THE UNIVERSITY OF CHICAGO

U.S. MONETARY SHOCKS AND INTERNATIONAL DOWNSIDE RISKS SPILLOVER

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREES OF

BACHELOR OF ARTS IN ECONOMICS
WITH HONORS

AND

MASTER OF ARTS
IN THE
MASTER OF ARTS PROGRAM IN THE SOCIAL SCIENCES

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CHICAGO, ILLINOIS
MAY 2023

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Acknowledgement

I am immensely grateful to my advisor, Professor Anil Kashyap, as well as Co-Directors of Undergraduate Studies in Economics, Professor Victor Lima and Kotaro Yoshida for invaluable guidance and support on the paper. I also thank classmates and friends at the Undergraduate Honors Workshop and MAPSS-Economics Macro Workshop for feedback throughout the year. I owe a great debt to my parents, and every community that has trusted and nurtured me in one way or another.

Abstract

Using quantile regression and orthogonalized high-frequency surprises, I estimate effects of US monetary shocks on international downside growth risks, in a panel of 20 AEs and EMEs from 1988-2016. It is shown that contractionary US monetary shocks lead to decreases in low quantiles of international projected growth, thereby amplifying downside risks up to 9 quarters after the shock. Heterogeneity exists in the magnitude of spillover at the country level, related to features including financial openness, ex-ante financial conditions, aggregate debt levels and near-term credit growth. Furthermore, effects of shocks are largely insignificant for median and upside growth projections. The results suggest that US monetary surprises primarily impact the lower segment of conditional growth distributions of international economies, which might be hard to rationalize in a conventional setup via induced interest rate and risk premia changes. In view of the empirical estimates, I propose a financial constraint view of tail risks spillover, where US contractionary shocks tighten financial and credit constraints in foreign economies, contributing to amplification effects under downside growth realizations.

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1 Introduction

A long tradition of work in International Economics has emphasized the prominent role of the United States and US Dollar in shaping aspects of the global economy, ranging from trade invoicing, sovereign debt to foreign exchange reserves and international banking. (Triffin, 1960; Eichengreen and Flandreau, 2008; Ilzetzki, Reinhart and Rogoff, 2019; Gopinath et al., 2020; Gopinath and Stein, 2020). In light of the outsize influence of the United States in the international monetary system, the cross-border spillover of US monetary policy changes has garnered much attention from academics and policymakers alike. A rapidly expanding body of empirical literature documents that US monetary policy shifts display significant effects in modulating international asset prices, capital flow and risk-taking behaviors over an extended period (Rey, 2015; Bruno and Shin, 2015; Miranda-Agrippino and Rey, 2020; Brauning and Ivashina, 2020).

If US monetary policy does influence observed *activities* of the international financial market, what can be said about the substantive *implications* of spillover, in terms of real growth outcomes? Granted, the intricate connections between financial conditions and the macroeconomy have been extensively investigated, with a heavy focus on financially-induced macroeconomic risks. One influential view holds that financial exuberance and excessive risk-taking plant the seed for macroeconomic fragility by raising the peril of endogenously generated busts (Lorenzoni, 2008; Bianchi, 2011; Jeanne and Korinek, 2019). A classic body of literature, on the other hand, documents a separate, albeit closely related dimension, that financial frictions and tight limits could significantly amplify macroeconomic shocks, turning temporary disturbances into large, persistent growth downturns (Kiyotaki and Moore, 1997; Bernanke, Gertler and Gilchrist, 1999).

A curious question thus arises: *how do US monetary policy changes impact international downside growth risks?* The potential direction of effect is not immediately straightforward in light of the two facets of financial risks expounded above. Indeed, empirical literature that directly estimates the relations between financial conditions and adverse growth outcomes also offers mixed evidences. A range of papers have proffered support in line with the "financial exuberance" point of view on risks, establishing that loose financial conditions predict sharp and more severe downturns (Schularick and Taylor, 2012; Jordà, Schularick and Taylor, 2013; Mian, Sufi and Verner, 2017). In contrast, authors have also documented that tight financial conditions tend to be associated with deeper recessions and slower recoveries (Claessens, Kose and Terrones, 2012; Adrian, Boyarchenko and Giannone, 2019). As an intriguing twist, Adrian et al. (2022) reports the term structure of financially-induced GDP tail risks, that when initial financial conditions are loose, downside risks are lower in the near term, but increase in later quarters. As such, even if one is to agree that US monetary policy causally influences global financial conditions, the overall implications of such a shift on downside risks might be contentious, and complicated by temporal horizons. Growth risks spillover of monetary policy changes, therefore, emerges as a pertinent empirical question over the term structure, with vast policy relevance for the international community.

This paper explores the empirical linkage between US Monetary Policy shocks and international downside growth risks. The key empirical framework is the estimation of policy shocks' effects on lower quantiles of conditional distribution of foriegn economies through panel quantile regressions, in line with the recent Growth-at-Risk (GaR) literature (Adrian, Boyarchenko and Giannone, 2019; Adrian et al., 2022; Suarez, 2022). To overcome identification challenges due to policy endogeneity, I employ orthogonalized high-frequency monetary surprises constructed by Bauer and Swanson (2022) as proxy of policy shocks. The analysis leverages on a quarterly panel dataset of 20 advanced and emerging economies over the period of 1988-2016, drawn from Adrian et al. (2022).

To the best of the author's knowledge, this paper represents the first attempt at empirically estimating the spillover effects of US Monetary Policy shocks on international growth risks. Most prior work on the empirical intersections between macro policy and risks have focused on the risk-mitigation effects of macro-prudential policies in domestic contexts. Methodologically, the paper integrates two expanding strands of empirical frameworks in macroeconomics—high frequency monetary shocks and quantile-based macro-risks estimation—in conferring a causal interpretation to the estimates.

The core empirical result of the paper is that in the context of the countries studied, positive US policy shocks lower international downside growth, thereby amplifying tail risks in the short-to-medium term. This is evidenced by a negative estimated coefficient for 5th percentile conditional growth associated with positive US monetary policy surprises, for growth outcomes up to 9 quarters ahead. Strong asymmetry exists in the direction of policy surprises, with consistent effects manifesting in positive shocks but not negative shocks. Such an impact, moreover, is not witnessed for both median and 95th percentile of the conditional growth distribution. Estimated impact is generally robust to the exclusion of 2008 crisis period, as well as alternative downside and upside quantiles.

The estimated spillover of monetary policy shocks, in addition, displays heterogeneity at the country level. It is shown that effect on downside risks is centered on core advanced and open economies with a high degree of financial openness. Moreover, countries with tight initial financial conditions experience stronger spillover for near-term growth risks, but slightly less for the medium-term. There is also evidence that countries with relatively large Credit-to-GDP ratios experience stronger downside spillover, and those with higher ex-ante debt growth see sharper tail risks spillover following a surprise US contraction in the very near term.

The rich structure of tail risks spillover, and in particular, the asymmetric impact on conditional growth quantiles, raise questions on the mechanisms of risks transmission. In this paper, I argue that uneven spillover to downside and upside growth does not square with the view of US monetary shocks transmitting exclusively through generalized interest rates and risk premia, and can be best rationalized through a class of models where surprise US monetary contractions affect credit constraints in foreign economies. I illustrate the proposed mechanism in a stylized setup, and provide brief discussions on policy implications through the lens of the model.

Relation to Literature: The ideas in this paper connect to several pertinent strands of research in macro and international economics. A large empirical literature studies the international transmission of US monetary policy. Rey (2015) and Miranda-Agrippino and Rey (2020), for example, document the Global Financial Cycle and point to U.S. monetary policy as a crucial contributing factor. Jordà et al. (2019) argues that US monetary policy leads to fluctuations in risk appetite across global equity markets, thereby affecting asset prices. Bruno and Shin (2015) and Brauning and Ivashina (2020) explore the negative impact of U.S. monetary contractions on bank leverage, cross-border capital flows and lending activities. This paper injects a new dimension to the monetary spillover literature by examining the implications of such observed spillover effects on global downside growth risks, along with country-level distributions of transmission.

On that note, the paper also ties up with a broader literature investigating the nexus between financial conditions and macroeconomic outcomes and risks. Starting with the influential paper of Bernanke and Gertler (1989), a long tradition of work in modern macrofinance has investigated channels through which domestic and international financial conditions contribute to, and magnify macroeconomic risks. While earlier papers in this area have focused on the dynamic amplification effects of financial frictions (Kiyotaki and Moore, 1997; Bernanke, Gertler and Gilchrist, 1999; Mendoza and Smith, 2006), post-2008 research has been largely concentrated on endogenously generated financial risks, along with normative implications and optimal policies (Lorenzoni, 2008; Bianchi, 2011; Gennaioli, Shleifer and Vishny, 2015; Jeanne and Korinek, 2019). This paper fuses with the above strand of work by studying the implications of financial conditions changes to international macro tail risks, through the lens of US policy as a potential driver of such shifts. In constructing its premise, it pays attention to the divergent connotations of the two facets of financial risks on the impact of monetary policy shocks, and room for empirical work in evaluating spillover effects.

This paper, furthermore, contributes to the recent Growth-at-Risk (GaR) literature, which estimates conditional growth distributions with a focus on downside quantiles. Adrian, Boyarchenko and Giannone (2019) and Adrian et al. (2022) pioneered the framework of GaR, along with quantile regression as a flexible way of estimating the impact of economic variables on domestic and international tail outcomes. Applied work by researchers has utilized this framework in examining the effect of macroprudential policy shocks on domestic growth quantiles (Franta and Gambacorta, 2020).

However, study on the influence of monetary policy shocks on growth risks is largely absent, let alone monetary spillover beyond national contexts. This paper extends the application of the GaR framework by estimating the impact of US monetary spillover on downside risks to a range of economies. It also sheds light on the utility of the GaR framework, and more generally, an understanding of higher-moment features of macro variable distributions, in informing theoretical understandings of transmission mechanisms, which has been a largely vacant area in this literature. This is attained through relating estimated quantile features of conditional growth distributions to plausible spillover mechanisms, and observing that empirical results impose stark restrictions to theoretical propositions. It also proposes a stylized mechanism and a class of models that, in the author's view, best agree with the estimated results.

Lastly, this paper extends the application high-frequency methods for monetary policy shock identification in the face of endogeneity, implemented in works such as Bernanke and Kuttner (2005), Hanson and Stein (2015), Nakamura and Steinsson (2018), Ottonello and Winberry (2020), and Miranda-Agrippino and Rey (2020), among others. In particular, it draws upon orthogonalized monetary policy surprises, given recent observations over correlations between past high-frequency surprises and macro and financial variables. Bauer and Swanson (2022) shows that high-frequency policy shocks, upon orthogonalizing with respect to contemporaneous macro and financial variables, produce strong estimated effects of monetary policy transmission in the contexts of previous studies. This paper embeds orthogonalized high-frequency shocks in a novel quantile regression framework, and explores its effectiveness in uncovering international spillover of US monetary surprises beyond first moment effects.

Road Map: The rest of the paper proceeds as follows: Section 2 discusses the core identification challenge and introduces the high-frequency monetary shock proxy. Section 3 presents the data and empirical strategy of the paper. Section 4 highlights the results. In Section 5, I discuss implications and potential mechanisms of downside risks spillover of US monetary shocks. Section 6 concludes.

2 High-frequency Shock Identification

2.1 The Endogeneity Challenge

The long-standing challenge in estimating the effect of monetary policy on macro-variables—growth risks included—lies in policy endogeneity. The intuition is that as monetary policy systematically responds to conditions in the macroeconomy, observed changes in monetary policy can be correlated with changes in economic conditions. Therefore, effects of policy cannot be separated from changes caused by factors beyond policy actions.

Analytically, consider a simple formulation of such simultaneous interactions:

$$y_t = Ai_t + B'z_t + \epsilon_t \tag{$*$}$$

$$i_t = Cy_t + D'z_t + \eta_t \tag{$**$}$$

where y_t is GDP growth at time t, i_t is the policy rate at time t, z_t is a k-vector of exogenous, contemporaneous variables, and ϵ_t, η_t are zero-mean $i.i.d.$ innovations. $A, C \in \mathbb{R}, B, D \in \mathbb{R}^k$ contain parameters defining the unidirectional causal effect of variables. Substituting ($*$) in ($**$) yields:

$$i_t = \frac{CB' + D'}{1 - CA} z_t + \frac{C}{1 - CA} \epsilon_t + \frac{1}{1 - CA} \eta_t$$

So $Cov(i_t, \epsilon_t) \neq 0$ in ($*$) assuming C, $1 - CA \neq 0$. It is well-known that estimation of ($*$) by OLS gives an inconsistent estimate of A. Importantly, such an intuition applies to linear quantile regression to be employed in this paper, as detailed in Section 3. For a structural Data Generating Process:

$$y_t = F(i_t, z_t) + \epsilon_t$$

violation of $Cov(i_t, \epsilon_t) = 0$ generally gives rise to inconsistency of linear quantile regression estimators, thereby depriving model estimates of causal interpretations (Chernozhukov and Hansen, 2013, Chernozhukov, Hansen and Wüthrich, 2020).

The identification challenge, admittedly, carries over to assessment of risk spillover over the term structure. The term y_t above extends to that of a foreign nation $y_{j,t}$, which could be correlated with US growth and policy changes, given that global economic conditions are frequently interrelated. The growth term can also be generalized to that of τ-quantile growth k periods ahead for country j, $y_{j,t+k}(\tau)$. Endogeneity could remain given that US monetary policy-making is conceivably forward-looking and takes into account growth projection of the world economy over a range of scenarios. *The overall implication is that observed US policy rates cannot be directly employed in a quantile regression structure, for a causal assessment of spillover to international growth risks.*

2.2 Orthogonalized High-frequency Shocks

The application of high-frequency monetary policy shocks in the past two decades offers a promising answer to the challenge. Construction of high-frequency shock variables, in general, entails aggregating interest rate changes around the Federal Reserve's Federal Open Market Committee (FOMC) announcements over a short window, usually pegged at 30 minutes. The intuition is that asset price movements during the short window should primarily reveal information from the announcement. Further, to the extent that the market should have incorporated all public information of macroeconomic conditions, as well as the Fed's response function prior to the announcement, price movements during the window should only reflect monetary surprises, which are orthogonal to the systematic feedback rule and do not suffer from the simultaneous causality problem.

While high-frequency identification has been applied in a range of studies (e.g. Bernanke and Kuttner, 2005, Hanson and Stein, 2015, Nakamura and Steinsson, 2018, Miranda-Agrippino and Rey, 2020), recent research has questioned the exogeneity of high-frequency policy surprises with respect to economic conditions. Cieslak (2018), Miranda-Agrippino and Ricco (2021), and Bauer and Swanson (2021) all document substantial predictability of monetary policy shocks with macroeconomic or financial market information before FOMC announcements, with Bauer and Swanson (2021) reporting R^2 of 10–40%. The large correlations reported put into question the capacity of high-frequency shocks in overcoming the endogeneity issue, in line with discussions in the previous section.

