in risk appetite. This outcome suggests that despite the QE policy compressing the TS, investors may interpret this as a pessimistic signal regarding long-term economic growth or inflation prospects, thereby intensifying risk aversion. On the other hand, as illustrated in Panel B of Figure 1, the impact on US MPU exhibits a nonmonotonic dynamic: MPU increases significantly by 7.42% in the first 2 months following the shock, then rapidly decays and turns negative from the fifth month onwards, reaching its lowest point at −3.79% in the eleventh month. Notably, the initial magnitude of MPU's response is approximately six times that of the VIX peak, with a shorter half-life. This finding implies that QE policies may initially elevate policy uncertainty due to ambiguous signals but effectively suppress it over the medium term as the policy path becomes clearer and market expectations stabilize.



Panel A. TS shocks: VIX channel.

Panel B. TS shocks: MPU channel.

Panel C. MS shocks: VIX channel.

Panel D. MS shocks: MPU channel.

Figure 1. Panels A and B illustrate the responses of financial markets in advanced and emerging economies, respectively, to a negative shock in the US TS through the VIX and MPU channels. Panels C and D illustrate the responses of financial markets in advanced and emerging economies, respectively, to a negative shock in the US MS through the VIX and MPU channels.

Furthermore, our analysis shows that through both the VIX index and MPU channels, the impact of a US TS shock on stock index returns, 10-year government bond yields, and nominal exchange rates does not exhibit significant intergroup differences between advanced and emerging economies. Following a one-standard-deviation negative shock to the US TS, global financial variables generally show an initial downward reaction, characterized by declines in stock index returns, reductions in 10-year government bond yields, and depreciations in the nominal effective exchange rates. These directional outcomes are consistent with the findings by Neely (2015) and Mulaahmetović (2022). Although the initial impact direction is convergent, AEs and EMEs display notable heterogeneity in their mid-term recovery paths. Specifically, stock index returns rebound positively in the later stages of the shock, with AEs experiencing smaller but faster recoveries, while emerging markets exhibit higher and more prolonged peaks (up to 0.33%). Regarding 10-year government bond yields, the shock effect is persistent across both economy types, with peak changes of -0.07% and -0.10%, respectively. Of particular note is the divergence in foreign exchange markets between the two groups: Emerging economies experience a rapid strengthening of their nominal effective exchange rates in the early

stages of the shock (the first month), marked by significant positive peaks (+0.34% via the VIX channel and up to +2.15% via the MPU channel), followed by swift depreciation and sustained decline. In contrast, AEs exhibit smaller exchange rate fluctuations (peak at −0.25%) and a smoother, more stable adjustment path overall. In summary, while a narrowing of the US TS generates synchronized initial shocks to global financial markets, AEs demonstrate greater resilience in terms of exchange rate stability and overall adjustment efficiency, reflecting their more mature financial market structures and policy response capabilities.

As shown in Panels C and D of Figure 1, the impulse response function analysis indicates that when the US MS is subjected to a one-standard-deviation negative shock (i.e., a narrowing spread corresponding to intensified QE), global risk appetite significantly increases while MPU markedly decreases. Specifically, the VIX index reaches its maximum reduction of −0.89% in the seventh month and maintains a negative response thereafter, indicating a systematic decrease in market volatility over the medium term. In contrast, MPU declines rapidly after the shock, reaching its peak effect of −10.40% in the second month, but this impact gradually diminishes over time and eventually approaches zero. This dynamic discrepancy suggests that QE policies transmitted through the MS not only effectively boost investors' willingness to take risks but also significantly alleviate policy uncertainty in the short term; however, the latter's influence is more transient compared with the sustained suppression of market volatility.

Further analysis reveals significant heterogeneity in the impacts on financial variables across AEs and EMEs via both the VIX and MPU channels. In stock and bond markets, both economy types exhibit positive responses in stock index returns and 10-year government bond yields with no significant intergroup differences within the same channel. For instance, under the VIX channel, stock index returns in both advanced and emerging economies increase by 0.01% in the first month, and both 10-year government bond yields maintain an upward trend, with those of AEs showing a consistently significant positive response throughout the sample period. However, the foreign exchange market displays notable divergence: AEs experience an appreciation in their nominal effective exchange rates, whereas emerging economies face continuous depreciation. This asymmetric pattern of appreciation in AEs and depreciation in emerging economies corroborates the asymmetric reaction mechanisms of international capital flows to QE shocks (Huang and Luk, 2020) and underscores the more enduring and widespread cross-border transmission efficacy of the global risk appetite channel represented by the VIX compared with MPU. Conversely, for the MPU channel, the peak impacts on 10-year government bond yields and nominal effective exchange rates in both economy types are smaller and less persistent, with a half-life of approximately 10 months. This indicates that although a decline in MPU has a positive short-term impact on financial markets, its effects are not as lasting as those through the VIX channel, especially concerning exchange rate movements. In conclusion, QE shocks transmitted through the VIX channel not only enhance global risk appetite but also induce significant heterogeneous effects on financial markets across different economies, particularly manifesting pronounced asymmetry in foreign exchange markets. The MPU channel's impacts are relatively brief and limited, mainly affecting short-term market volatility relief. This finding highlights the importance of understanding different transmission mechanisms and their varied impacts on various economies within the global financial environment.

Although both TS and MS serve as indicators of QE, they influence global risk appetite through distinctly different channels. The TS primarily reflects market expectations regarding long-term economic growth and inflation. Under the ZLB constraint, a narrowing of the TS often stems from

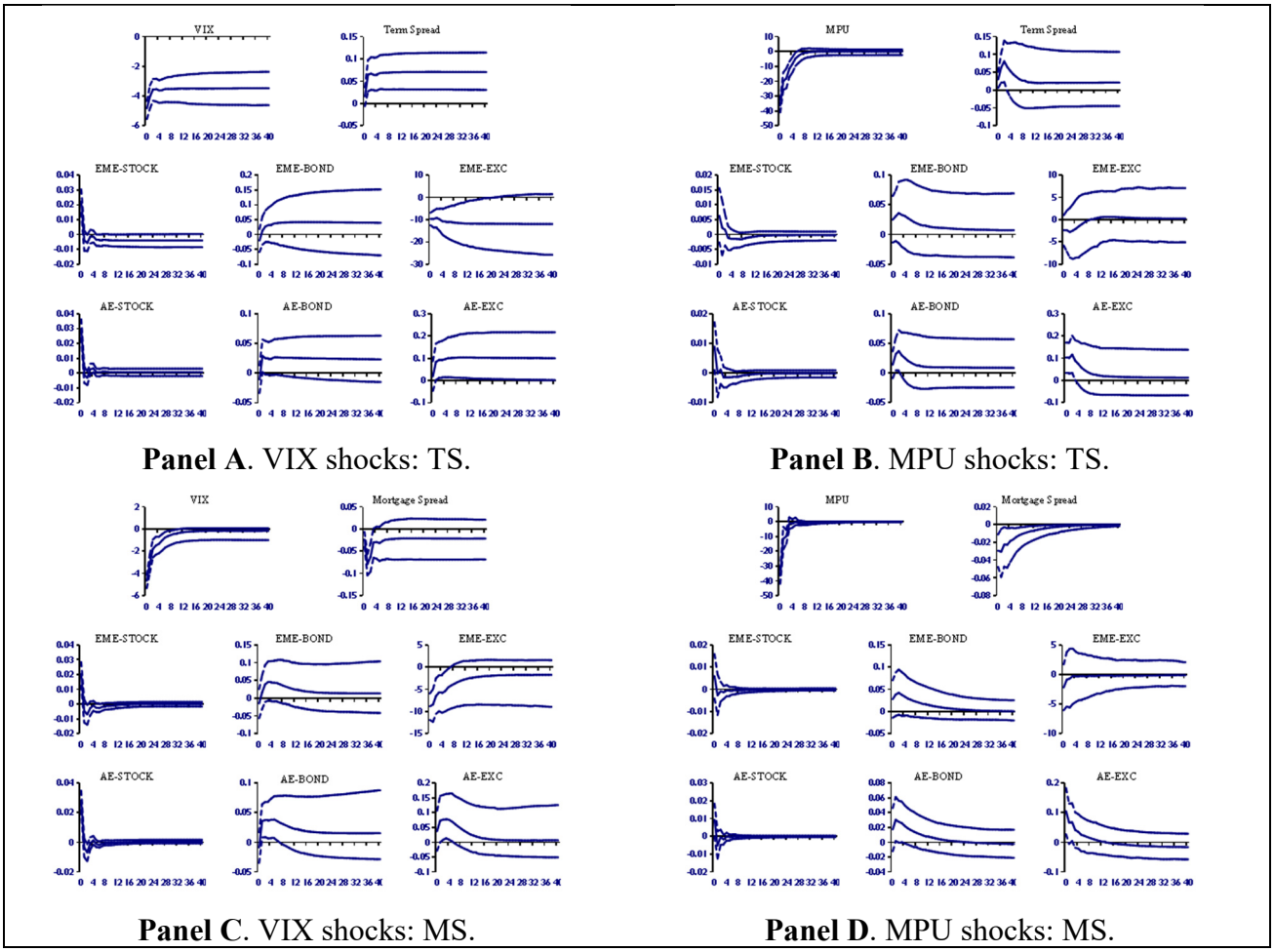
deteriorating growth prospects or heightened deflationary concerns. When the TS experiences a negative shock, such as a pronounced decline in the 30-year Treasury yield relative to the 10-year yield, investors typically interpret this as a signal of persistent economic weakness or even impending recession, implying subdued future demand and persistently low inflation. Such pessimistic expectations trigger flight-to-safety behavior, prompting capital reallocation from risky assets to safe havens, thereby elevating the VIX index and signaling a decline in risk appetite. Concurrently, MPU tends to rise sharply in the immediate aftermath of the shock, as policymakers face ambiguity in interpreting the incoming data and struggle to communicate a clear response; only later does MPU subside as central banks potentially reinforce accommodative measures. In contrast, movements in the MS exhibit greater policy endogeneity and signal clarity. A compression of the MS is typically a direct consequence of the Fed's large-scale purchases of MBS and ultra-long-term Treasury securities, which is an active, transparent, and largely anticipated form of monetary accommodation. Such interventions not only reduce household borrowing costs for housing but also generate portfolio rebalancing effects that lift the prices of equities and other risk assets, thereby bolstering investor confidence. Consequently, a negative shock to the MS is widely perceived by markets as a positive signal of abundant liquidity and improved credit conditions, leading to enhanced risk-taking. The VIX declines rapidly and remains suppressed over an extended horizon, reflecting sustained optimism and stability; MPU also falls markedly in the short run, indicating that clearer policy signaling effectively alleviates uncertainty.

In summary, while both TS and MS are closely tied to QE, they convey fundamentally different information. The TS predominantly transmits pessimistic signals about long-run fundamentals, tending to provoke risk-off reactions, whereas the MS directly reflects the scale and efficacy of policy interventions, reinforcing risk-on sentiment. This mechanistic distinction reveals that QE spillovers are not channeled through a single homogeneous pathway; rather, different financial spreads operate on distinct dimensions, with the TS acting through the expectations channel (the long-term macro outlook) and the MS through the policy implementation channel (monetary transmission mechanics), thereby generating complex and heterogeneous effects across global financial markets.

To address potential concerns that spreads' movements might be contaminated by non-QE factors, we conduct robustness checks using the Federal Reserve's direct holdings of Treasury securities and MBS as alternative proxies for QE intensity; the results remain qualitatively unchanged. Moreover, existing event-study evidence based on high-frequency QE announcement dates shows that unexpected declines in mortgage-related rates significantly lower the VIX (Swanson, 2021), consistent with the transmission mechanism emphasized in this paper.

5.2. Channels of the TS and MS shocks

This study posits that QE policy influences international financial markets through two distinct channels: Tthe VIX index, which captures global risk appetite, and MPU, which reflects the clarity of policy expectations. To test this mediating mechanism, we separately impose a one-standard-deviation negative shock on VIX and MPU. The results are shown in Figure 2. The resulting dynamic responses, —characterized by rising equity returns, declining government bond yields, and currency appreciation—, closely mirror the patterns generated by TS and MS shocks in Figure 1. This alignment provides strong support for our core hypothesis that QE operates via a dual transmission mechanism: "market Market sentiment" and "policy expectations."



Panel A. VIX shocks: TS.

Panel B. MPU shocks: TS.

Panel C. VIX shocks: MS.

Panel D. MPU shocks: MS.

Figure 2. Panels A and C illustrate the impulse responses of financial markets in advanced and emerging economies, respectively, as well as the US TS, to a one-standard-deviation shock in the VIX index. Panels B and D present the corresponding impulse responses to a one-standard-deviation shock in the MPU index, respectively.

Further analysis reveals that the VIX channel, due to its direct linkage to global risk-taking behavior and its relatively persistent response, exhibits greater explanatory power in accounting for medium- to long-term asset price adjustments. In contrast, the MPU channel effectively captures short-term volatility during periods of ambiguous policy signaling; its effect diminishes as expectations converge over time, thereby offering valuable insight into markets' immediate reactions to policy shifts.

Notably, however, when VIX or MPU is directly shocked, the model also registers a feedback effect on TS and MS. While this reverse causality is economically plausible—improved risk appetite or clearer policy guidance can indeed influence long-term rate expectations and credit conditions—the magnitude of this feedback is negligible, typically less than 1% of the impact of QE-induced shocks on VIX/MPU. Moreover, the initial movements in TS and MS are primarily driven by the exogenous expansion of the Fed's balance sheet, reinforcing their role as policy instruments rather than endogenous outcomes.

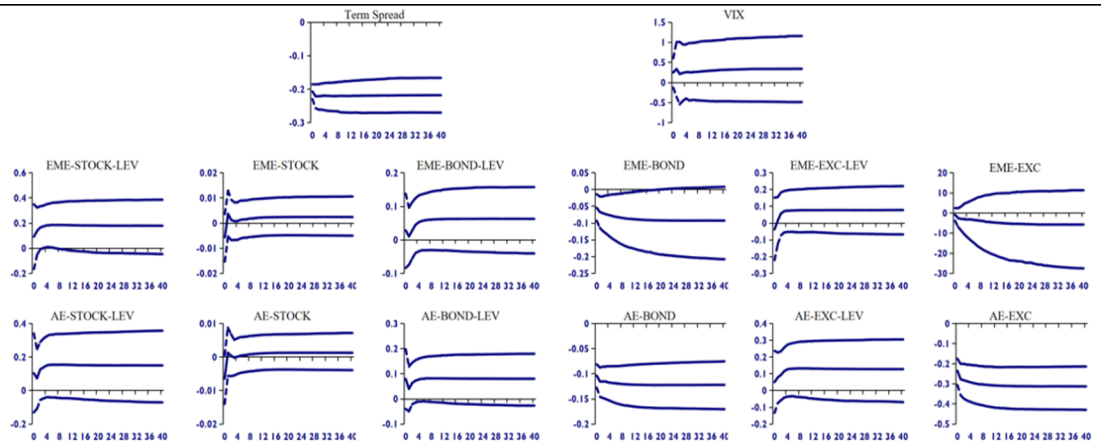
Thus, the dominant direction of transmission stands as QE → spreads (TS/MS) → VIX/MPU → global financial variables. That said, we acknowledge that the GVAR framework inherently models dynamic interdependencies among variables rather than strict unidirectional causality. Future research

combining high-frequency event studies or external instrumental variables could further sharpen causal identification. In the present context, our findings should be interpreted within a coherent mechanism: A QE shock alters financial spreads, which, in turn, adjust market sentiment and policy expectations, ultimately propagating effects across global financial markets.

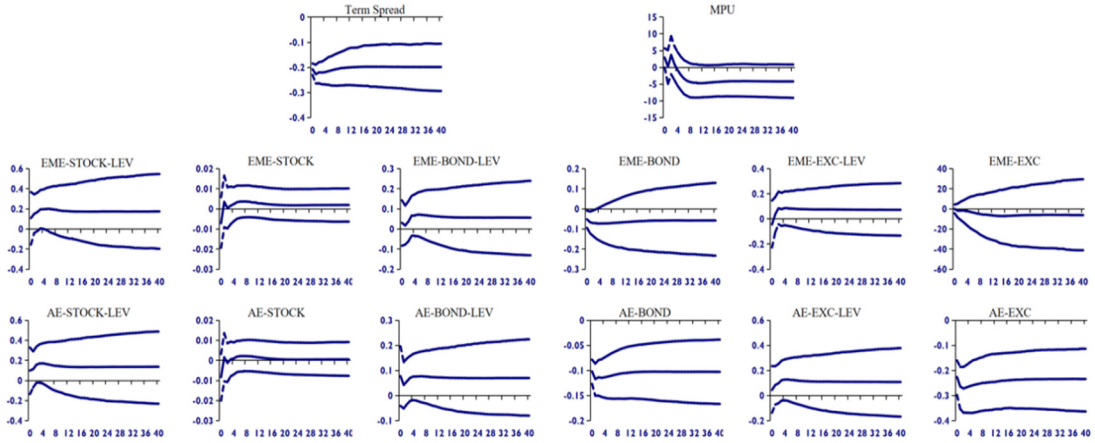
5.3. The moderating role of financial leverage in the transmission of TS and MS shocks

Existing studies have shown that during the transmission of QE to international financial markets via TS and MS, financial leverage does not merely act as a simple risk amplifier but serves as a conditional and structural moderator. Its role manifests not only as amplifying or dampening the slope of the shock response (i.e., changes in marginal sensitivity) but also as inducing level shifts (i.e., differences in the baseline leverage levels). Notably, despite some AEs having lower average leverage ratios compared with emerging markets, their leverage elasticity (the magnitude of change in leverage ratios in response to policy shocks) under negative TS shocks is significantly higher. This suggests that the amplification effect in advanced markets primarily stems from their financial systems' high sensitivity and rapid adjustment capabilities to policy signals, rather than from the initial leverage levels themselves.