Bauer and Swanson (2022) proposes an orthogonalizing treatment to monetary policy shocks to address the predicability concern. It is suggested that high-frequency monetary policy shocks be orthogonalized with respect to macroeconomic and financial data before the policy announcements, so as to remove the correlated elements. A US monetary shocks series from 1988Q1 to 2019Q4 is also constructed by taking the first principal component of changes in the first four quarterly Eurodollar futures contracts (ED1–ED4) around FOMC announcements, and orthogonalizing against US macro and financial data prior to the announcements.

The Bauer and Swanson (2022) orthogonalized series is adopted in this paper as a proxy for US monetary shocks. To match meeting-level shocks with macro data frequencies, I construct the quarterly US shocks series (MPS_t) by aggregating orthogonalized shocks for each quarter t, following approaches in Ottonello and Winberry (2020), Miranda-Agrippino and Rey (2020), and others.

Table 1: Summary Statistics of Bauer and Swanson (2022) Quarterly Shock

Mean	SD	Max	Min	$Corr(MPS_t, \Delta EFFR_t)$	$Corr(MPS_t, \Delta WXS_t)$
0	0.069	0.196	-0.239	0.148	0.220

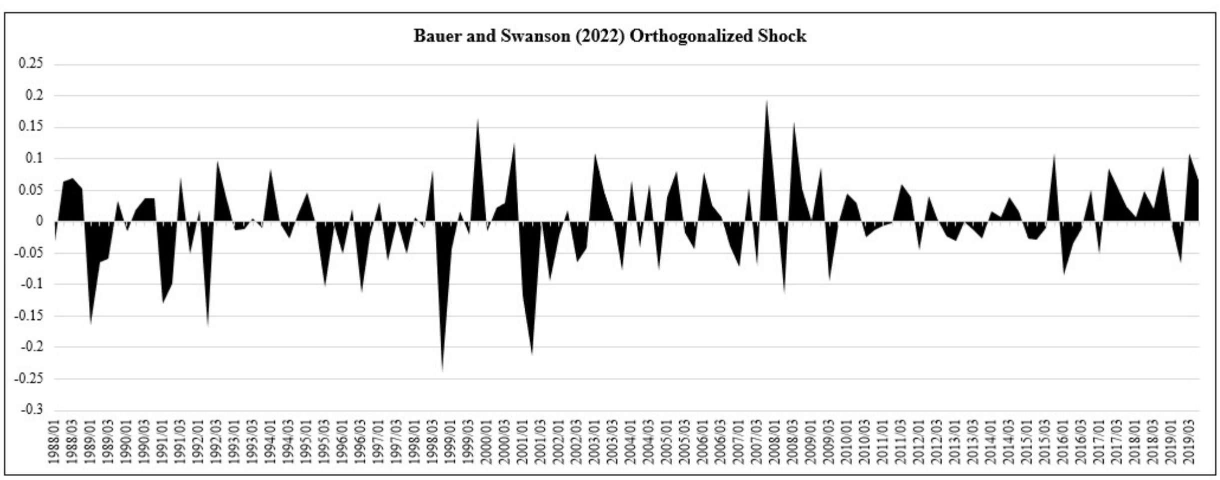


Figure 1: Bauer and Swanson (2022) Quarterly Shock Time Series

From the summary statistics and time series plot, quarterly MPS_t carries zero mean, and is roughly symmetric in upper and lower bounds. The series displays no clear temporal pattern over time. Correlations between the series and quarterly changes in Effective Federal Funds Rate (EFFR) and the Wu-Xia Shadow Rate (WXS) are both positive but moderate. The results are reasonable as one would expect that positive policy surprises, on average, drive up changes in actual rate, but might not always match the exact magnitude and sign of nominal rate changes, and vice versa.

3 Data and Empirical Strategy

3.1 Data

Analysis in this paper is based on the dataset of Adrian et al. (2022), which consists of quarterly panel data from 20 Advanced Economies (AEs) and Emerging Market Economies (EMEs) over the period of 1988-2016 on a set of macroeconomic and financial variables. I include data from the 10 EMEs which are not featured in Adrian et al. (2022)'s analysis, but nevertheless shared by the authors. The start period of the panel data is chosen to align with that of the policy shock series. Appendix A presents descriptive statistics, as well as exact periods of coverage of country variables.

Quarterly financial conditions of countries are summarized by the Financial Condition Index ($FCI_{j,t}$). The standardized index is constructed using factor methods and captures domestic and global price factors, such as short-term funding spreads, corporate bond risk spreads, equity prices and volatility, and banking sector expected default frequencies (EDFs). A tighter financial condition in quarter t in country j corresponds to a higher value of $FCI_{j,t}$ in that quarter.

A pertinent question immediately arises over the relationship between orthogonalized monetary shocks and international financial and macroeconomic conditions. In Appendix B.1, I run Jorda (2005)-style Linear Projection and show that a positive monetary shock dynamically generates tighter financial conditions in foreign economies over quarters ahead, which sheds light on potential channels of risk transmission. I also present evidence that quarterly shocks do not significantly correlate with financial conditions and key macroeconomic variables in the dataset, which further assuages endogeneity concerns. Appendix B.2 documents the results.

3.2 Empirical Methodology

The estimation of downside risks entails modelling the conditional GDP growth rate under adverse scenarios over some periods. In line with the Growh-at-Risk (GaR) literature, this is attained through estimating lower quantiles of the conditional growth distributions for countries in a quantile regression framework, for growth between two periods of specific lengths.

More precisely, define the τ-quantile k-quarter conditional growth for country j at time t as:

$$Q_\tau(y^j_{t,t+k}|X^j_t) := \inf\{y^j_{t,t+k} : F_{Y^j_{t,t+k}}(y^j_{t,t+k}|X^j_t) \geq \tau\} \tag{3.1}$$

where $y^j_{t,t+k}$ is the annualized average GDP growth rate for country j between quarters t and $t+k$, X^j_t is a vector of macro and financial variables of the country observed at time t, and $F_{Y^j_{t,t+k}}(y^j_{t,t+k}|X^j_t)$ is the Cumulative Distribution Function (CDF) for annualized k-quarter ahead growth for country j conditional on X^j_t.

For a small value of $\tau \in (0,1)$, $Q_\tau(y^j_{t,t+k}|X^j_t)$ can be interpreted as the realization of k-quarter ahead growth outcome under a particularly "bad" situation, such as when the economy is hit by an adverse shock. This is termed as "Growth-at-Risk" in prior literature. A fall in value of $Q_\tau(y^j_{t,t+k}|X^j_t)$ corresponds to an increase in τ-quantile downside risks k-quarters ahead, and heightened vulnerability of the economy at that horizon.

Similarly, one could also consider larger values of τ in this framework as portraying the possible future growth performance of a country under more regular, and upside scenarios. With a view of characterizing features of the entire conditional distribution, the main analysis present estimates for the $\tau = (0.05, 0.5, 0.95)$ tuple. However, I also test for alternative quantiles in a later section, and demonstrate that results are analogous for general downside and upside growth risks.

The main empirical specification for risks spillover estimation is Panel Quantile Regression with Fixed Effects à la Koenker (2004). The model estimates the conditional quantile functions:

$$Q_\tau(y^j_{t,t+k}|X^j_t) = \alpha_{j,k} + X^{j\prime}_t \beta_k(\tau) \qquad j = 1 \dots J,\ \ t = 1 \dots T \tag{3.2}$$

for an m-tuple of quantiles, via solving:

$$\min_{(\alpha_k, \beta_k)} \sum_m \sum_t \sum_j w_k \rho_{\tau_m}(y^j_{t,t+k} - \alpha_{j,k} - X^{j\prime}_t \beta_k(\tau_m))$$

where $\rho_\tau(u) = u(\tau \mathbb{1}(u < 0))$ is the piecewise linear quantile loss function. The weights w_m control the relative influence of quantiles estimated, and is set as equal for all quantiles throughout the analysis. For the main analysis, the covariate vector X^j_t is defined by:

$$X^j_t = \begin{bmatrix} 1 \\ MPS_t \\ FCI_{j,t-1} \\ Inflation_{j,t} \\ \Delta GDP_{j,t} \\ \Delta Credit/GDP_{j,t} \end{bmatrix} \tag{3.3}$$

where $Inflation_{j,t}, \Delta GDP_{j,t}, \Delta Credit/GDP_{j,t}$ are quarter-on-quarter inflation and GDP growth, and change in credit-to-GDP ratio for a country at time t[1].

The focus of the analysis is on the coefficient associated with MPS_t in $\beta_k(\tau)$, which measures the estimated effect of a unit of US monetary policy shock on τ-quantile conditional growth for international economies, in k quarters after the shock. For small τ (e.g. 0.05), this is interpreted as the estimated spillover effect of US shock on k-quarter ahead international downside risks.

[1] GDP change is in percentage. Credit-to-GDP growth is measured over the past eight quarters, for the reflection of extended debt buildup.

The coefficient terms above measure the *overall* impact of spillover on all countries. Country-level heterogeneity in spillover is, in turn, investigated by (a) performing main analysis on sub-samples, or (b) adding to (3.3) an interaction term $MPS_{j,t} \times Feature_{j,t}$, where $Feature_{j,t}$ is some characteristics of country j at t. The second approach is implemented for features that vary considerably over time (e.g. financial conditions and Credit-to-GDP growth), so that a time-dependent variable adds to the accuracy of the estimate of the interaction term coefficient, interpreted as the *additional* spillover effect of US monetary shocks. An extensive set of heterogeneity tests are performed in Section 4.2, after the presentation of main results in the following section.

4 Results

4.1 Overall Spillover Effects

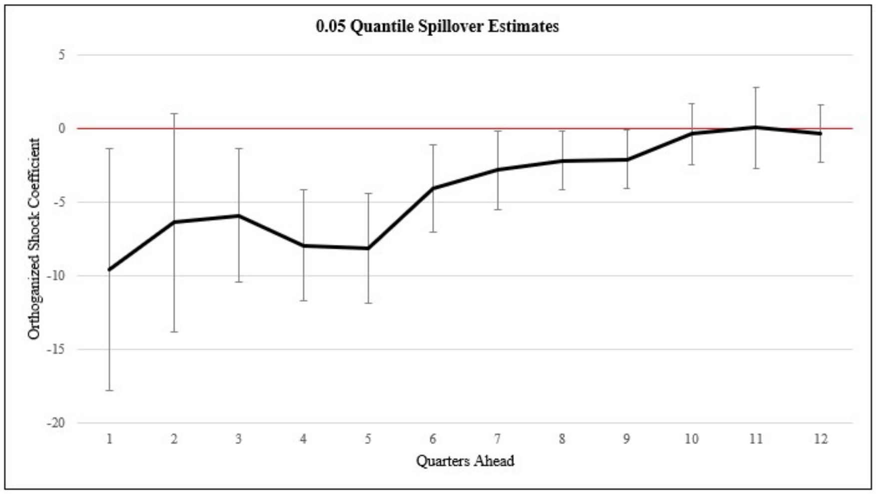
4.1.1 Main Effects

Table and Figure 2 present the estimated coefficients representing monetary shocks spillover for 0.05-quantile growth, for horizons up to 12 quarters ahead. Standard errors, p-values and 95% confidence intervals are constructed based on generalized bootstrap of Bose and Chatterjee (2003). *Estimated coefficients indicate that US monetary shocks spillover on downside tail risks is negative and* 95% *significant, for the bulk of* 9 *quarters after realization of shocks.*

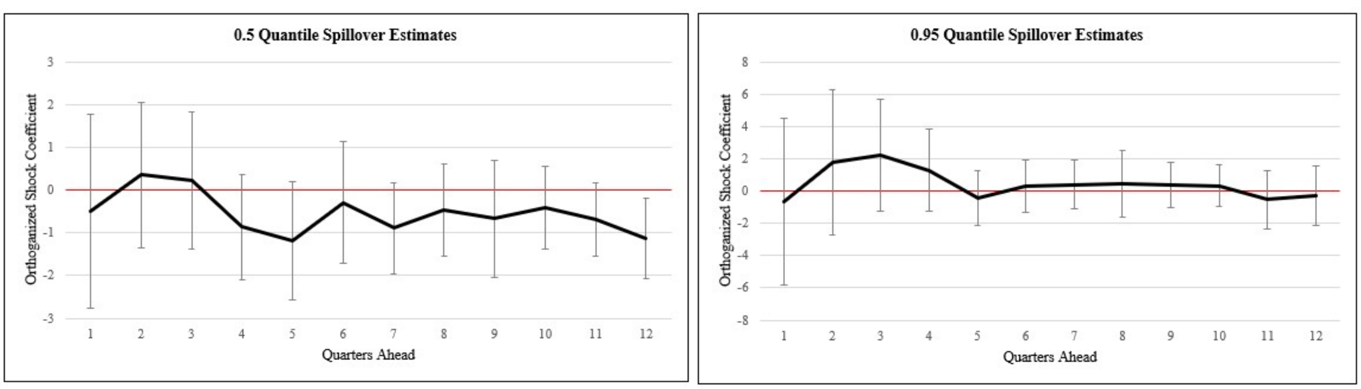
Table 2: Quantile Growth Spillover Estimate, $\tau = 0.05$

Quarters Ahead	Estimated Coefficient	p-value	Quarters Ahead	Estimated Coefficient	p-value
1	-9.61	0.022	7	-2.83	0.037
2	-6.41	0.090	8	-2.19	0.032
3	-5.92	0.011	9	-2.11	0.032
4	-7.95	3.6×10^{-5}	10	-0.37	0.721
5	-8.15	2.3×10^{-5}	11	0.05	0.973
6	-4.09	0.007	12	-0.34	0.737

Figure 2: $\tau = 0.05$ Quantile Growth Spillover with 95% Confidence Interval (CI)



The spillover effects for median and upside risks, on the other hand, display vastly different characteristics. As shown in Figures 3(a) and 3(b), *estimated coefficients for* $\tau = 0.5$ *and* $\tau = 0.95$ *are largely insignificant throughout 12 quarters, which sheds light on the distinct effects of monetary shocks spillover to different parts of the conditional growth distribution.* The concentration of spillover on downside growth outcomes over the term structure is a crucial conclusion of the paper, and will be revisited and extensively discussed in Section 5 afterwards.



(a) $\tau = 0.5$ (b) $\tau = 0.95$

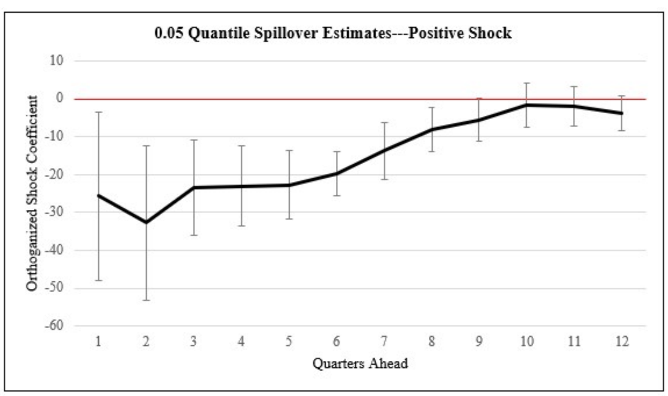
Figure 3: $\tau = 0.5$ and $\tau = 0.95$ Quantile Growth Spillover with 95% CI

4.1.2 Directional Asymmetry

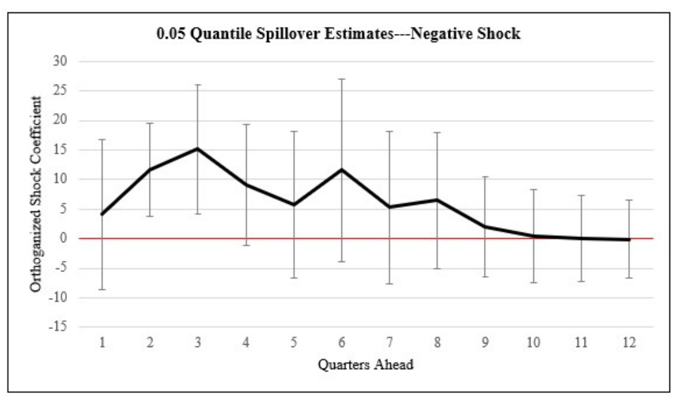
Do spillover effects on international downside risks differ by the direction of US Monetary Shocks? Separating positive and negative shocks in the main analysis, in turn, reveals strong directional asymmetry in the estimated effects of downside risks spillover.

As shown in Figure 4(a), estimated coefficients for positive shocks for $\tau = 0.05$ mirror those of the overall effects, and come with significantly larger magnitudes. A surprise monetary contraction generates a fall in 0.05-quantile conditional growth over the next 9 quarters, and in this way, amplifies international downside risks over the short-to-medium term.

The estimated effects of negative shocks, on the other hand, do not display strong consistency. A positive spike is seen for $k = 2, 3$ in Figure 4(b), but significance do not last beyond the two quarters, putting reasonable doubt on robustness (to be examined in the next section). *Overall, estimated spillover effects on international downside risks appear to be strongly driven by positive shocks, or surprise monetary contractions by US authorities.*



(a) Positive Shocks



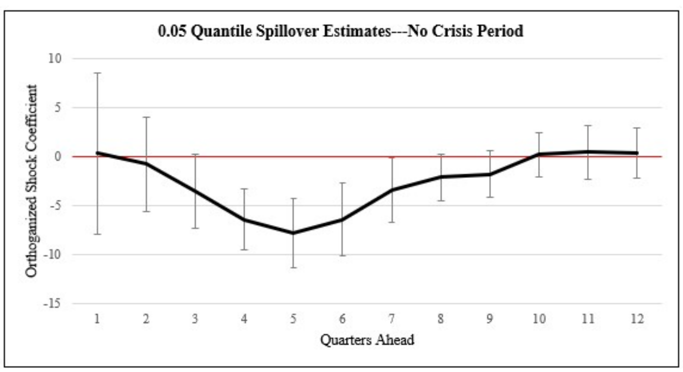
(b) Negative Shocks

Figure 4: $\tau = 0.05$ Quantile Growth Spillover with 95% CI, Positive and Negative Shocks

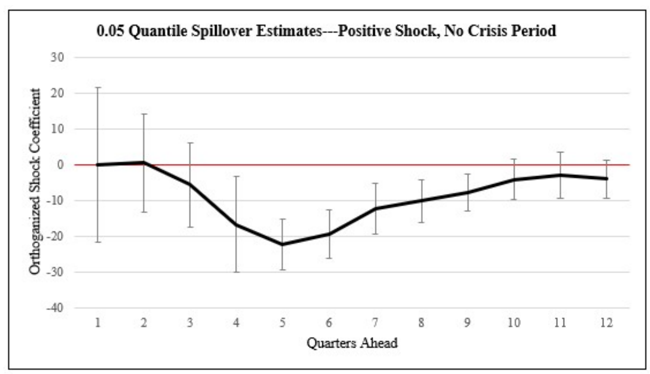
4.1.3 Sub-sample Robustness

It is entirely plausible that results of estimation might be influenced by periods of drastic economic downturn, which are characterized by abrupt gyration of real and financial variables, as well as large policy shocks. Robustness of main results is here tested by removing observations from 2008Q1-2009Q2.

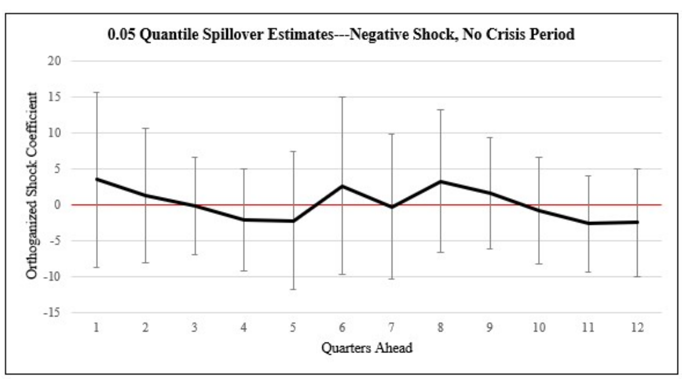
Figure 5 shows that the overall patterns of estimated coefficients and magnitudes for overall and positive shocks are similar to that in baseline analysis, with the exception of the very near term, which possibly reflects the removal of extreme events associated with the within-crisis shocks. Positive spillover coefficients in the near term for negative shocks, in addition, turn insignificant. Appendix B.5 shows that results for $\tau = 0.5$ and $\tau = 0.95$ are also in line with estimates in previous sections. The sub-sample results therefore do not significantly challenge those obtained in the baseline analysis, for both downside risks spillover and directional asymmetry.



(a) Main Effect



(b) Positive Shocks



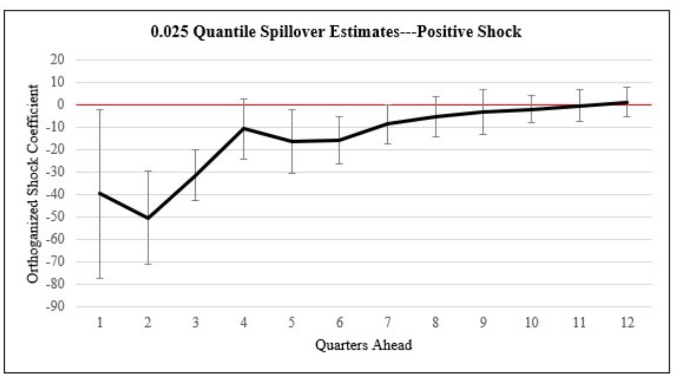
(c) Negative Shocks

Figure 5: $\tau = 0.05$ Quantile Growth Spillover with 95% CI, No Crisis Period

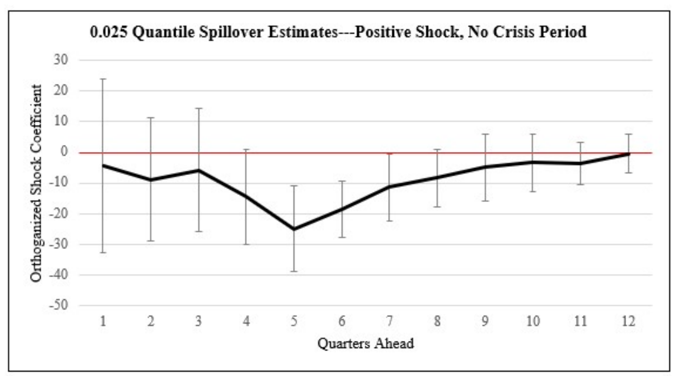
4.1.4 Alternative Quantiles

To further examine the integrity of prior results and features of conditional growth distributions after monetary shocks, the main analysis and sub-sample robustness checks are performed with alternative quantile tuples: $\tau \in (0.025, 0.5, 0.975)$ and $\tau \in (0.1, 0.5, 0.9)$.

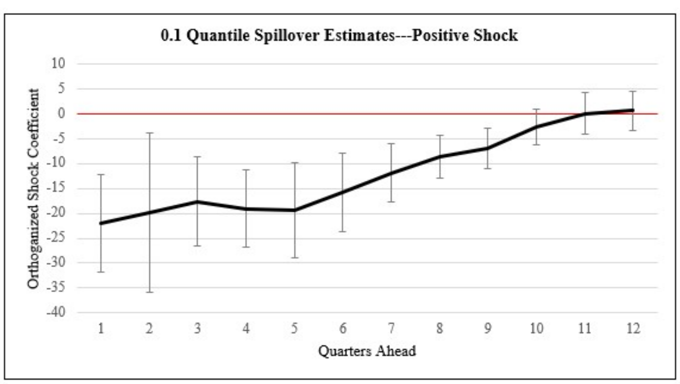
As shown in Figure 6, effects of positive shocks spillover for alternative downside quantiles ($\tau = 0.025$ and $\tau = 0.1$) are generally in line with those of the main analysis, for both full and sub-sample data. Appendix B.5 demonstrates that the estimated effects for upside quantiles ($\tau = 0.9, 0.975$) also agree with previous conclusions, and are generally insignificant over the term structure. *This further reinforces the main proposition that tail risks spillover is persistent, and mainly occurs through downside portions of conditional growth distributions.*



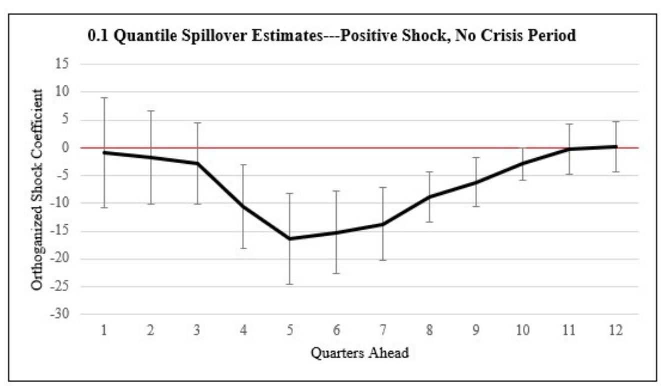
(a) $\tau = 0.025$



(b) $\tau = 0.025$, No Crisis Period



(c) $\tau = 0.1$



(d) $\tau = 0.1$, No Crisis Period

Figure 6: Alternative Quantiles Growth Spillover with 95% CI for Positive Shocks

4.2 Country-level Heterogeneity

The analysis above furnishes consistent estimates supporting lasting spillover effects of US monetary contraction shocks on international downside risks. It is however unclear whether such effects are driven by a particular set of countries, or whether spillover magnitudes are contingent upon certain characteristics of recipient economies. This section probes into spillover heterogeneity by considering differentiated spillover patterns on sub-groups of national economies. It also examines the interaction of downside risks spillover with particular country-level features—a) financial conditions prior to shock, and b) aggregate debt levels and ex-ante credit growth.

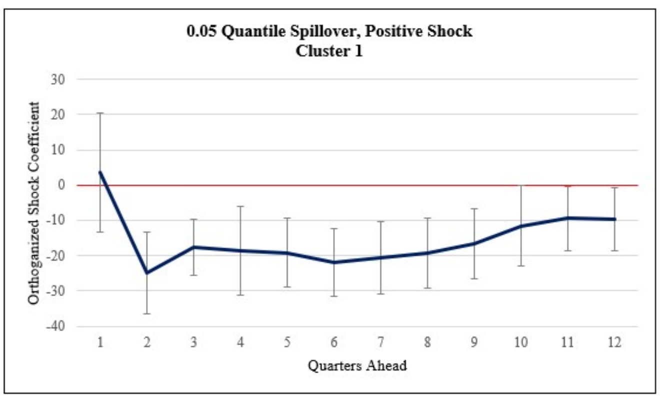
4.2.1 Cluster Analysis

A number of structural and institutional features could influence an economy's susceptibility to downside risks spillover of US monetary shocks. As a starting point for heterogeneity analysis, a first-pass grouping of countries is obtained through Hierarchical Clustering based on historical correlations of standardized Financial Condition Index (FCI). The motivation is that countries with parallel patterns of financial conditions might be susceptible to common risk factors, and could be similar in their economic structure and degrees of exposure to US monetary shocks. This approach, by design, aims to furnish a richer hierarchy of country sub-samples beyond binary AE/EME classification adopted in prior Growth-at-Risk literature. Algorithmically generated clusters are then adjusted with considerations over countries' external orientations and overall developmental status over the sample period[2]. Table 3 summarizes the country clusters and their interpretative labels adopted for analysis.

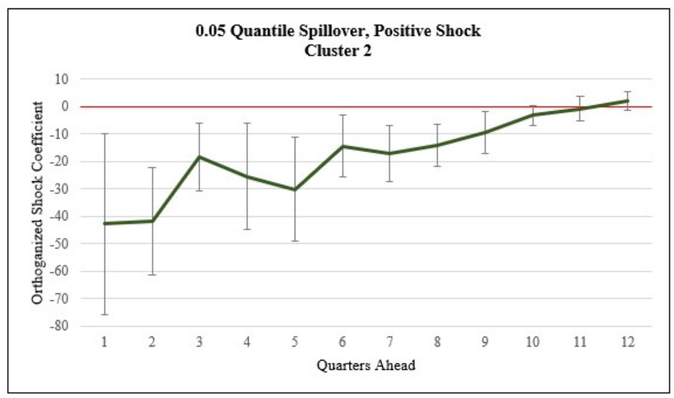
[2]Algorithm clustering results are presented in Appendix B.3. Clustering based on financial condition correlations categorizes the economies into 3 clusters. With a view of capturing broader structural difference across economies, I manually select traditional Small Open Economies (SOEs) with strong external orientations and separate them from other Advanced Economies into a single cluster. This is intuitive and turns out to be economically meaningful as shown in the estimated results. Another revision is over Japan's categorization, given its known AE status and structural differences from many economies under the core emerging markets cluster. The cluster structure of the rest of the countries is in line with algorithmic results.