Specifically, when TS experiences a one-standard-deviation negative shock (as illustrated in Panels A and B of Figure 3), significant and sustained positive responses in the leverage ratios are observed across major global financial markets. For the MPU channel, the peak leverage ratios in advanced market equity, government bond, and foreign exchange futures markets are +0.17%, −0.11%, and +0.13%, respectively, while those in emerging markets are +0.20%, −0.07%, and +0.09%. These reactions reflect investors' active interpretation of policy easing signals: In an environment with a low interest rate, leveraging up to enhance returns on risky assets becomes a prevalent strategy. Introducing leverage ratios reveals that the response magnitudes of 10-year government bond yields and nominal effective exchange rates to TS shocks in advanced markets increase by 20% and 10%, respectively; however, in emerging markets, these metrics rise by 10% and up to 200%, respectively. In contrast, the amplification effects in stock markets across both economy types are almost identical. This structural divergence can be explained through the micromechanisms of futures markets. Stock index futures, characterized by high liquidity, low transaction costs, and flexible intraday margin requirements, enable institutional investors to quickly adjust their positions with relatively controlled volatility. Although stock market leverage ratios increase most notably (+0.17% in advanced markets, +0.20% in emerging markets), their amplification effects on stock index returns remain relatively limited. Government bond futures, supported by market-making depth and central clearing systems, involve robust leverage operations that are highly sensitive to interest rate movements. A narrowing TS directly lowers the forward rate expectations, triggering substantial long-position building, which results in the strongest leverage ratio responses; for instance, the peak leverage ratio in advanced markets' government bond futures reaches −0.11%, indicating a strong moderating effect despite the negative value. Foreign exchange futures in emerging markets, constrained by lower liquidity, higher margin requirements (averaging 30–50% more than in advanced markets), and wider bid–ask spreads (approximately 2–3 times those in advanced markets), exhibit jump-like leverage adjustments, often seen as initial appreciation followed by rapid reversals, leading to pronounced volatility amplification effects.



Panel A. TS shocks: VIX channel.

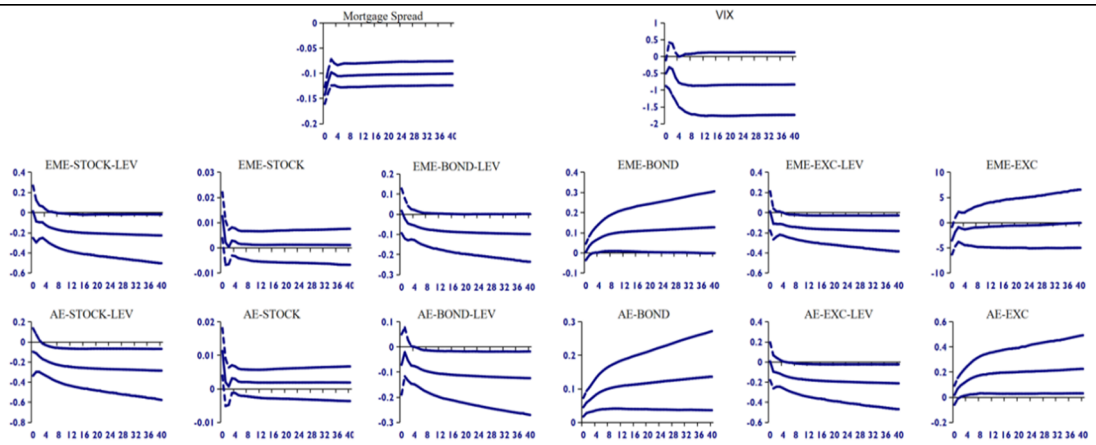


Panel B. TS shocks: MPU channel.

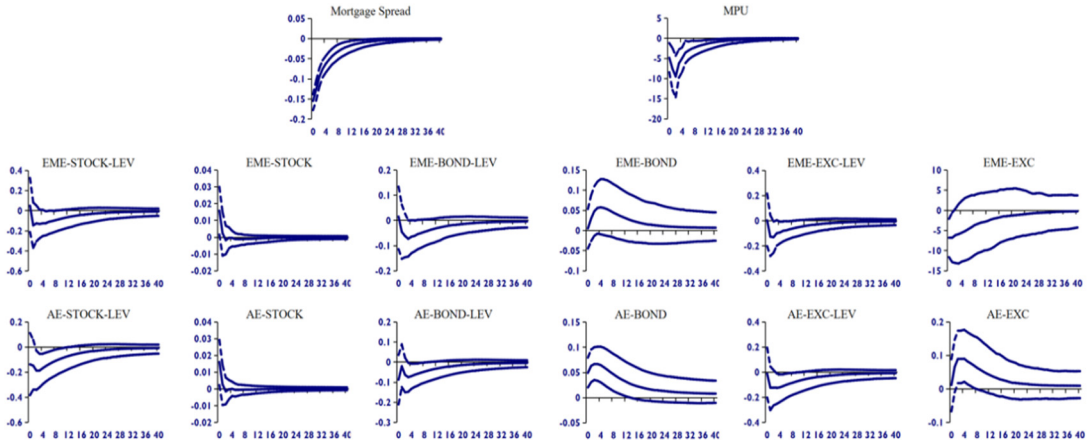
Figure 3. Panels A and B illustrate the responses of financial markets in advanced and emerging economies, respectively, to negative shocks originating from US TS shocks through the VIX and MPU channels, with leverage effects incorporated.

In contrast, under a negative MS shock (as illustrated in Panels A and B of Figure 4), leverage behavior exhibits a predominantly deleveraging pattern characterized by caution. Although a narrowing MS signifies reduced household sector financing costs, if investors lack confidence in the overall economic outlook—especially given that public debt/GDP ratios in emerging markets have surpassed 60%—they are more inclined to actively reduce risk exposure rather than leveraging up for yield. Specifically, under the VIX channel, emerging markets' equity, government bond, and foreign exchange futures market leverage ratios decline by −0.10%, −0.05%, and −0.11%, respectively, during the first 2 months after the shock; however, these responses do not become statistically significant until the fourth month. This delay reflects market ambiguity regarding MBS purchase policies: Unlike the macroeconomic growth expectations conveyed by TS, a narrower MS primarily indicates targeted easing in housing credit, which is insufficient to substantially boost overall growth confidence, leading to more cautious and delayed investor adjustments. Meanwhile, advanced markets, despite starting with lower initial leverage levels, initiate deleveraging faster and respond more promptly due to higher information efficiency and stronger policy interpretation capabilities. Moreover, deleveraging does not

uniformly affect all asset classes but triggers significant cross-market reallocation effects. Under the VIX channel, stock index futures' leverage ratios plummet by −0.14% within the first 2 months, indicating active risk reduction by investors; government bond futures' leverage ratios also decline by −0.05% during the same period while price volatility increases (+0.07%), reflecting a shift of funds from risky assets to safer ones: A typical "flight-to-safety" behavior. In the foreign exchange futures market, there is notable intergroup divergence. Emerging markets experience capital outflow pressures, resulting in reduced foreign exchange futures holdings and converging exchange rate volatility, whereas advanced markets, benefiting from arbitrage capital inflows, see their foreign exchange futures' leverage ratios decrease by −0.10%, but their exchange rate volatility rises (+0.10), highlighting greater sensitivity to cross-border capital flows.



Panel A. MS shocks: VIX channel.



Panel B. MS shocks: MPU channel.

Figure 4. Panels A and B present the corresponding responses to negative shocks transmitted via US MS shocks through the same two channels (VIX and MPU), again distinguishing between advanced and emerging economies.

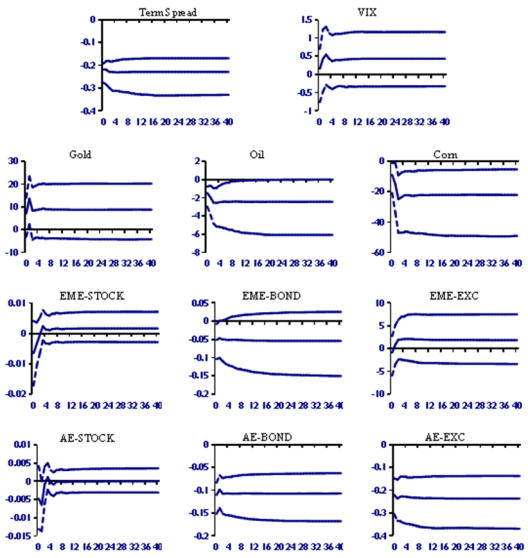
Overall, leverage ratios in the cross-border transmission of QE are not merely simple risk amplifiers but act as highly contingent and structural moderators, dependent on the type of shock, asset class, and market structure. Under the macro-easing signal of a narrowed TS, advanced markets,

despite having lower average leverage, exhibit stronger marginal leverage elasticity due to an efficient derivatives infrastructure and institutionally dominated market structures, significantly amplifying the transmission of policy impacts on government bond yields and exchange rates. Emerging markets, despite higher leverage levels, are constrained by liquidity shortages and institutional frictions, leading to sluggish leverage adjustments, where high leverage often manifests as static vulnerability, resulting in extreme volatility only in specific segments like exchange rate quotations due to structural imbalances. Under a narrowly targeted easing signaled by a narrower MS, markets generally engage in deleveraging, albeit with distinct paths: Advanced markets react swiftly and trigger cross-asset reallocations; emerging markets, burdened by debt concerns and financing constraints, undergo larger but more delayed deleveraging, accompanied by a flight from stocks to bonds for safety. Additionally, the moderating role of leverage varies asymmetrically across different risk channels. In short-term panic driven by the VIX, it significantly amplifies contagion sell-off risks in emerging markets through margin mechanisms; under MPU-led long-term uncertainty, its impact is weak, as investors rely more on nonleverage strategies such as duration matching. Therefore, the critical aspect of leverage lies not in its absolute level but in its dynamic responsiveness and coupling with market microstructures. Macro-prudential policies should transcend static leverage ratio monitoring and focus on the marginal elasticity differences across economies under specific shocks, integrating considerations of liquidity, margin rules, and participant structures in futures markets to implement differentiated regulation, being particularly vigilant against nonlinear financial risks in emerging markets, where the coexistence of high leverage and low liquidity can trigger destabilizing feedback loops.

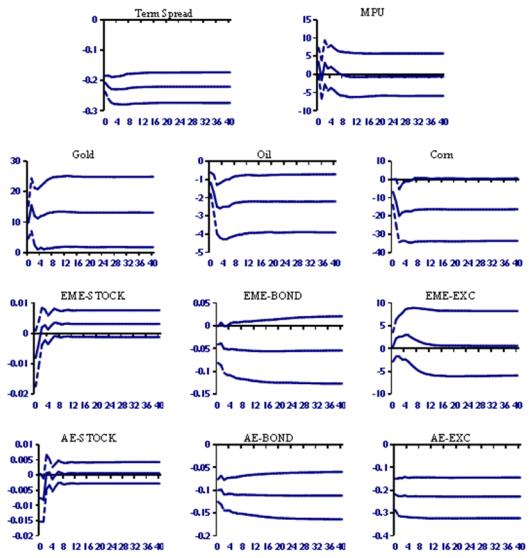
5.4. The moderating role of commodity prices in the transmission of TS and MS shocks

This section examines how the introduction of global commodity variables, such as gold, crude oil, and agricultural product prices. affects international financial markets through the VIX index (representing market volatility) and MPU channels following shocks to TS and MS. The results indicate that commodities are not merely passive reflections of shocks but actively modulate transmission intensity and pathways (as illustrated in Figure 5).

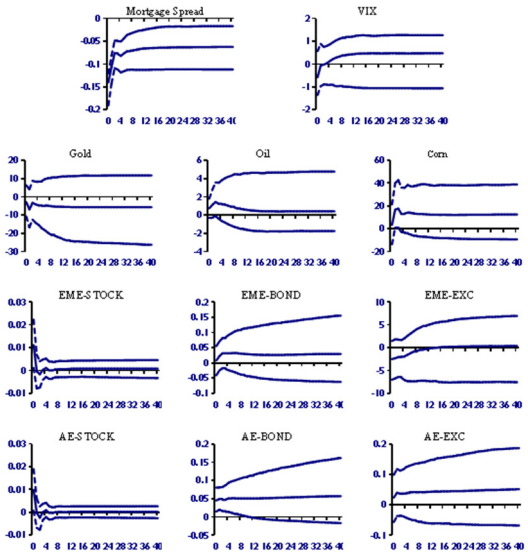
Under a negative TS shock, market risk sentiment deteriorates rapidly: The VIX index rises by 0.54% in the second month, concurrently triggering global flight-to-safety behaviors. Gold prices, as a classic safe-haven asset, increase significantly by 1.62% in the first month; meanwhile, procyclical commodities generally face downward pressure, with crude oil prices falling by 2.57% and agricultural product prices experiencing a more severe decline of 24.91%, reflecting investors' concerns about economic growth prospects and rapid divestment from risky assets. Simultaneously, MPU increases notably by 3.15%, leading to an even stronger flight-to-safety reaction: Gold prices surge by 15.52% in the first month, underscoring its robust safe-haven function during periods of policy uncertainty. During this period, crude oil prices also fall by 2.57%, while the decline in agricultural products narrows to 5.26%, indicating heterogeneous impacts of different risk sources on commodities, namely that MPU primarily depresses assets related to policy expectations and demand prospects, whereas VIX-driven panic has a broader impact on overall risk appetite.



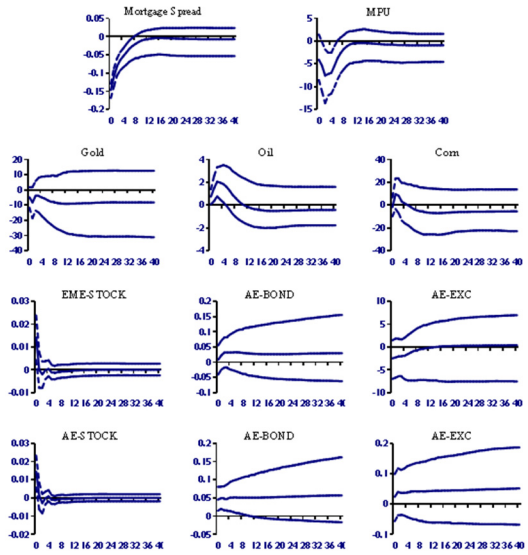
Panel A. TS shocks: VIX channel.



Panel B. TS shocks: MPU channel.



Panel C. MS shocks: VIX channel.



Panel D. MS shocks: MPU channel.

Figure 5. Panels A and B depict how financial markets in advanced and emerging economies respond to negative shocks transmitted through the VIX and MPU channels via the US TS, after incorporating commodity prices. Panels C and D show the corresponding responses to shocks originating from the US MS through the same transmission channels.

In contrast, market reactions under a negative MS shock are more complex and exhibit significant divergence across different risk transmission channels. Under the VIX channel, despite increased market volatility, gold prices anomalously decrease by up to −6.81%, possibly due to initial liquidity squeezes prompting "cash is king" behavior, where investors sell liquid assets, including gold, to meet funding pressures. Meanwhile, crude oil prices rise by 1.45% in the second month, reflecting expectations of inflation and economic demand driven by QE policies. Agricultural product prices

continue to climb, accumulating gains of 17.64%, likely driven by supply chain disruptions coupled with speculative inflows. Under the MPU channel, all three commodity categories exhibit a rising then falling dynamic pattern. Gold prices initially drop by −8.17%, showing a temporary suppression of its safe-haven function during high uncertainty phases; crude oil prices first rise by 2.06% before retreating to −0.42%; and agricultural products initially increase by 9.67% before correcting by 5.46%. This pattern suggests that the market initially interprets MS easing as a supportive policy signal, boosting risk appetite and speculative premiums, which later fade as policy uncertainties subside.

Introducing commodity variables significantly dampens the responses of VIX and MPU to the original monetary policy shocks, indicating a buffering role for commodities in risk transmission. Specifically, under a negative TS shock, the peak VIX response decreases from +0.58% to +0.54%, and the MPU increase narrows from +7.42% to +3.15%; under an MS shock, the initial negative VIX response shifts from −0.89% to +0.47%, and the decrease in MPU moderates from −10.40% to −7.55%. These changes suggest that commodities, especially gold as a tail-risk hedge and commodity futures as a means of diversifying inflation exposure, provide effective alternative risk management channels for investors. By absorbing some hedging or speculative demands, commodity markets alleviate concentrated selling pressures on financial assets, thereby curbing panic spreads and enhancing the resilience of the overall financial system.