Table 3: Country Clusters for Sub-sample Analysis

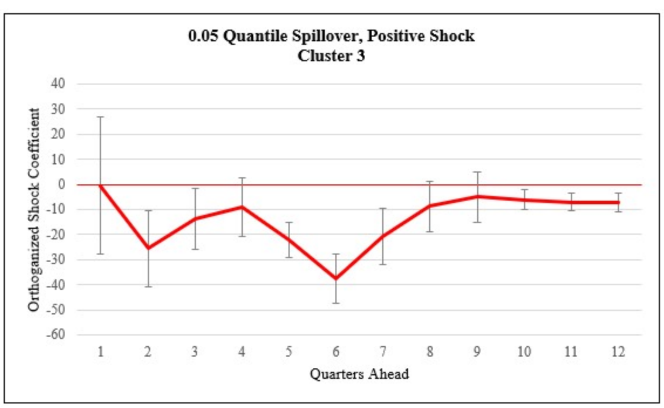
Cluster	Economies	Label
1	Australia, Britain, France, Germany, Japan	Core AEs
2	Canada, Sweden, Switzerland	Small Open Economies (SOEs)
3	Italy, Spain	Peripheral European Economies
4	Brazil, Chile, China, India, Indonesia, Korea, Mexico Russia, South Africa, Turkey	Core EMEs



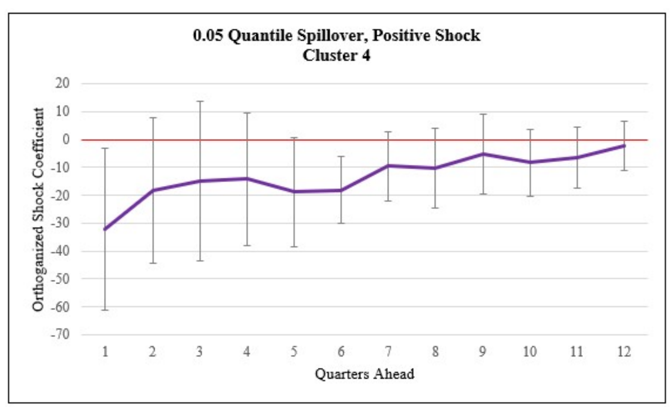
(a) Cluster 1 (Core AEs)



(b) Cluster 2 (Small Open Economies)



(c) Cluster 3 (Peripheral European Economies)



(d) Cluster 4 (Core EMEs)

Figure 7: $\tau = 0.05$ Quantile Growth Spillover with 95% CI by Country Clusters

Patterns of downside risks spillover to each of the country clusters in response to positive US shocks are displayed in Figure 7. Observe that estimated coefficients of $\tau = 0.05$ quantile growth spillover for Clusters 1 and 2 are generally significant over the term structure, while those of Clusters 3 and 4 display a more irregular pattern with weaker statistical significance. Notably, coefficients for the group of Small Open Economies are especially large in magnitude and respond swiftly at near-term horizons, reflecting strong sensitivities to US monetary policy shocks. *Overall, the above reflects that significant estimates of downside risks spillover are largely driven by the group of advanced, open economies, relative to peripheral European countries and emerging market economies.*

Why might core AEs and SOEs display distinct patterns of downside spillover estimates, and be more susceptible to US monetary shocks? One potential factor lies in the higher degree of financial openness of such economies. If US monetary policy shocks transmit risks by instigating changes in international financial conditions, one might reasonably expect countries with open financial systems and high capital account mobility to display greater sensitivities to such shocks. This is in turn, consistent with the higher estimated sensitivity of SOEs compared to relatively closed AEs. As a quick validation, Figure 8 plots the the mean Chinn and Ito (2008) Financial Openness Index from 1988-2016. It easily manifests that countries in Clusters 1 and 2 predominantly occupy the upper end of the index ranking, reflecting the fact that such countries tend to possess way more open and internationally connected financial systems over the sample period.

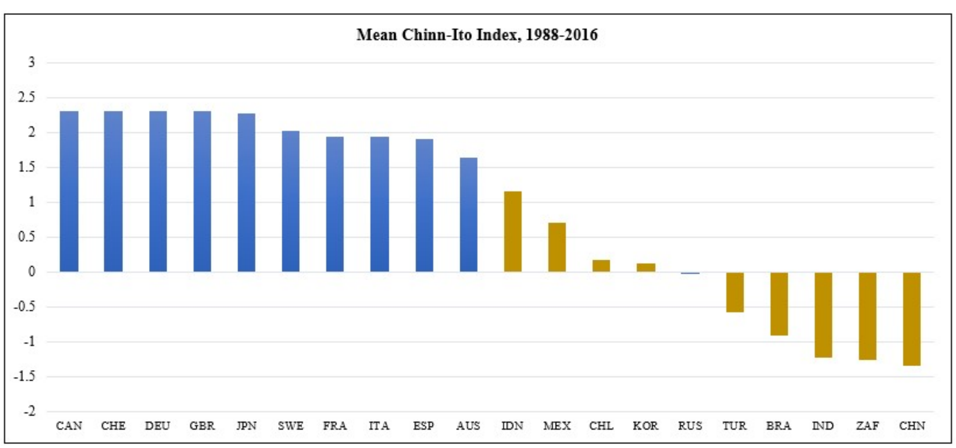


Figure 8: Mean Chinn-Ito (2008) Index of Sample Economies, 1988-2016

4.2.2 Initial Financial Conditions

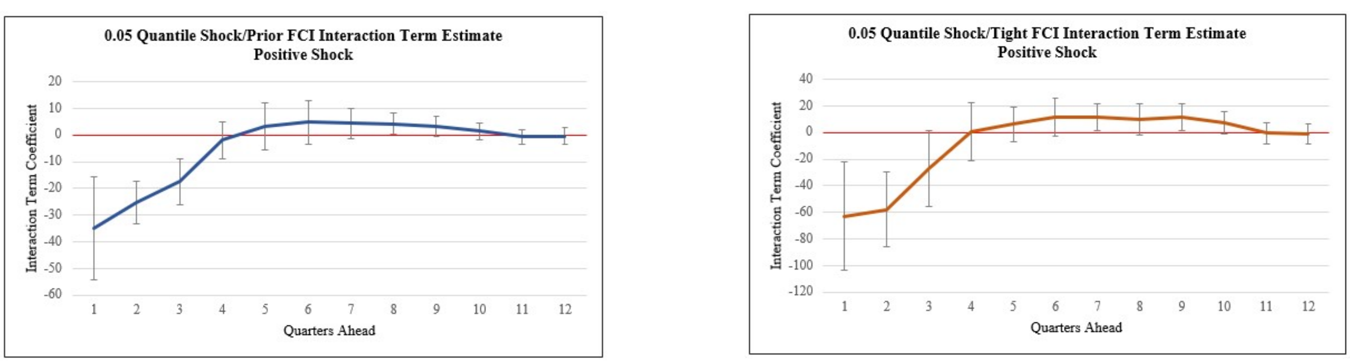
Beyond cluster-level features, country-specific factors could contribute to variations in spillover impact. One plausible attribute is the relative tightness of financial conditions prior to US tightening surprises. The connection between risk spillover and initial financial conditions is examined through an interaction term, $MPS_t \times FCI_{j,t-1}$, added to the covariate specification in (3.3).

The coefficient estimates for $\tau = 0.05$, as shown in Figure 9(a), display an intriguing pattern. *Estimated coefficients imply that additional positive shocks spillover for countries with tighter initial financial condition is stronger in the near term, but slightly lower in the medium term.* This is reminiscent of the term structure of financial conditions documented in Adrian et al. (2022), that tighter financial conditions lead to lower downside growth in the near term, but higher downside growth in quarters further ahead. The estimated coefficients here evoke an analogous term structure of spillover effects, with respect to ex-ante financial conditions.

To further examine the implications for countries with particularly tight financial conditions prior to shocks, I test the interaction estimate over the indicator variable, $TIGHT_{j,t-1}$, which takes on value 1 if $FCI_{j,t-1}$ is above 75-percentile of all FCI values. From Figure 9(b), the near term negative estimates for tight financial conditions is larger in value compared to (a). Appendix B.6 shows that while removal of extreme events revokes significance for near-term estimates in (a), robustness persists firmly for $TIGHT_{j,t-1}$, validating the strong interactive effects for tight financial conditions.

Figure 9: $\tau = 0.05$ Quantile Spillover Interaction Estimates for FCI Variables, Positive Shocks

(a) $MPS_t \times FCI_{j,t-1}$ (b) $MPS_t \times TIGHT_{j,t-1}$



4.2.3 Aggregate Debt and Credit Buildup

A strand of literature documents the likelihood of debt accumulation and overhang as adverse shock amplifiers (Occhino and Pescatori, 2015; Kose et al., 2021). In this subsection, I investigate the impact of aggregate debt levels and credit growth on the effects of downside risks spillover.

Aggregate Debt Levels

The level of aggregate debt for national economies is measured by total credit scaled by domestic GDP. Since Credit-to-GDP ratios do not tend to fluctuate strongly on a quarterly basis, an interaction term with monetary shock might not provide sufficient statistical power for uncovering the added spillover impacts. Influence of aggregate credit, in addition, can be predominantly absorbed by country fixed effects. Given this, relative indebtedness of national economies is evaluated by their credit-to-GDP positions relative to AE/EME country groups over the sample period.

Specifically, a country is identified as a high debt economy if its Credit-to-GDP ratios stayed above the quarterly median of its AE/EME group at least 75% of the time over the sample period. That is, for each quarter t, I first compute the median Credit-to-GDP ratios of all AEs and EMEs, $m_{j,t}$, for $j \in \{\text{AE, EME}\}$. Define $m_{i,j,t}$ as the median Credit-to-GDP ratios of the AE/EME group country i belongs to. Let $H^m_{i,t} = \mathbb{1}\{D_{i,t} > m_{i,j,t}\}$ be an indicator that takes on value 1 if and only if country i's Credit-to-GDP ratio in quarter t, $D_{i,t}$, is above its group median. A country is then designated as a high debt economy if $\bar{H}^m_{i,t} = \frac{\sum H^m_{i,t}}{T} \geq 0.75$. This classification scheme, by construction, accounts for time-series variations in world credit conditions, as well as structural differences between advanced and emerging economies in country-level debt capacity.

Estimated coefficients for groups of relative high debt and low debt economies are plotted in Figure 10 below. It emerges that estimated spillover coefficients for economies carrying relative high level of debt are way larger in magnitude and more significant for the bulk of quarters ahead, compared to countries with lower aggregate credit-to-GDP ratios within their country group over the sample period. In Appendix B.7, I provide evidence that this pattern holds within both of AE and

EME subgroups. The above highlights high aggregate debt as a potential source of vulnerability to downside risks from US monetary shocks, to the extent that *countries with relatively high amount of debt as a percentage of GDP tend to experience larger tail risks spillover following a positive US monetary surprise.*

Table 4: Classification of High and Low Debt Economies Relative to AE / EME Country Groups

High Debt Economies	**Low Debt Economies**
AEs: Canada, Sweden, Switzerland	AEs: Australia, Britain, France, Germany, Italy, Japan, Spain
EMEs: Chile, China, Korea, South Africa	EMEs: Brazil, India, Indonesia, Turkey, Russia, Mexico

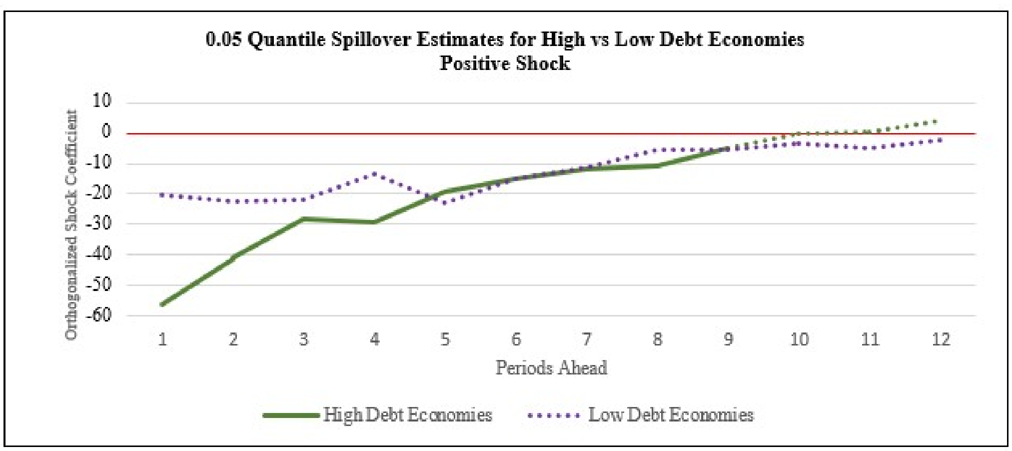


Figure 10: $\tau = 0.05$ Quantile Growth Spillover, Positive Shocks by High and Low Debt Economies (Solid line indicates significant estimates at 0.95 confidence level)

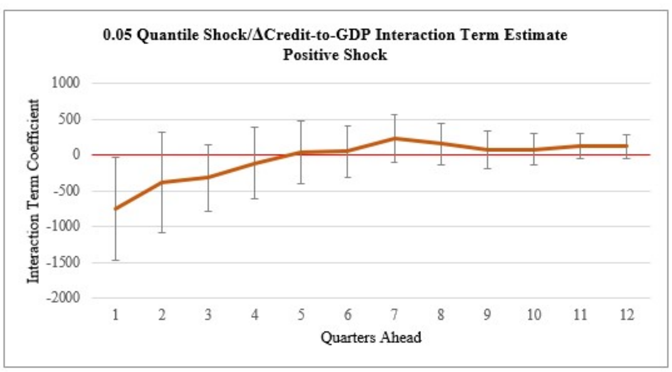
Near-Term Credit Buildup

Another dimension of domestic debt conditions lies in near-term credit buildup prior to shock. The possibility of interactive effects between credit growth and spillover from US monetary shocks is investigated through a different term, $MPS_t \times \Delta Credit/GDP_{j,t}$, added to (3.3).