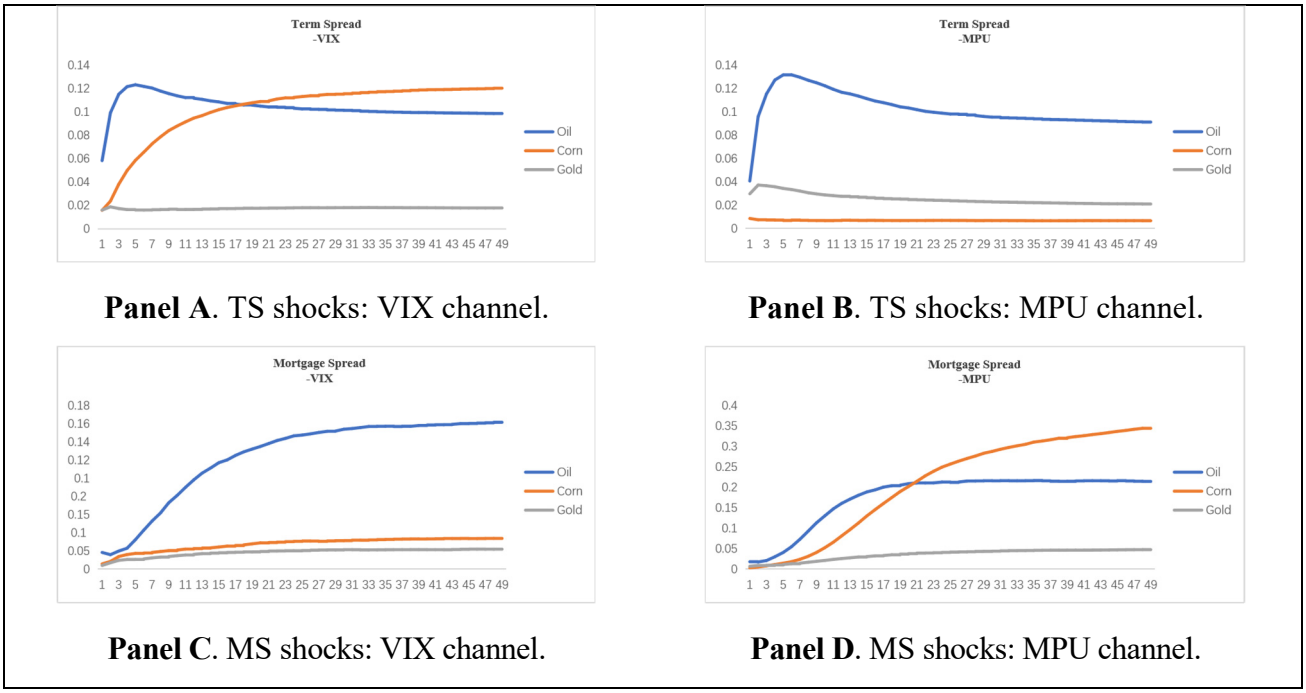
From a cross-border perspective, the introduction of commodities exhibits significant heterogeneity in modulating the transmission of monetary policy shocks through VIX and MPU channels, differing between advanced and emerging markets in particular. Under a negative TS shock transmitted via the VIX channel, global stock indices experience slightly reduced declines.

In emerging markets, government bond yields' negative response softens from a decline of 0.08 percentage points to just 0.05 percentage points, while in advanced markets, bond yields remain largely stable. Particularly noteworthy is the structural reversal in foreign exchange markets. Emerging markets' nominal effective exchange rates shift from depreciation (−1.92%) without commodity inclusion to appreciation (+2.12%), indicating that commodities like gold mitigate capital outflow pressures and attract some safe-haven flows into higher-yielding emerging assets. Under combined TS and MPU shocks, stock and bond markets in both advanced and emerging economies remain relatively stable, with changes mainly concentrated in exchange rates: Emerging markets' currencies shift from sustained depreciation to brief appreciation, peaking at +2.99%. This shift further corroborates that commodities, particularly gold, effectively curb the cross-border spillover of panic and alter capital flow directions under certain conditions, highlighting their role as buffers for global financial stability, especially for emerging markets.

In MS shock models, commodities also demonstrate evident risk mitigation effects. The responses of various financial variables to shocks are weakened across both the VIX and MPU channels. However, it is worth noting that although the initial reactions under the MPU channel are moderated, their duration extends: The significant response of government bond yields no longer reaches its half-life by the twelfth month but persists longer, indicating that the policy uncertainty triggered by MS narrowing has a more prolonged disturbance on market expectations. This reflects that while commodities can absorb some short-term fluctuations, structural doubts conveyed through the MPU channel, such as long-term concerns about policy effectiveness or economic outlooks, continue to influence interest rate pricing over extended periods, underscoring fundamental differences in transmission mechanisms compared with TS shocks.

Overall, commodities play an active regulatory role in the cross-border transmission of global monetary policy shocks, effectively mitigating short-term market panics and reshaping the transnational response paths of financial variables. Their inclusion significantly weakens the initial shock intensity through the VIX and MPU channels, often causing directional reversals in emerging markets, highlighting their functions as risk absorbers and stabilizers of capital flows. Notably, the persistence of different policy shocks varies: TS shocks are more easily buffered, whereas MS shocks convey long-lasting doubts through policy uncertainty, demonstrating that commodities are not merely passive price carriers but crucial structural forces influencing global financial stability and are indispensable in analyzing the spillover effects of unconventional monetary policies.

In the analysis of how commodity prices influence the transmission mechanisms of US QE policy shocks, the application of the generalized forecast error variance decomposition (GFEVD) method offers a robust quantitative framework. This approach enables a detailed assessment of the degree to which variations in different types of commodity prices, such as gold, crude oil, and agricultural products, contribute to explaining the volatility observed in international financial markets after the implementation of US QE policies. By using GFEVD, researchers can quantify the relative importance of each commodity price in driving financial market fluctuations, thereby providing deeper insights into the complex interactions among monetary policy, commodity markets, and global financial stability.



Panel A. TS shocks: VIX channel.

Panel B. TS shocks: MPU channel.

Panel C. MS shocks: VIX channel.

Panel D. MS shocks: MPU channel.

Figure 6. The role of commodity prices in transmitting US QE policy shocks (generalized forecast error variance decomposition).

The empirical results indicate that in the model where US TS affects international financial markets via the financial market volatility channel (measured by the VIX index) (Figure 6, Panel A), crude oil prices contribute most significantly to forecast error variance during the initial shock phase, reflecting their direct and immediate transmission effect on global financial fluctuations. However, as the dynamic interactions among the output variables across countries intensify within the GVAR