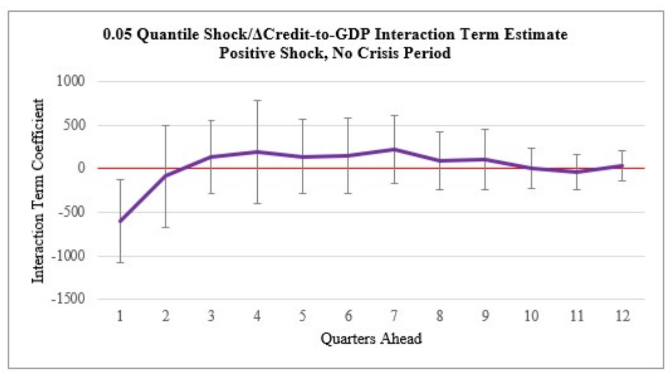
Figure 11(a) reports the results for positive shocks. The estimated coefficients associated with the interaction term for $\tau = 0.05$ display a negative trend in the first few quarters, and are 95% significant in the very near term, for $k = 1$. Remarkably, significance is robust to removal of crisis period data, and appears to be augmented when analysis is performed on HP-filtered Credit-to-GDP trend growth, shown in Figures 11(b)-(c). *There is hence, some evidence that higher debt buildup prior to the materialization of US contraction shocks could amplify spillover, at least in the very near term.*

Figure 11: $\tau = 0.05$ Quantile Spillover Interaction Estimates for $\Delta Credit/GDP_{j,t}$, Positive Shocks

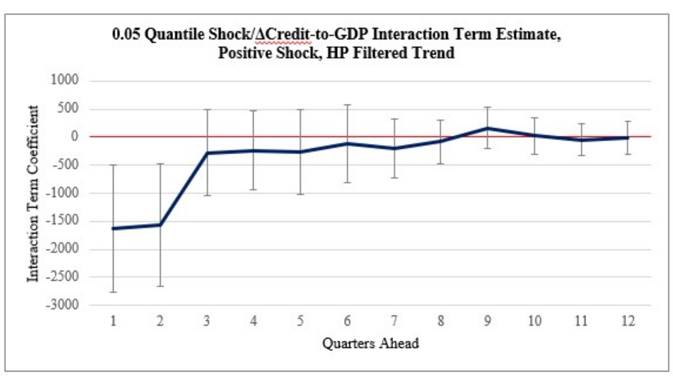
(a) Full Data



(b) Without Crisis Period



(c) Full Data, HP Filtered Credit-to-GDP ($\lambda = 1600$)



4.3 Stylized Conclusions

Summarizing the above, estimation of US monetary shock spillover to international growth risks leads to the following Stylized Conclusions (S.C.):

S.C.1: *In the context of countries studied, US monetary shocks exert significant effects on the lower end of conditional growth distributions of international economies, for a period up to 9 quarters after the shock.*

S.C.2: *Spillover of US monetary shocks is strongly driven by positive surprises, with persistent negative effects on downside quantiles. In this way, contractionary US surprises amplify international downside growth risks over a large part of the term structure.*

S.C.3: *Estimated effects of US monetary shocks are largely insignificant for median and upside growth outcomes. Hence, US monetary shocks influence conditional growth of international economies primarily through the lower end of growth distributions.*

S.C.4: *Country-level heterogeneity exists in tail risks spillover for contractionary shocks. Spillover effects are centered on core advanced and open economies with a high degree of financial openness.*

S.C.5: *Countries with tight financial conditions prior to contractionary shocks experience stronger spillover in the near term, but slightly weaker effects on downside risks in the medium term.*

S.C.6: *Countries with large Credit-to-GDP ratios relative to other advanced or emerging economies experience stronger downside spillover over the term structure. Moreover, evidence exists that higher aggregate debt growth prior to US contractionary shocks could amplify spillover effects in the very near term.*

5 Implications and Mechanism

5.1 Rethinking Expected Effects of Monetary Spillover

To put the set of stylized results into context, a range of past literature document international spillover effects of US monetary policy changes to real macroeconomic variables, primarily in VAR or local projection settings. Dedola, Rivolta and Stracca (2017), for example, finds that US monetary tightening surprises lead industrial production and real GDP to fall in foreign economies via a BVAR specification. Bräuning and Sheremirov (2019) employs panel local projection with high-frequency IVs, and reports large effects of US monetary contractions on real output.

The prior studies, however, differ fundamentally from this paper as past findings pertain to the *expected effects* of monetary spillover. That is, estimated results capture the *average* impact of spillover to conditional distributions of macro variables. This is embedded in the setup of apparatuses including VAR and local projection methods, which provide the "best" estimate of dynamic effects in a statistical sense, by setting the context in an "average" future world with zero ex-post shocks[3].

The stylized results in this paper inject a more nuanced perspective to monetary spillover. To the extent that contractionary US monetary shocks, by S.C.1 - S.C.3, primarily move the lower portion of future conditional growth distributions, spillover effects largely materialize under adverse growth scenarios. These correspond to cases when growth is relatively "bad", such as when the economy is hit by a negative shock. In other words, spillover makes bad future outcomes worse, but might not make "regular" outcomes bad. The results also imply that estimates of expected spillover effects could, in fact, be predominantly driven by tail-end movements of conditional growth distributions, rather than a parallel shift of all growth outcomes following US contractionary shocks.

[3]Both VAR and panel linear projection seek to estimate the Impulse Response Function with respect to a particular covariate element, $IR(t,k,d_i) = E(Y_{t,t+k}|\epsilon_t = d_i, X_t) - E(Y_{t,t+k}|\epsilon_t = 0, X_t)$ for $X_t \in \mathbb{R}^n$. In the VAR case, $d_i \in \mathbb{R}^n$ is a vector containing unit disturbance of that element. For linear projection, $d_i \in \mathbb{R}$ similarly records unit shock of the element at time t (Koop, Pesaran and Potter, 1996; Jordà, 2005). The implicit formulation of the expectation operator is that under the forecast scenario, $\epsilon_{t+1} \ldots \epsilon_{t+k} = 0$, or when future states are "average" after the unit shock.

To formalize the idea, consider a probability space $(\Omega, \mathcal{F}, \mathcal{P})$ such that the random variable for k-quarter ahead international growth, $Y_{t,t+k}$, is defined on the space. Since realization of growth depends on both past and future states, $\Omega = \mathcal{S}_P \times \mathcal{S}_A$, where $\mathcal{S}_P$ collects ex-post state sequences after t, and $\mathcal{S}_A$ collects ex-ante state sequences up to t. Further assume that $\mathcal{S}_P$, with realization s_p, can be partitioned into disjoint sets of finite 'regular' and 'bad' future state sequences. That is, $\mathcal{S}_P = \mathcal{R} \cup \mathcal{B}$, $\mathcal{R} = \cup_{i=1}^{m} s_p^i$, $\mathcal{B} = \cup_{i=m+1}^{n} s_p^i$, and $s_p^i \cap s_p^j = \emptyset$ for $i \neq j$.

Define the US monetary policy shock variable MPS_t at time t. The expectation formulation of US monetary spillover to international growth k quarters ahead, β_{t+k}^E, can be flexibly expressed as:

$$\beta_{t+k}^E = E[Y_{t,t+k}|MPS_t = i_t^*] - E[Y_{t,t+k}|MPS_t = i_t] \tag{5.1}$$

for a policy shock change from i_t to i_t^* at time t. The estimates on downside spillover imply:

$$Y_{t,t+k}(i_t^*, s_p \in \mathcal{R}) = Y_{t,t+k}(i_t, s_p \in \mathcal{R}) \tag{5.2}$$

for all i_t^*, i_t. Applying the law of total expectation to (5.1), and substituting (5.2) yields:

$$\beta_{t+k}^E = P\left(s_p \in \mathcal{B}\right) \times \left(E[Y_{t,t+k}|i_t^*, s_p \in \mathcal{B}] - E[Y_{t,t+k}|i_t, s_p \in \mathcal{B}]\right) \tag{5.3}$$

so the expectation-based estimand β_{t+k}^E captures *solely* the effect of spillover when the future state of the economy is bad, scaled by the probability of bad states occurring.

The addition of the qualification, $s_p \in \mathcal{B}$, to the conditional expectation of future growth carries strong implications. On the practical side, if contractionary US shocks only affect the economy under particularly adverse scenarios, international policymakers, when faced with a large tightening surprise, should be primarily concerned with the degree of resilience of the economy and availability of tools of intervention under egregious, but unlikely contexts. This is opposed to the case where US contractionary shocks affect the entire conditional growth distribution under virtually all scenarios, which might warrant impending interventions for macro-stability considerations.

Theoretically, the uneven upside and downside impacts of US policy shocks also raise important questions over risks spillover channels of policy surprises. Current expositions of financial mechanisms of US monetary spillover tend to focus on propagation through international interest rates or risk premia changes (Ammer et al., 2016). However, it is difficult for such changes alone to account for the distinct impact of US contractionary shocks on lower and upper ends of conditional growth distributions. It can be fashioned that in a standard formulation such as the canonical New Keynesian model, if US contractionary shocks transmit by raising inflation-adjusted interest rates of recipient countries, spillover effects should be evident in both good and bad states, regardless of whether the economy experiences positive or negative shocks in a particular period[4]. The large asymmetric impact of spillover to various parts of the conditional growth distribution, for all intent and purposes, cannot be exclusively delivered through interest rate adjustments in a conventional setup, and therefore, does not fully square with such a view [5].

One prospective alternative approach is to posit US tightening surprises as itself an exogenous negative shock ϵ_t for international economies. Suppose that US surprise contractions directly contribute to downside events for foreign countries on a larger scale and severity than without the shock, low quantiles of the conditional distribution would indeed fall as observed in the estimates. Given the contractionary nature of the shocks, upside quantiles would not be affected, which presumably accounts for the asymmetry.

[4]For a cursory illustration, consider the New Keynesian IS Curve: $x_t = E_t[x_{t+1}] - \sigma(i_t - r^f) + \epsilon_t$, where x_t is the output gap, i_t is the real interest rate, and r^f is the natural real rate. For simplicity, assume $E_t[x_{t+1}] = \rho_t x_t$ for $0 < \rho_t < 1$. Then $x_t = \frac{1}{1-\rho_t}(-\sigma(i_t - r^f) + \epsilon_t)$. Suppose a US monetary shock at time $t-k$ raises i_t from i_t^1 to i_t^2, it easily follows that $x_t(i_t^2) < x_t(i_t^1)$ regardless of the size of ϵ_t. That is, spillover-induced rate increase should lead to poorer outcomes in both upside and downside scenarios. This exposition easily generalize to the case where i_t captures a wide range of inflation-adjusted rates inclusive of risk premia.

[5]Note that estimates for median and upper quantiles spillover associated with positive shocks, as presented in Appendix B.3, are still largely negative for the first few quarters. It is plausible that these are attributable to induced domestic rate changes, and the lack of significance arises over statistical power issues. The results in this paper, therefore, do not fundamentally challenge the interest rate spillover argument. The focus, however, is on why spillover effects appear to be *primarily* driven by downside growth movements, and why downside quantiles display so *vastly different* behaviors and significance compared to median and upside parts of the conditional growth distributions upon receiving shocks. These are pertinent observations interest rate spillover alone cannot satisfactorily account for, and what the rest of this papers seeks to further explore.

This direct impact framework, however, is unsatisfactory for two major reasons. First, if a US surprise contraction amounts to a negative innovation at time t, the spillover effect is likely to be carried over to future periods due to shock persistence, even in the absence of $\epsilon_{t+1}, \epsilon_{t+2}$, and so on. Given this, spillover should be consistently reflected in median growth in the periods ahead, which is not the case in the empirical results. Furthermore, it is hard to believe that a large surprise US contraction alone would push international economies to the bottom 5 percentile of conditional growth or the like, in view of the very frequency of US shocks, as well as indirect correlations between real growth outcomes and financial market fluctuations potentially induced by such shocks.

The above implies that major drivers of extreme downside growth must be distinct from US monetary shocks. However, it is likely that US contractionary shocks interact and amplify such drivers, giving rise to higher likelihood of extreme recessions. As such, $P(s_p \in \mathcal{B})$ in (5.3) is a likely a function of US monetary shocks, but $P(s_p \in \mathcal{B}) \neq 1$ even with large contractionary shock realizations.

In the following section, I propose a financial constraint view of risks spillover through downside amplification, and argue that a class of models with occasionally-binding credit constraints—plausibly affected by US monetary surprises—provides a framework for rationalizing the empirical estimates.

5.2 Risks Spillover Mechanism—Hypothesis

It has been widely surfaced that severe recessions tend to be associated with drastic funding needs, with demand arising out of both cashflow disruptions and the desire to raise precautionary liquidity. This is consistent with experiences during past tail risks events, including the GFC and the recent pandemic crisis (Brunnermeier, 2009; Logan, 2021; Allen, Hortaçsu and Kastl, 2021). In such a context, insufficient aggregate credit and liquidity could tighten constraints to the financing of real activities, resulting in sharp amplification of business cycle fluctuations (Holmstrom and Tirole, 1997; Kiyotaki and Moore, 2019).

Under this premise, one might relate US contractionary shocks to international downside growth by considering the interactive effects of monetary shocks with recession-time money market dynamics. It is plausible that a surprise tightening proceeding tail risk events could further compress liquidity and credit supply when the shock hits, given ex-ante international financial tightening. As such, both stress in the international market and the real financing gap could be enlarged, feeding into amplification during downturn. This gives rise to the core hypothesis that US contractionary shocks transmit international downside risks through effects on financial constraints in foreign economies.

Hypothesis: *Amplification effects of US contractionary monetary shock on international downside risks arise through tightening of foreign financial constraints.*

The view on the interactions of financial limits with adverse macroeconomic outcomes builds on a long tradition of work starting with Kiyotaki and Moore (1997). On the modelling front, explicit financial limit has been incorporated into standard international macroeconomic models in works such as Mendoza (2010) and Akinci and Chahrour (2018). The key friction in such models is usually an occasionally-binding credit constraint that induces nonlinear contractionary effects under adverse scenarios. While the focus of these papers tend to be on liquidity sudden stops and induced recessions in the context of emerging economies, this class of models offer a natural setup for the rationalization of tail risks transmission of US monetary shocks. This paper argues that the credit constraint friction, with suitable assumptions over its relationship with adverse shocks and surprise US tightening, could satisfactorily account for the key empirical estimates over international downside risks spillover in this paper, as illustrated in the next section.

5.3 Illustrative Model

For the most direct presentation of intuition, I illustrate the mechanism using an analytically tractable two-period model. The setup is an international economy populated by a unit measure of consumer-entrepreneurs, with $t = 1, 2$. The representative household possesses log utility, and owns firms with production technology $F(A_t, K_t) = A_t K_t^\alpha$, $0 < \alpha < 1$, where A_t is the productivity parameter and K_t is the aggregate capital stock. Households hold fixed initial capital stock K_1, consume goods, and invest in future capital stock K_2. They also inherit a fixed liability of principal D_1 at the start of period 1. Liquidity intermediation is provided through a financial sector which enables saving or borrowing at a fixed real rate r, with a time-varying credit constraint. Aggregate shocks are delivered at $t = 1$ through a fall in A_t, with persistence absorbed within the period.

The optimization problem of the household is given by:

$$\max_{C_1, K_2} \; U = \log(C_1) + \beta E[\log(C_2)]$$

subject to the production technology:

$$Y_t = F(A_t, K_t) = A_t K_t^\alpha \qquad t = 1, 2 \tag{5.4}$$

and constraints:

$$C_1 + I_1 + (1 + r)D_1 = Y_1 + D_2 \tag{5.5}$$

$$C_2 + (1 + r)D_2 = Y_2 \tag{5.6}$$

$$K_2 = (1 - \delta)K_1 + I_1 \qquad 0 < \delta < 1 \tag{5.7}$$

$$D_2 \leq \kappa H(K_1, D_1, A_1) \qquad \kappa, H(\cdot), \nabla H(\cdot) > 0 \tag{5.8}$$

$$I_1, A_1, A_2, C_1, C_2 \geq 0 \tag{5.9}$$

The core friction lies in (5.8), which restricts the amount of borrowing available from the financial market in period 1 to a real constraint. This is in turn, determined by the amount of capital stock, outstanding debt, productivity, and a positive parameter κ that captures the stress of the market. First order partial derivatives of $H(\cdot)$, as collected in gradient $\nabla H(\cdot)$, are assumed to be positive over the domain. The setup reflects a range of borrowing limits over common frictions related to corporate collateral, macroeconomic and credit risks, and market liquidity conditions.

To relate US monetary policy to credit constraints, foreign market stress κ is seen as partially affected through ex-ante US contractionary shocks. It is also assumed that $\beta(1+r) = 1$, so that subjective and market rates of discount are set as equal as in standard literature.