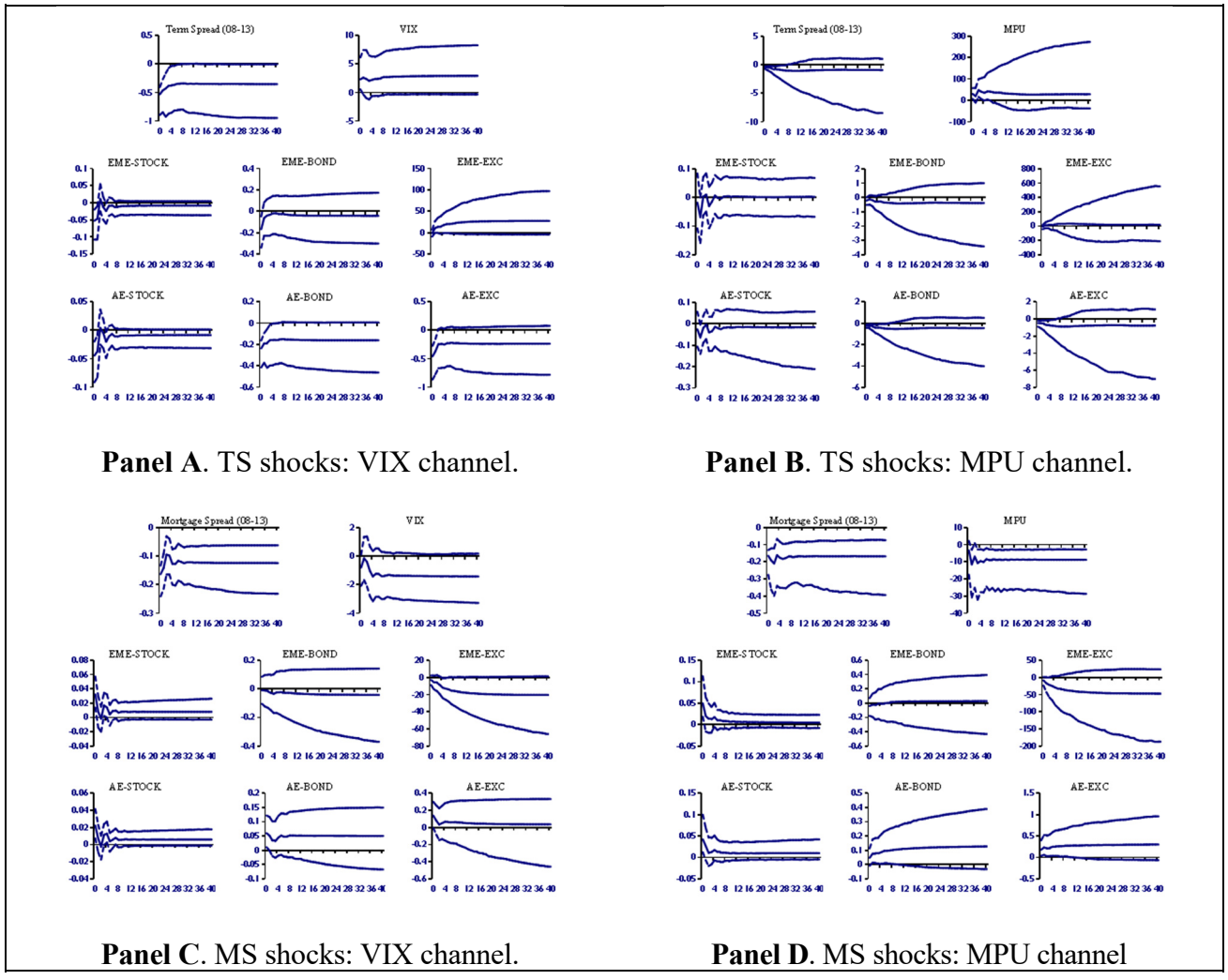
model, the dominance of crude oil diminishes, while agricultural product price variances continue to rise, eventually surpassing crude oil to become one of the key sources explaining financial market volatility. Notably, gold prices maintain a consistently low variance contribution throughout the sample period, indicating the lack of a significant systemic influence in this transmission pathway. Similar patterns are observed in other transmission scenarios. Under the MPU channel (Figure 5, Panel B), crude oil not only exhibits the most prominent explanatory power but also sees its influence grow over time, underscoring its role as a core barometer of global economic activity. In the context of MS shocks (Figure 6, Panels C–D), crude oil demonstrates robust and increasing variance contributions through both the VIX and MPU channels. Meanwhile, agricultural products show significant increases in variance contributions in specific combinations, such as when TS shocks are transmitted through financial market volatility or MS shocks through MPU, sometimes surpassing those of crude oil, highlighting their structural importance under certain institutional and policy environments.

An intriguing phenomenon worthy of deeper exploration is that although gold prices often experience sharp movements in the early stages of shocks (e.g., a 15.52% increase in the first month under dual shocks from TS and MPU), their contribution to GFEVD remains consistently low. Conversely, crude oil and, in some contexts, agricultural product prices exhibit relatively moderate initial fluctuations yet demonstrate stronger explanatory power in systemic risk transmission. This seemingly contradictory result can be clarified by distinguishing between assets' functional roles and temporal dimensions. Specifically, gold primarily acts as a short-term sentiment amplifier rather than a driver of long-term volatility. As a non-interest-bearing safe-haven asset, gold rapidly responds to market panics (such as spikes in the VIX) or heightened policy uncertainties, sending strong risk-averse signals and potentially reinforcing investors' risk aversion behaviors, triggering deleveraging or cross-border capital reallocations. However, such reactions are highly concentrated within gold's own price path and seldom persistently transmit to other financial variables, thereby limiting their cumulative explanatory power for overall forecast errors in multiperiod dynamic systems. In other words, gold functions more like a sentinel for risk sentiment rather than a transmission shaft for systemic volatility. By contrast, despite initially modest price fluctuations, crude oil and agricultural products play enduring intermediary roles in the shock transmission chain due to their deep integration with real economy fundamentals, inflation expectations, global supply chain stability, and emerging markets' fiscal conditions. Fluctuations in crude oil prices directly impact global production cost structures and central banks' inflation assessments, continuously affecting interest rate expectations, exchange rate trends, and cross-border capital flows over multiple periods. Agricultural products, under specific policy environments (such as liquidity excesses caused by QE coupled with climatic disturbances or inventory constraints), generate trend-driven price pressures, reshaping trade conditions, fiscal sustainability, and external vulnerabilities in emerging markets. These intertemporal and cross-market spillover mechanisms lead to higher accumulated variance contributions under the GFEVD framework. Moreover, the explanatory power of agricultural products shows significant contextual dependence. In pathways where TS shocks are transmitted through financial market volatility or MS shocks through MPU, despite small price fluctuations, their variance contributions are notable, reflecting their implicit influence as structural constraint variables. In other combinations, even if price fluctuations are substantial, without clear macro-transmission mechanisms, their systemic impacts remain limited. This suggests that the explanatory power of commodities regarding financial volatility depends not only on the magnitude of their own price fluctuations but, more critically, on whether they are embedded in effective policy shock–real economy–financial market feedback loops.

In summary, GFEVD analysis reveals the heterogeneous roles of commodities in the spillover effects of global monetary policy. Gold serves as a short-term risk sentiment amplifier with limited systemic explanatory power; crude oil acts as a core hub with both immediate responsiveness and medium-term transmission capabilities; and agricultural products exert implicit stabilizing or disruptive influences in specific institutional and shock combinations through a low volatility–high contribution approach. This finding transcends a simplistic focus on price fluctuations, emphasizing the need to understand the complex roles of commodities in the international financial system from three dimensions: Temporal dynamics, mechanism embedding, and functional positioning. It provides a more refined theoretical foundation for macro-prudential regulation and cross-border risk warnings.

6. Robustness check and further analysis

6.1. Restricting the sample period to 2008–2013



Panel A. TS shocks: VIX channel.

Panel B. TS shocks: MPU channel.

Panel C. MS shocks: VIX channel.

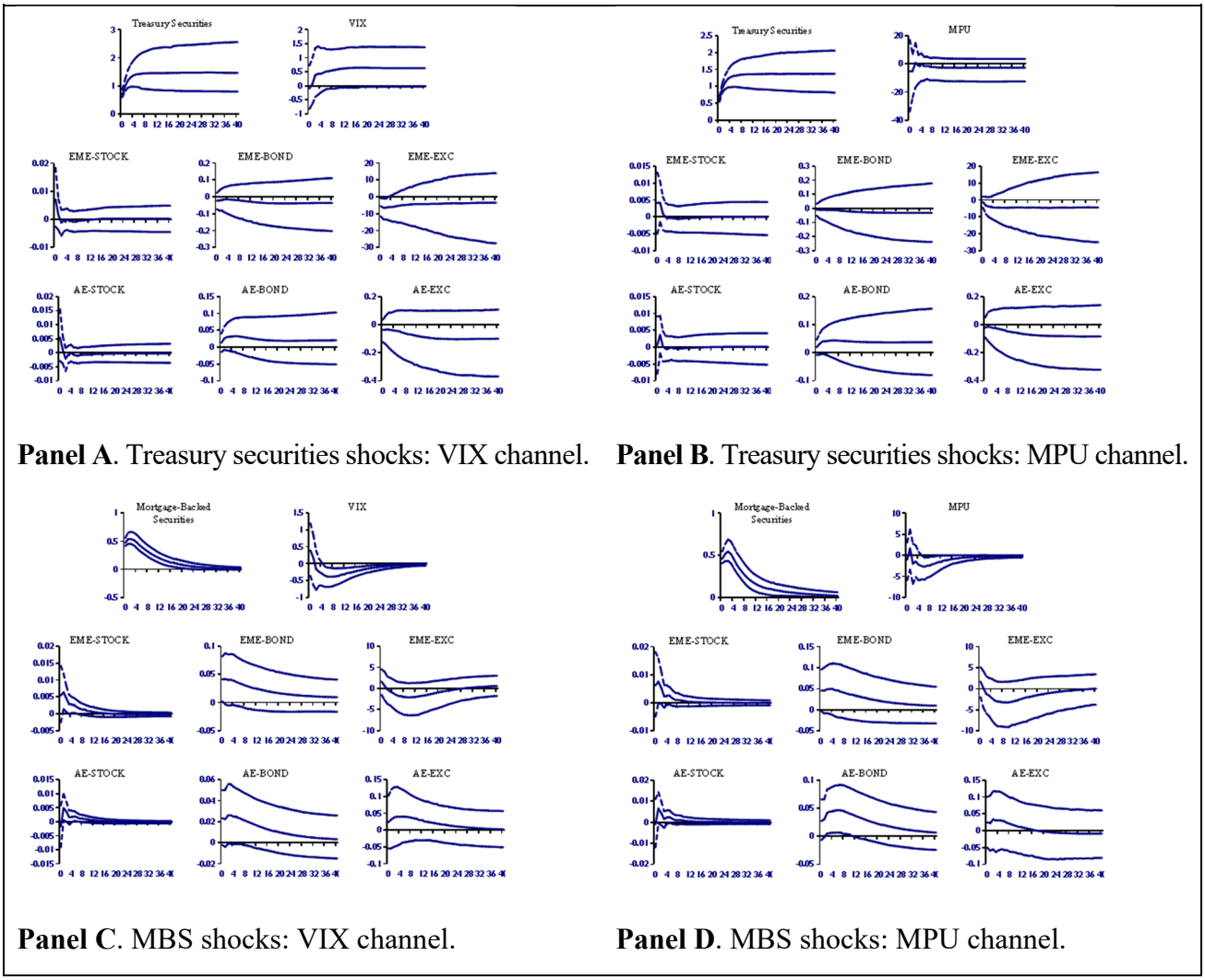
Panel D. MS shocks: MPU channel

Figure 7. Restricting the sample period to 2008–2013.