Assumption 1: $\kappa = \Gamma(MPS_{1^-})$ *where* MPS_{1^-} *is US monetary shock delivered some time before period 1. In addition,* $\Gamma(\cdot) > 0$ *strictly decreases over* MPS_{1^-}*.*

Assumption 2: $\beta(1+r) = 1$.

The last crucial assumption emerges from the observation that in this model, a negative shock to A_t at $t = 1$ increases the optimal level of debt that matures in period 2, D_2^*, chosen by the representative household in period 1. The driving force comes from standard motives for income smoothing and capital accumulation in light of future productivity gains, coupled with a fall in current period resources given the shock.

Proposition 1: *Given two distinct realizations of* A_1, $0 < A_1' < A_1''$, $D_2^*(A_1') > D_2^*(A_1'')$, *where* D_2^* *is the optimal level of* D_2 *for households given preceding assumptions, ceteris paribus.*

Proof: Appendix C.1

Building on Proposition 1, predictions of the model rest on the assumption that in a particularly adverse scenario as characterized by a low-quantile realization of A_1, credit constraint binds in light of increasing demand for borrowing. This directly contributes to the predicted downside amplification effect of US contractionary shocks, as will be momentarily demonstrated.

Assumption 3: *Given the cumulative distribution function of* A_1, F_{A_1} *and exogenous* K_1, D_1, *and* MPS_{1^-}, *there exists* $\tilde{\tau} \in (0,1)$ *such that for all* $A_1 \leq \inf\{\tilde{A}_1 : F_{A_1}(\tilde{A}_1) \geq \tilde{\tau}\}$, *the period 1 credit constraint binds. That is,* $D_2^*(A_1) > \Gamma(MPS_{1^-})H(K_1, D_1, A_1)$ *for such realizations of* A_1*.*

Downside Risks Spillover

For the core prediction of the model, consider an increase in MPS_{1^-} from i to i', corresponding to a contractionary US monetary shock. By Assumption 3, there is some set of realizations of A_1, say A_1^{BIND}, under which the credit constraint will bind at i' given other exogenous parameters. We might picture ourselves in a scenario that at some time during period 1, the foreign economy experiences a large negative shock to A_1, from the steady-state value A_1^s to A_1', such that $A_1' \in A_1^{BIND}$.

The credit constraint in the foreign economy will bind by assumption. In the counterfactual scenario where the US contractionary shock didn't occur, the credit constraint may or may not bind in period 1. In either case, the solution to the optimization problem without the credit constraint (5.4) will be the same, given that the other exogenous parameters are fixed. However, the credit constraint tightens by Assumption 1. As such, the contractionary shock amounts to a widening of distance between the optimal debt D^* and the credit constraint. Intuitively, this compresses resources in period 1, resulting in falling investments and decreased output in period 2. Aggregate utility also declines as consumption smoothing and cross-period investments cannot effectively take place.

Proposition 2: *Given an increase in US contractionary shock from i to i', suppose that the realization of A_1, $A_1^{'}$, satisfies $A_1' \in A_1^{BIND}$ as defined above, then $Y_2^*(i') < Y_2^*(i)$. Also, $U^*(i') < U^*(i)$.*
Proof: Appendix C.2

Proposition 2 corresponds exactly to the type of downside risks spillover reported in the preceding sections. Observed growth, ΔY_2^*, in period 2 relative to the time of US monetary shock is negatively affected by the surprise tightening, with the materialization of bad states up till the point of observation. Proposition 2 also sheds light on the potential welfare consequences of positive shocks spillover under such adverse scenarios. Asymmetry is accounted for since the effect of US monetary surprise is evident only in the presence of a large negative productivity shock, such that the credit constraint binds with the contractionary surprise.

Country-level Heterogeneity

The illustrative model, with reasonable assumptions, can also flexibly accommodate the key results on country-level heterogeneity. If the degree of sensitivity to US contractionary shocks, as captured by the partial derivative of κ with respect to shocks, is contingent upon the state of financial openness and development, binding effect on credit constraints will be larger for countries with open and deeper financial markets under adverse scenarios. Therefore, downside risks spillover will be magnified for such countries via identical mechanisms.

Corollary 1: *Suppose the partial derivative $\frac{\delta\Gamma(\cdot)}{\delta MPS_{1^-}} < 0$ exists on its domain, and is strictly decreasing some country-specific latent feature F_j, capturing 1) financial openness and 2) financial market development, then given identical US monetary tightening shocks i', and other conditions satisfying Lemma 2, observed growth satisfies $Y_2^*(i', F_1) < Y_2^*(i', F_2)$, for Country 1 with more open and/or deeper financial market than Country 2, ceteris paribus.*

Some explanations can also be provided to heterogeneity results on financial conditions and debt buildup. If a country's initial financial condition is tighter, as modelled by a lower κ, downside risks spillover is indeed stronger as predicted by the model, via the same argument as Corollary 1. Meanwhile, if a country inherits a larger initial debt, as reflected through a higher D_1 in the model, borrowing needs would increase under adverse conditions. Period 1 borrowing gaps, in turn, would be broadened to a greater extent, resulting in lower capital accumulation and output growth observed. Such predictions might provide clues to the sharper near-term downside spillover of US monetary shocks associated with such features, as furnished in the stylized conclusions.

Corollary 2: *Given US monetary tightening shocks i', and other analogous conditions satisfying Lemma 2, $Y_2^*(i', \kappa_1) < Y_2^*(i', \kappa_2)$ for $\kappa_1 < \kappa_2$.*

Corollary 3: *Given the same conditions as in Corollary 2, $Y_2^*(i', D_1^1) < Y_2^*(i', D_1^2)$ for $D_1^1 > D_1^2$.*

5.4 Policy Implications

Under the financial constraint view of downside risks spillover, one naturally wonders what the implications are for macroeconomic policies, for countries at the receiving end of US contractionary shocks. A central implication of Corollary 2, supported by empirical results, is that domestic financial stress tend to amplify downside spillover of US monetary shocks. Meanwhile, by Corollary 3, high domestic debt level could be another aggravating factor. If these are indeed the case, *conditional* on an unfortunate "double coincidence" of large contractionary shock from the US, along with projected realization of certain downside risks, natural policy responses of susceptible countries would be to foster an accomodative financial condition and restrict excessive liability growth. A combination of monetary and macroprudential tools is likely needed to enhance resilience under such scenarios, given potential feedback effects of financial easing to liability buildup.

A core caveat of the above proposition is that these are not equivalent to the *unconditional* optimal response of foreign economies to US contractionary shocks. The lens of focus of the analysis above, by construction, is centered on adverse, but arguably unlikely downside scenarios for domestic economies. Policy actions called for in such situations might differ from the best response when the domestic economy is projected to be in an extra good state, or more commonly, when the information set on future states is ultimately restricted. Deciding on the unconditional optimal response inevitably brings up the question of how should each alternative states be weighed, and whether tail risks events should be given attention apart from those implied by the statistical mean. Conventional macroeconomics models, along with prescriptions such as the Taylor Rule do not offer a nuanced answer to such questions. Suarez (2022), as one of the early papers in this respect, proposes a social welfare criterion that rewards expected GDP growth and penalizes the gap between expected GDP growth and Growth-at-Risk, taking inspiration from mean-variance analysis in portfolio theory. A unified approach to this type of question, however, has not been featured in macroeconomic literature, and might warrant further explorations and discussions.

6 Conclusion

This paper furnishes a set of fresh conclusions on the effects of US monetary shocks on international downside growth risks. It is empirically shown that contractionary US monetary shocks augment downside risks by lowering international growth projections under tail risks scenarios. Heterogeneity exists in the magnitude of spillover effects at the country level, related to features such as financial openness, ex-ante financial conditions, aggregate debt levels and near-term credit growth. In addition, impact of shocks works through the downside portion of international conditional growth distributions, and is largely insignificant for median and upside growth projections. This intriguing asymmetry, as the paper argues, reveals higher-dimensional features of expected spillover effects, and does not conform to the view of spillover occurring solely through linear changes in generalized interest rates. A plausible explanation lies in the tightening of foreign financial and credit constraints following US contractionary shocks, which generates amplification effects amidst future downturns.

Some important questions remain with the observations. An implied scheme of discussion, as expounded, lies in an understanding of optimal policy regimes associated with such tail events, which calls for consideration of welfare criteria incorporating the scale and likelihood of downside growth. A separate question concerns the asymmetry in the direction of monetary policy shocks, as effects of negative shocks are surprisingly muted in this paper's estimates. Do easing surprises lead to different dynamics compared to contractionary shocks? Can the effects of monetary easing, which presumably associate with international credit buildup, materialize only after prolonged policy changes, which a quarterly shock measure cannot reliably identify? These are arguably timely issues as the global economy is placed in a volatile environment characterized by high likelihood of large US monetary shocks, as well as future downside events. Understanding the interconnections of such factors is, no doubt, critical to building country-level resilience and facilitating effective international policy coordinations.

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Appendices

A Descriptive Statistics

Variable	Periods (T)	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
			Country: AUS				
ΔGDP	116	3.02	2.411	-5.424	1.826	4.37	11.85
$Inflation$	116	2.944	1.868	-0.288	1.645	3.457	8.375
FCI	115	0	1	-2.01	-0.445	0.391	4.456
$\Delta Credit/GDP$	116	0.009	0.016	-0.031	-0.002	0.021	0.045
			Country: BRA				
ΔGDP	104	1.397	10.947	-94.746	-0.285	5.843	17.338
$Inflation$	108	58.58	110.071	1.807	5.425	14.789	424.85
FCI	103	0	1	-2.601	-0.469	0.627	3.409
$\Delta Credit/GDP$	80	0.002	0.016	-0.045	-0.007	0.012	0.056
			Country: CAN				
ΔGDP	116	2.215	2.588	-9.245	0.718	3.822	7.185
$Inflation$	116	2.168	1.318	-0.868	1.351	2.629	6.236
FCI	115	0	1	-2.569	-0.502	0.503	4.372
$\Delta Credit/GDP$	116	0.008	0.018	-0.033	-0.001	0.02	0.058
			Country: CHE				
ΔGDP	116	1.701	2.371	-6.463	0.226	3.434	8.383
$Inflation$	116	1.234	1.676	-1.384	0.099	1.781	6.065
FCI	115	0	1	-1.768	-0.729	0.65	3.513
$\Delta Credit/GDP$	116	0.004	0.018	-0.054	-0.006	0.014	0.046
			Country: CHL				
ΔGDP	104	4.72	4.581	-12.505	2.107	7.009	17.415
$Inflation$	116	6.749	5.798	-0.605	2.893	8.536	25.349
FCI	103	0	1	-2.416	-0.461	0.637	3.96
$\Delta Credit/GDP$	116	0.007	0.026	-0.054	-0.011	0.023	0.096
			Country: CHN				
ΔGDP	103	9.444	3.106	0.406	7.391	11.135	18.844
$Inflation$	116	4.94	6.349	-1.889	1.216	5.992	24.374
FCI	103	0	1	-2.168	-0.505	0.719	3.528
$\Delta Credit/GDP$	116	0.011	0.031	-0.099	-0.009	0.03	0.131

Variable	Periods (T)	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
			Country: DEU				
ΔGDP	116	1.775	3.658	-18.345	-0.08	3.48	12.698
$Inflation$	116	1.784	1.05	-0.235	1.122	2.25	4.598
FCI	115	0	1	-2.666	-0.629	0.605	3.186
$\Delta Credit/GDP$	116	0	0.011	-0.039	-0.005	0.007	0.028
			Country: ESP				
ΔGDP	107	2.009	3.254	-8.383	0.791	3.891	16.121
$Inflation$	108	2.898	2.219	-3.91	1.937	4.303	6.755
FCI	107	0	1	-2.602	-0.417	0.534	2.676
$\Delta Credit/GDP$	107	0.009	0.025	-0.063	-0.005	0.023	0.07
			Country: FRA				
ΔGDP	116	1.716	2.081	-6.866	0.491	2.965	7.81
$Inflation$	116	1.69	0.945	-0.424	1.129	2.155	3.559
FCI	115	0	1	-1.449	-0.593	0.377	3.462
$\Delta Credit/GDP$	116	0.007	0.01	-0.014	0	0.014	0.028
			Country: GBR				
ΔGDP	116	2.015	2.408	-9.151	1.064	3.274	7.218
$Inflation$	116	3.271	1.961	-1.388	2.264	3.947	9.926
FCI	115	0	1	-1.973	-0.639	0.371	4.531
$\Delta Credit/GDP$	116	0.007	0.021	-0.04	-0.005	0.02	0.065
			Country: IDN				
ΔGDP	104	4.771	6.485	-31.565	4.089	6.656	19.432
$Inflation$	116	8.955	8.711	-0.574	5.682	9.017	57.88
FCI	103	0	1	-2.065	-0.752	0.557	3.475
$\Delta Credit/GDP$	116	0	0.06	-0.372	-0.005	0.012	0.308
			Country: IND				
ΔGDP	83	6.625	5.342	-5.876	3.128	9.858	20.315
$Inflation$	116	7.315	3.196	0.46	4.602	9.405	16.433
FCI	103	0	1	-2.175	-0.467	0.387	4.075
$\Delta Credit/GDP$	116	0.003	0.011	-0.024	-0.004	0.008	0.039
			Country: ITA				
ΔGDP	116	0.859	2.785	-11.775	-0.332	2.473	6.509
$Inflation$	116	2.838	1.797	-0.42	1.758	4.275	6.491
FCI	115	0	1	-1.474	-0.79	0.886	2.555
$\Delta Credit/GDP$	116	0.005	0.02	-0.055	-0.007	0.014	0.1

Variable	Periods (T)	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
			Country: JPN				
ΔGDP	116	1.389	4.31	-19.844	-0.832	3.961	12.091
$Inflation$	116	0.518	1.279	-2.238	-0.31	1.164	3.656
FCI	115	0	1	-2.844	-0.39	0.524	3.46
$\Delta Credit/GDP$	116	-0.002	0.021	-0.047	-0.016	0.01	0.066
			Country: KOR				
ΔGDP	104	4.82	5.403	-29.124	2.489	7.402	17.673
$Inflation$	116	3.858	2.242	0.562	2.259	5.044	10.418
FCI	103	0	1	-2.028	-0.613	0.732	3.833
$\Delta Credit/GDP$	116	0.008	0.024	-0.087	-0.005	0.021	0.072
			Country: MEX				
ΔGDP	104	2.556	4.764	-22.136	1.092	5.24	10.878
$Inflation$	116	12.273	15.642	2.249	3.898	15.917	102.045
FCI	103	0	1	-2.072	-0.651	0.615	3.49
$\Delta Credit/GDP$	116	0.001	0.015	-0.086	-0.004	0.01	0.04
			Country: RUS				
ΔGDP	103	-0.189	16.724	-90.078	-1.666	7.615	36.885
$Inflation$	96	33.977	54.114	3.766	8.393	20.083	235.414
FCI	103	0	1	-1.892	-0.516	0.5	3.721
$\Delta Credit/GDP$	83	0.006	0.022	-0.041	-0.006	0.015	0.095
			Country: SWE				
ΔGDP	116	2.053	3.948	-15.138	0.75	4.405	9.37
$Inflation$	116	2.204	2.63	-1.427	0.458	2.776	10.616
FCI	115	0	1	-1.79	-0.923	0.858	2.557
$\Delta Credit/GDP$	116	0.01	0.03	-0.072	-0.012	0.027	0.105
			Country: TUR				
ΔGDP	104	4.214	10.778	-42.743	0.109	11.078	21.871
$Inflation$	116	32.001	23.442	4.253	8.762	52.338	80.513
FCI	103	0	1	-2.18	-0.603	0.543	3.606
$\Delta Credit/GDP$	116	0.005	0.016	-0.038	-0.004	0.012	0.051
			Country: ZAF				
ΔGDP	104	2.439	2.684	-6.271	0.904	4.367	7.423
$Inflation$	116	7.43	3.526	0.436	5.065	9.594	14.935
FCI	103	0	1	-2.112	-0.625	0.599	3.679
$\Delta Credit/GDP$	116	0.002	0.012	-0.032	-0.006	0.01	0.035

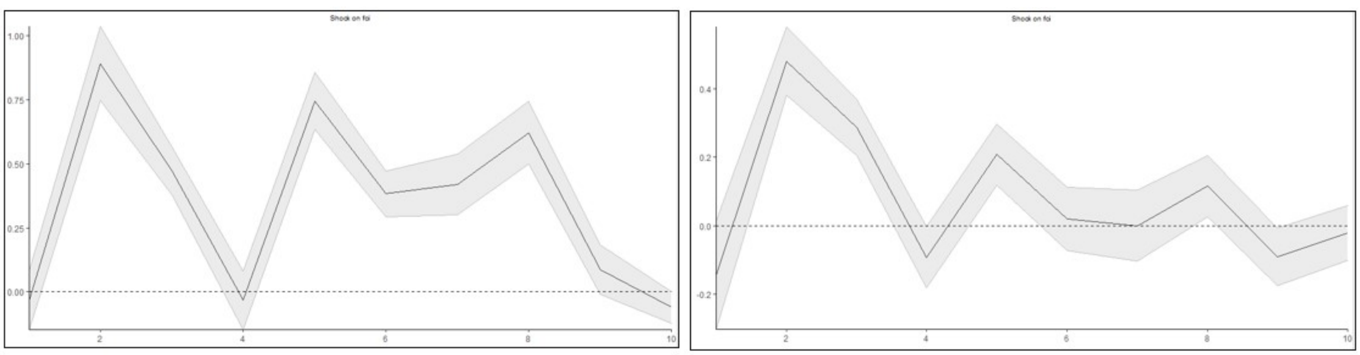
B Additional Empirical Results

B.1 Dynamic Effect of Policy Shocks on FCI

I estimate Jorda(2005)-style panel local projection of the following specification:

$$FCI_{j,t+h} - FCI_{j,t-1} = \alpha_{j,h} + \beta_h MPS_t + \Gamma_h X_t^{j\prime} + \epsilon_{j,h} \qquad h = 0, 1, ..., H \tag{B.1.1}$$

where X_t^j is as in (3.3). Figure 13 presents estimated coefficients β_h over quarters h, interpreted as the dynamic effect of orthogonalized monetary policy shock on international financial conditions over quarters. Shaded areas in the figures report heteroskedastic-robust 95% error bands. Estimations are performed for both the full dataset and the sub-sample after removing crisis-period data.



(a) Full Data (b) No Crisis Period

Figure 12: Dynamic Effect of Orthogonalized Policy Shock on FCI

Results indicate that an increase in US orthogonalized shock leads to increase in international FCI over quarters ahead. Sub-sample estimates are more muted, potentially reflecting removal of periods where global financial conditions are extremely tight following the crisis. However, it is clear that both sub-figures confirm that surprise US monetary contractions contribute to dynamic tightening in international financial conditions. This conforms to broad expectations, and provides clues to potential risks transmission mechanisms of monetary spillover.

B.2 Relationship between Orthogonalized Shocks and Variables

To test the correlations between orthogonalized US monetary shocks and individual co-variates, I estimate robust OLS regressions:

$$x^n_{j,t} = \alpha + \beta MPS_t + \epsilon_{j,t} \tag{B.2.1}$$

where $x^n_{j,t}$ for country j at time t is some macroeconomic variable included in (3.3) at time t, normalized by country j's observations. Separate regressions are run for each variable to avert co-linearity issues due to contemporaneous associations of macroeconomic variables. Results reported in Table 5 show that estimated coefficients for all covariate are insignificant at $\alpha = 0.05$, which provides evidence that orthogonalized US shocks are not strongly associated with country-level covariates.

Table 5: Robust Regressions of Normalized Variables Against Orthogonalized Monetary Shock

	Dependent variable:			
	FCI_{t-1}	$Inflation_t$	ΔGDP_t	$\Delta Credit/GDP_t$
	(1)	(2)	(3)	(4)
Orthogonalized Shock	−0.3	−0.6·	0.04	0.3
	(0.3)	(0.3)	(0.3)	(0.3)
Note:				·p<0.1, *p<0.05; **p<0.01,***p<0.001

Overall predictability of shocks by covariates is examined through the OLS regression:

$$MPS_t = \phi + \gamma' X^n_{j,t} + \eta_{j,t} \tag{B.2.2}$$

where $X^n_{j,t}$ collects all country-normalized explanatory variables in (3.3) at time t. Since co-llinearity issue is present, the focus is on R^2 and F-statistic, which conveys how international co-variates as a whole predict US shocks. Table 6 shows that R^2 of the regression is small and the F-statistic is insignificant, hence offering further evidence against endogeneity concerns.

Table 6: Output Features for Regression B.2.2

R^2	Adjusted R^2	F-statistic	p-value
0.0022	0.0003	1.18 (4, 2104)	0.3176

B.3 Algorithmic Clustering Output

For preliminary categorization of country subgroups, I implement Hierarchical Cluster Analysis based on standardized FCI as described in Section 4.2.1. The Ward Method is adopted to agglomeratively combine countries into clusters based on a cluster distance function defined by the Minimum Increase of Sum of Squares (MISSQ):

$$\Delta(A,B) = \sum_{i \in A \bigcup B} ||\overrightarrow{x_i} - \overrightarrow{m}_{A\bigcup B}||^2 - \sum_{i \in A} ||\overrightarrow{x_i} - \overrightarrow{m}_A||^2 - \sum_{i \in B} ||\overrightarrow{x_i} - \overrightarrow{m}_B||^2 = \frac{n_A n_B}{n_A + n_B} ||\overrightarrow{m}_A - \overrightarrow{m}_B||^2$$

where $\overrightarrow{m}_j$ is the center of cluster j, and n_j is the number of points (economies) within the cluster. The algorithm aims to minimize the total within-cluster variance of quarterly observations. Starting from singleton clusters of each individual economy, at each step the pair of clusters with minimum between-cluster distance are merged.

Implementation of the Ward Method leads to a natural categorization of 3 country clusters based on patterns of FCI correlations. Cluster dendrogram, cluster features of standardized FCI, as well as time-series variations of mean standardized FCI for each cluster are reported below.

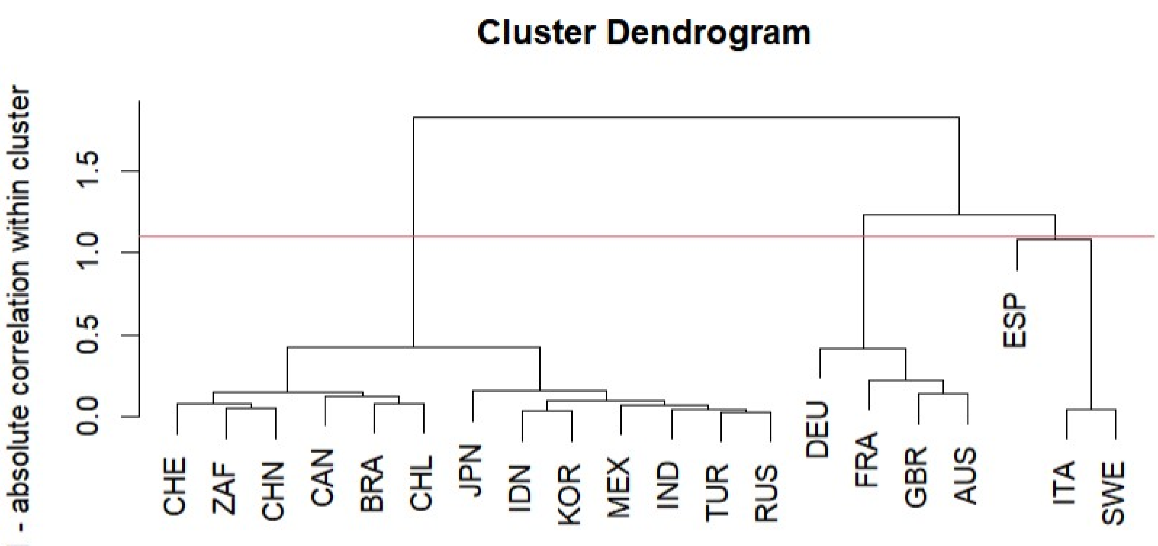


Figure 13: Dendrogram of Standardized FCI by Ward Method

Table 7: Algorithmic Clustering Output and Cluster Features of Standardized FCI

	Cluster	Avg. Within Cluster Corr.	Avg. Corr. with Closest Cluster	Closest Cluster
GBR	1	0.82	0.62	3
FRA	1	0.76	0.63	3
DEU	1	0.73	0.65	3
AUS	1	0.66	0.51	3
ITA	2	0.60	0.56	3
SWE	2	0.54	0.65	3
ESP	2	0.18	0.13	1
CHE	3	0.92	0.57	1
CAN	3	0.92	0.55	1
JPN	3	0.92	0.64	1
TUR	3	0.92	0.53	1
ZAF	3	0.92	0.65	1
BRA	3	0.90	0.70	1
CHL	3	0.90	0.62	1
MEX	3	0.89	0.47	1
IND	3	0.87	0.49	1
IDN	3	0.87	0.71	1
KOR	3	0.86	0.69	1
RUS	3	0.85	0.69	1
CHN	3	0.84	0.52	1

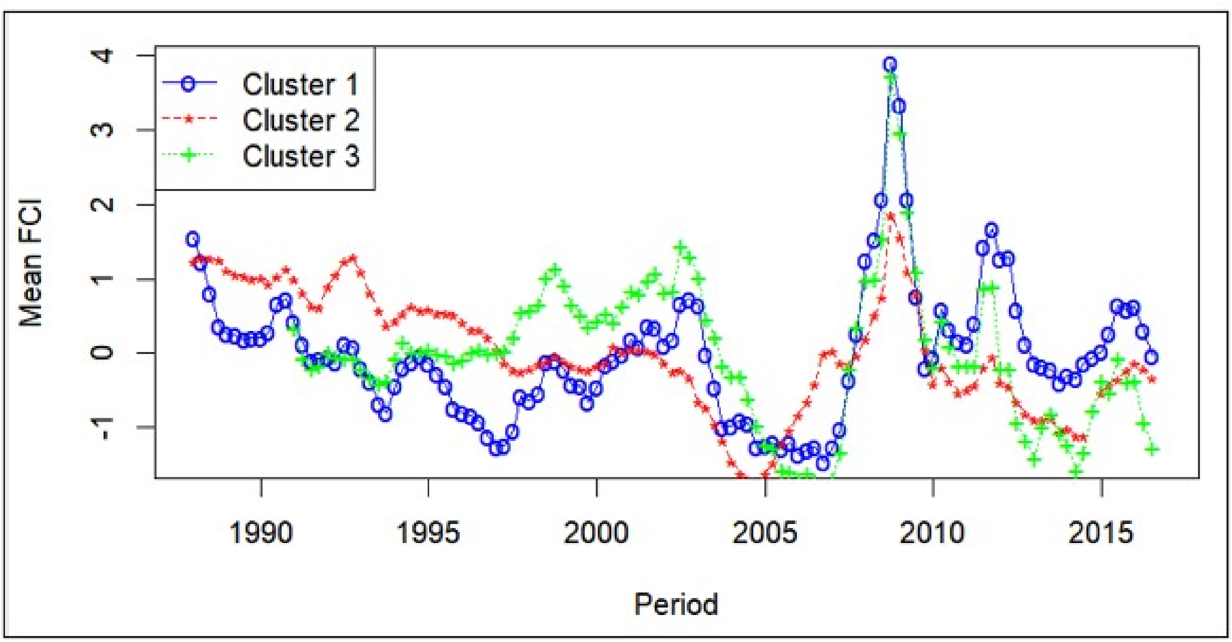


Figure 14: Mean Standardized FCI by Algorithmic Clusters, 1988-2016

As elucidated in Section 4.2.1, algorithmic clustering output is revised with a view of capturing broader structural difference across economies beyond FCI correlations. In particular, I manually select traditional Small Open Economies (SOEs) with strong external orientations and separate them from other Advanced Economies into a single cluster. Another revision is over Japan's categorization, given its known AE status and structural differences from many economies under the core emerging markets cluster. Figure 15 reports the time series of mean standardized FCI by final clusters adopted for analysis, as detailed in Section 4.2.1.