To assess the robustness of the main findings regarding the spillover effects of US QE policies on international financial markets, this study shortens the sample period from 2008–2023 to 2008–

2013. This adjustment allows the analysis to focus specifically on the direct spillovers associated with the initial QE programs (QE1, QE2, and QE3) while minimizing potential confounding effects from subsequent economic developments and policy changes. Furthermore, narrowing the sample period helps reduce interference from other macroeconomic variables. Since 2013, the global economy has experienced significant shifts, including the European debt crisis, emerging market volatility, and escalating global trade tensions. These events may introduce additional complexity and uncertainty into model estimation. A comparison of results reveals that the findings based on the shortened sample period (2008–2013), as illustrated in Figure 7, are broadly consistent with those from the baseline analysis covering 2008–2023 (as shown in Figure 1). This consistency across time horizons confirms the robustness of the baseline results and underscores the stability of US QE spillovers on international financial markets under different temporal frameworks.

6.2. Replacing TS and MS with balance sheet data



Panel A. Treasury securities shocks: VIX channel.

Panel B. Treasury securities shocks: MPU channel.

Panel C. MBS shocks: VIX channel.

Panel D. MBS shocks: MPU channel.

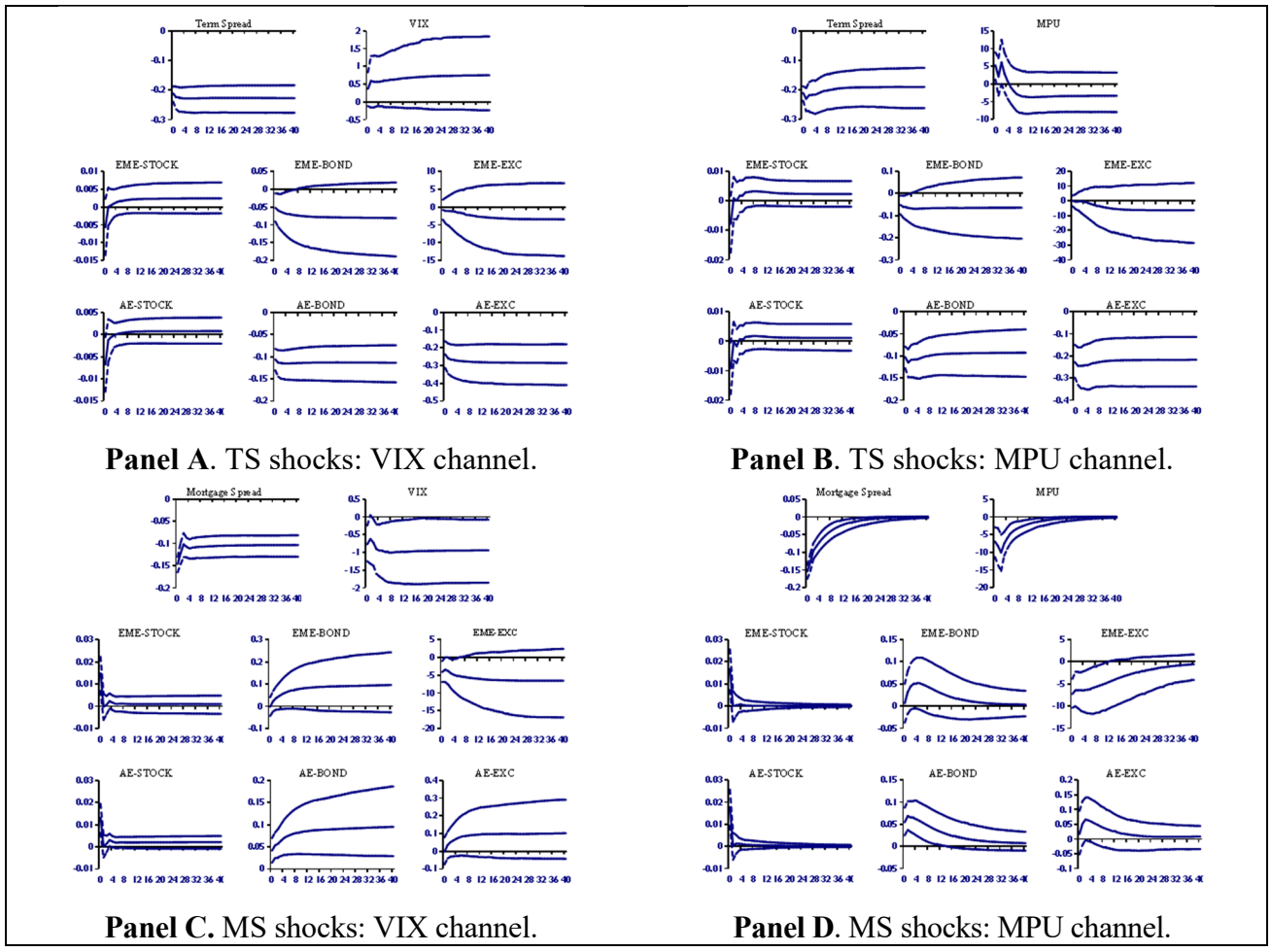
Figure 8. Replacing TS and MS with balance sheet data.

To further validate the robustness of the findings on the spillover effects of US QE policies on international financial markets, this study uses alternative variables based on the US Federal Reserve's

direct holdings of MBS and treasury securities from its balance sheet, in place of the TS and MS (Dahlhaus et al., 2018). These balance sheet components serve as more direct indicators of the Fed's unconventional monetary policy stance. The results from this robustness check using MBS and Treasury holdings as proxies (as illustrated in Figure 8) are broadly consistent with those obtained in the baseline analysis using TS and MS (shown in Figure 1). This consistency across different empirical specifications confirms the robustness of the baseline findings and provides further evidence that the spillover effects of US QE policies on global financial markets remain stable even when alternative measures are used.

6.3. Alternative lag order criteria

In the selection of the optimal lag length, the baseline analysis uses the AIC to separately determine the lag order for domestic and foreign variables. As part of the robustness checks, the SBC is used instead to select the lag structure for both sets of variables. The results from this robustness check, based on lag orders selected using the SBC (as shown in Figure 9), are broadly consistent with those obtained in the baseline specification using the AIC (as illustrated in Figure 1). This consistency across different lag selection criteria confirms the robustness of the baseline findings and provides further evidence that the spillover effects of US QE policies on international financial markets remain stable under alternative model specifications.



Panel A. TS shocks: VIX channel.

Panel B. TS shocks: MPU channel.

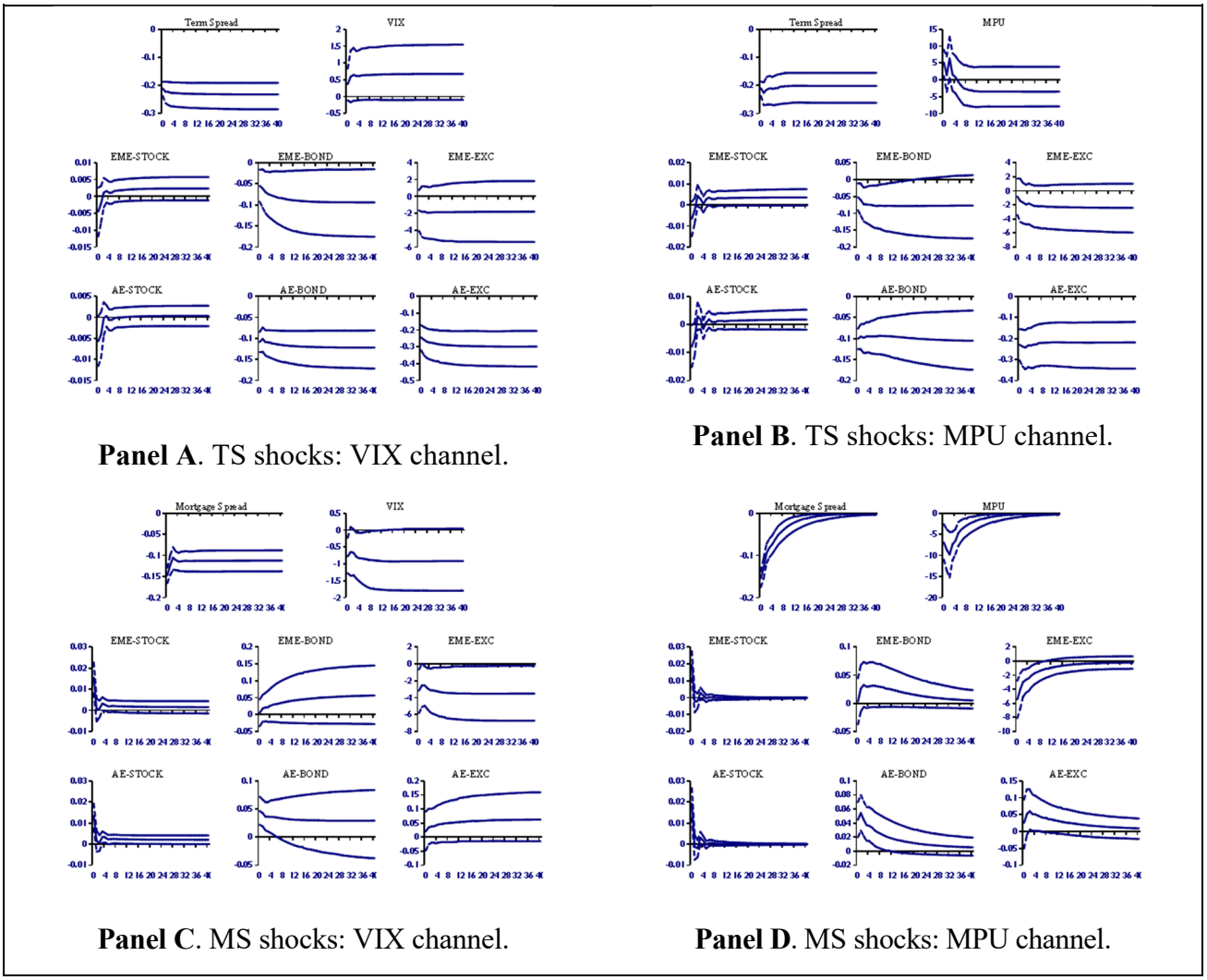
Panel C. MS shocks: VIX channel.

Panel D. MS shocks: MPU channel.

Figure 9. Alternative lag order criteria.

6.4. Alternative linkage matrix

In traditional GVAR model studies, scholars commonly use bilateral trade data as a proxy for economic linkages between countries (Dees et al., 2007; Attílio, 2023), relying on the flow of goods to depict the degree of economic integration across nations. While this approach effectively captures real-sector linkages, it may overlook the increasingly important role of international financial connections. As highlighted by Ripley (1973), three key factors underpin the comovements of national stock market indices: (1) The strength of financial linkages between countries, (2) the degree of capital mobility, and (3) the intensity of trade ties. Against this background, to more comprehensively capture cross-border financial linkages, this paper introduces a novel approach in its robustness checks. Bilateral direct investment positions are used in place of conventional bilateral trade flows. The data are drawn from the International Monetary Fund's (IMF's) Coordinated Direct Investment Survey (CDIS). Following the methodology of Attílio et al. (2024), we construct a row-standardized weight matrix to better reflect financial interconnections among countries. This method not only accounts for the influence of cross-border capital flows but also better represents the structural financial relationships between economies, offering a more comprehensive and systematic understanding of global economic interactions.



Panel A. TS shocks: VIX channel.

Panel B. TS shocks: MPU channel.

Panel C. MS shocks: VIX channel.

Panel D. MS shocks: MPU channel.

Figure 10. Alternative linkage matrix.

Comparative analysis reveals that the results from the robustness check, based on the linkage matrix constructed using bilateral direct investment positions (as shown in Figure 10), are broadly consistent with those obtained from the baseline specification using trade-based linkages (as illustrated in Figure 1). These findings confirm that the spillover effects of US QE policies on international financial markets remain stable across different measures of economic connectivity. They further reinforce the robustness and generalizability of the baseline results.

7. Conclusions and policy recommendations

This study uses a GVAR model to systematically investigate the cross-border transmission mechanisms of QE through TS and MS on global financial markets, with a particular focus on two core channels: Financial market volatility (measured by the VIX index) and MPU. The empirical results indicate that MS more accurately reflects the targeted easing intentions of QE, whereas TS more clearly conveys signals about macroeconomic growth expectations. Under both types of shocks, significant heterogeneity is observed between AEs and EMEs. Emerging markets exhibit some resilience in stock and long-term government bond markets but are particularly vulnerable in foreign exchange markets. For instance, during the initial phase of a negative TS shock, the average nominal effective exchange rate depreciation in emerging markets reaches 1.92%, significantly higher than in AEs. However, when commodity variables such as gold, crude oil, and agricultural products are introduced into the model, this depreciation trend not only moderates but even reverses into appreciation under certain scenarios, peaking at 2.12%. This suggests that commodities play a substantive buffering role in cross-border risk transmission. The impact of leverage exhibits distinct temporal characteristics and channel dependence. In the short term, moderate leveraging can help investors capture policy dividends; however, over the long term, especially in emerging markets, increased leverage amplifies stock and foreign exchange markets' volatility via the VIX channel. Notably, although gold prices often experience sharp increases during the early stages of shocks, such as a 15.52% rise in the first month under dual shocks from TS and MPU, the GFEVD results show that its explanatory power for the overall financial system's volatility remains consistently low. This indicates that gold primarily functions as a short-term sentiment signal rather than a systemic driver of other asset movements. In contrast, despite relatively moderate price fluctuations, crude oil and agricultural products gain increasing explanatory power for financial market volatility over time due to their deep integration with the real economy, inflation expectations, and supply chain systems. Particularly in scenarios where TS shocks are transmitted through financial market volatility or MS shocks through MPU, agricultural products' variance contributions even surpass those of crude oil, highlighting their low volatility–high transmission structural stability roles.

These findings provide quantitative support for developing more targeted macro-prudential and cross-border risk mitigation policies. Given the high vulnerability of emerging foreign exchange markets to TS shocks, introducing countercyclical leverage control mechanisms in the foreign exchange futures market could be considered. Counterfactual simulations suggest that dynamically raising the margin requirements by 10% to 15% when the VIX index breaches specific thresholds could reduce the peak depreciation of nominal effective exchange rates by 30% to 40%, narrowing it from 1.92% to within 1.2%, effectively disrupting the negative feedback loop of high leverage–low liquidity–forced liquidation. Additionally, while acknowledging gold's safe-haven attributes, policymakers should recognize its limited systemic spillover effects and instead pay closer attention

to the mid-term evolution trends of crude oil and agricultural product prices, which demonstrate higher sustained explanatory power in GFEVD. These trends serve as crucial leading indicators for assessing whether QE spillovers have materially impacted the real economy. Therefore, it is recommended to establish a joint monitoring framework encompassing commodities, exchange rates, and cross-border capital flows and to utilize strategic reserves to stabilize market expectations when agricultural supply chains face disruptions. In terms of leverage regulation, differentiated strategies based on the nature of shocks and temporal dimensions should be adopted. Moderate tolerance of leverage increases may be permissible to maintain market liquidity during the short-term shocks driven by financial market volatility; however, stricter constraints on nonbank financial institutions in emerging markets should be enforced under conditions of persistently high MPU, given their weaker adjustment capabilities under prolonged uncertainty, which can lead to procyclical deleveraging behaviors. Leveraging dynamic margin mechanisms like standard portfolio analysis of risk, which tie leverage limits to real-time risk indicators such as market volatility and position concentration, can enhance the precision and foresight of regulatory measures. Lastly, promoting more operational international policy coordination is essential. Encouraging emerging economies to expand currency swap arrangements with major central banks and linking the swap activation conditions to objective quantitative metrics such as TS, MS, and the VIX index—rather than relying solely on bilateral political relationships—can provide timely buffers against external shocks, mitigating self-reinforcing capital outflows triggered by structural vulnerabilities in foreign exchange markets, thereby enhancing the overall resilience of the global financial system.

Author contributions

Huang Weiqiang: Writing – review and editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. Li Xiaomeng: Writing – original draft, Visualization, Validation, Software, Formal analysis, Data curation, Conceptualization.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors declare that they have no conflicts of interest.

Data availability

Data will be made available on request.

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