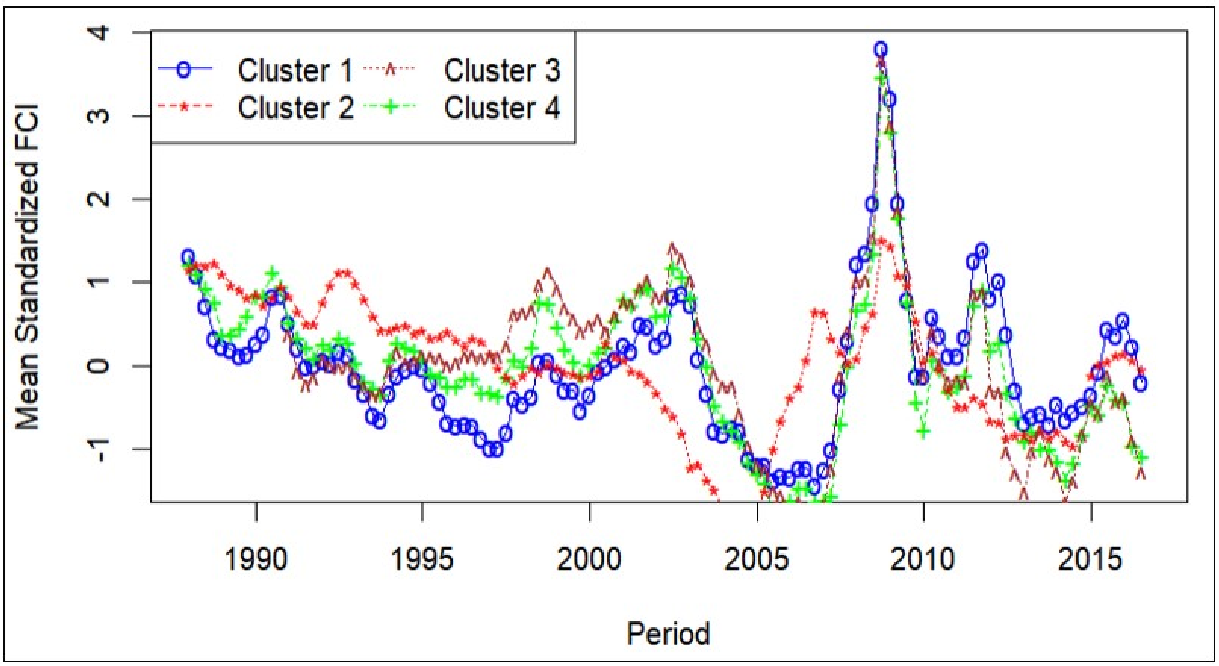


Figure 15: Mean Standardized FCI by Revised Clusters, 1988-2016

B.4 Country Credit-to-GDP Levels Relative to Group Median

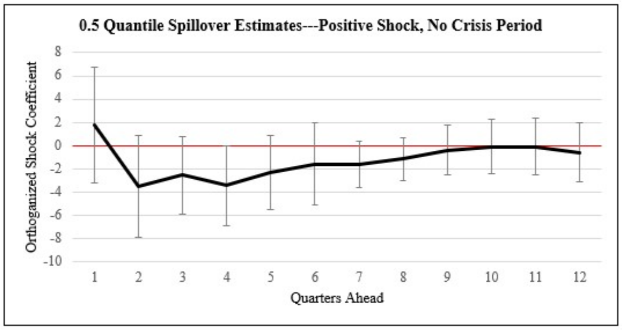
In assessing the position of an country's Credit-to-GDP ratio relative to other Advanced and Emerging Market Economies, I compute the proportion of quarters a country i's Credit-to-GDP ratios lie above the median of the AE/EME country group it belongs to, over the sample period 1988-2016. I categorize an economy as one carrying a relatively high level of debt (High Debt Economy) if its Credit-to-GDP ratios stayed above the quarterly median of its AE/EME group at least 75% of the time over the sample period. Table 8 reports the proportion of above-group-median debt periods ($\bar{H}^m_{i,t}$), along with the categorization of country's aggregate debt status in line with the criteria above.

Country	$\bar{H}^m_{i,t}$	High Debt Economy	Country	$\bar{H}^m_{i,t}$	High Debt Economy
CHE	1.00	Y	AUS	0.38	N
CHL	1.00	Y	ESP	0.35	N
CHN	1.00	Y	FRA	0.30	N
KOR	1.00	Y	IDN	0.27	N
SWE	1.00	Y	TUR	0.10	N
ZAF	0.81	Y	IND	0.08	N
CAN	0.78	Y	RUS	0.01	N
JPN	0.64	N	DEU	0.00	N
BRA	0.62	N	ITA	0.00	N
GBR	0.50	N	MEX	0.00	N

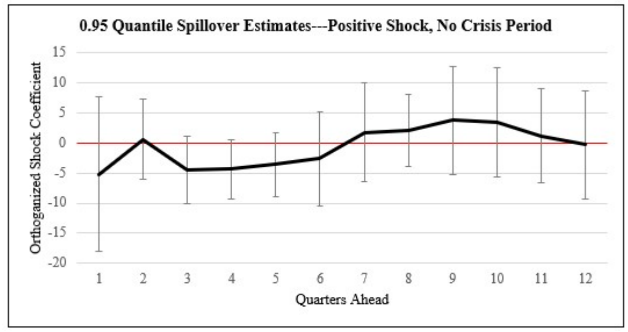
Table 8: Country Credit-to-GDP Levels Relative to Group Median Statistics, 1988-2016

B.5 Additional Results on Positive Shocks Spillover Effects

(a) Sub-sample Robustness for Median and 0.95 Quantile Results



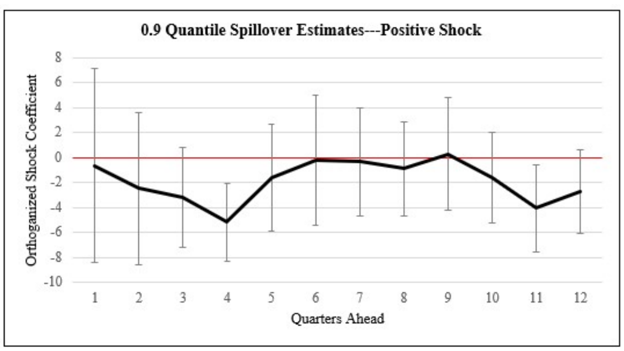
(a) $\tau = 0.5$



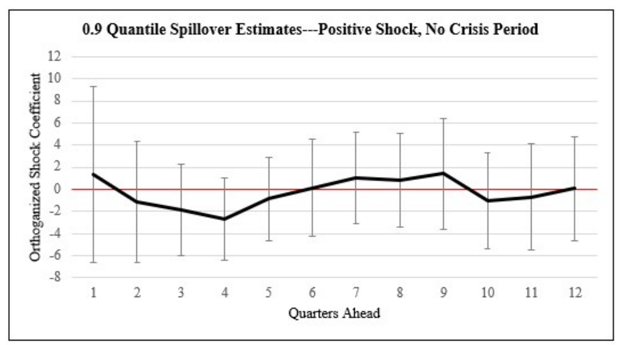
(b) $\tau = 0.95$

Figure 16: Median and Upside Growth Spillover with 95% CI for Positive Shocks, No Crisis Period

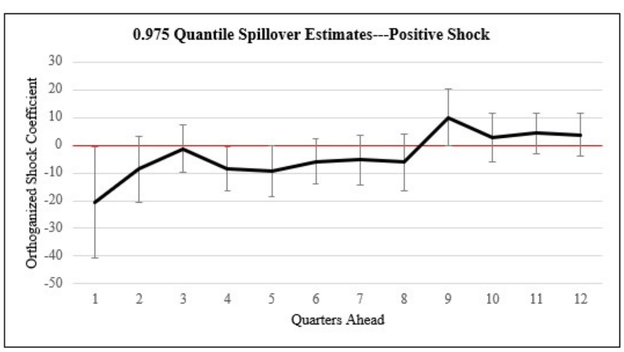
(b) Alternative Upside Quantiles Results, Full and Sub-sample Data



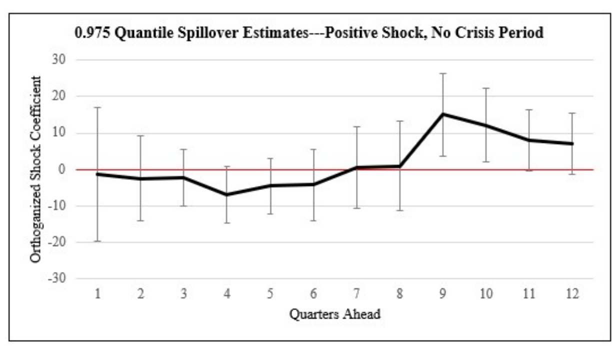
(a) $\tau = 0.9$



(b) $\tau = 0.9$, No Crisis Period



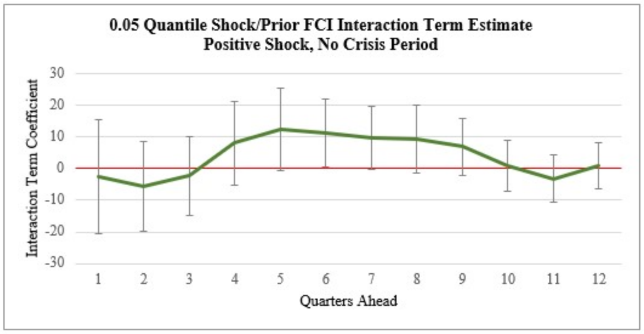
(c) $\tau = 0.975$



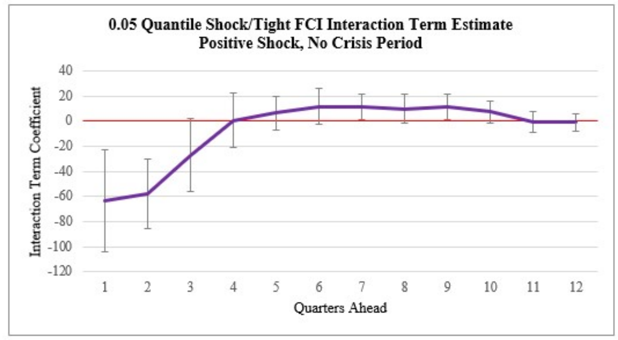
(d) $\tau = 0.975$, No Crisis Period

Figure 17: Alternative Upside Quantiles Growth Spillover with 95% CI for Positive Shocks

B.6 Interaction Term for FCI Variables, Sub-sample Data



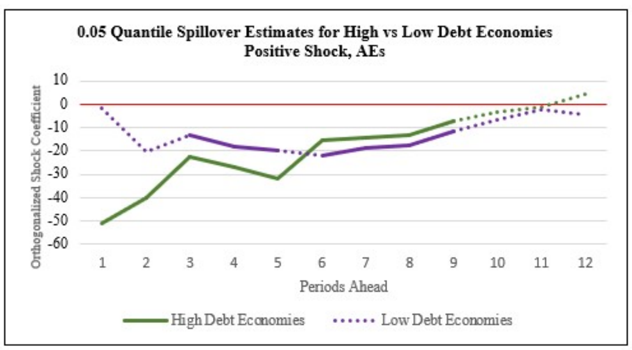
(a) $MPS_t \times FCI_{j,t-1}$



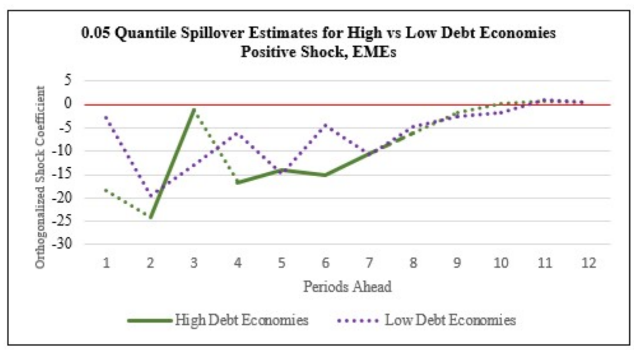
(b) $MPS_t \times TIGHT_{j,t-1}$

Figure 18: $\tau = 0.05$ Quantile Spillover Interaction Estimates for FCI Variables, Positive Shocks

B.7 Spillover to High and Low Debt Economies by Country Group



(a) Advanced Economies



(b) Emerging Market Economies

Figure 19: $\tau = 0.05$ Quantile Growth Spillover, Positive Shocks by High and Low Debt Economies (Solid line indicates significant estimates at 0.95 confidence level)

C Proofs

C.1 Proof of Proposition 1

From production technology (5.4), and period-wise resource constraints (5.5) - (5.7), re-write the household's optimization problem as:

$$\max_{C_1,K_2} \log(C_1) + \beta E[\log((1+r)(A_1K_1^\alpha - C_1 + (1-\delta)K_1 - K_2) + A_2K_2^\alpha - (1+r)^2D_1]$$

Uncertainty in this model is resolved since exogenous parameters are deterministic. With model-consistent expectations, the first order conditions are:

$$\frac{1}{C_1} = \frac{\beta(1+r)}{(1+r)(A_1K_1^\alpha - C_1 + (1-\delta)K_1 - K_2) + A_2K_2^\alpha - (1+r)^2D_1} \tag{C.1.1}$$

$$\alpha A_2 K_2^{\alpha-1} = 1+r \tag{C.1.2}$$

By Assumption 2, $\beta(1+r) = 1$. (C.1.1) then implies:

$$C_1 = (1+r)(A_1K_1^\alpha - C_1 + (1-\delta)K_1 - K_2) + A_2K_2^\alpha - (1+r)^2D_1$$

$$\implies C_1^* = \frac{(1+r)(A_1K_1^\alpha + (1-\delta)K_1 - K_2^*) + A_2K_2^{*\alpha} - (1+r)^2D_1}{(2+r)} \tag{C.1.3}$$

Rearranging (C.1.2):

$$K_2^* = \left(\frac{\alpha A_2}{1+r}\right)^{\frac{1}{1-\alpha}} \tag{C.1.4}$$

where $*$ denotes optimal choice without credit constraint. Finally, substituting law of motion of capital (5.7) into (5.5) for optimal choices yields:

$$D_2^* = C_1^* + K_2^* - Y_1 - (1-\delta)K_1 + (1+r)D_1 \tag{C.1.5}$$

For two distinct realizations of A_1, $0 < A_1' < A_1''$, observe from (C.1.4) that K_2^* remains constant. By (C.1.3), with a negative shock from A_1'' to A_1', C_1^* drops by $\frac{(1+r)}{(2+r)}(A_1'' - A_1')K_1^\alpha$, which reduces the demand for borrowing. This is, however, counteracted by an increase in demand for borrowing from the fall in Y_1, by an amount $(A_1'' - A_1')K_1^\alpha$ from (5.4). Substituting above into (C.1.5) yields:

$$D_2^*(A') - D_2^*(A'')$$

$$= (A_1'' - A_1')K_1^\alpha - \frac{(1+r)}{(2+r)}(A_1'' - A_1')K_1^\alpha$$

$$= \frac{1}{2+r}(A_1'' - A_1')K_1^\alpha > 0$$

as asserted.

C.2 Proof of Proposition 2

Treating D_2^* as fixed, we can re-frame the period-wise incomes as ones including the optimal debt decision and payment. With this, household's choice can be reduced to a simple investment decision. Re-write household's optimization problem as:

$$\max_{I_1} \; U = \log(C_1) + \beta E[\log(C_2)]$$

s.t.

$$C_1 + I_1 = W_1 \tag{C.2.1}$$

$$C_2 = W_2 \tag{C.2.2}$$

$$K_2 = (1-\delta)K_1 + I_1 \qquad 0 < \delta < 1 \tag{C.2.3}$$

$$I_1, A_1, A_2, C_1, C_2 \geq 0 \tag{C.2.4}$$

where

$$W_1 = A_1 K_1^\alpha + D_2^* \tag{C.2.5}$$

$$W_2 = A_2 K_2^\alpha - (1+r)D_2^* \tag{C.2.6}$$

It is easy to show that the solutions to the two problems are equivalent, since credit decision substituted here is optimal by definition.

From assumption of Lemma 2, the credit constraint binds under $MPS_{1^-} = i', A_1 = A_1'$. Hence, $D_2^*(i')$ is a corner solution equal to the nominal credit constraint when $A_1 = A_1'$. By Assumption 1, the credit constraint will be slacker without the positive shock increase, so $D_2^*(i) > D_2^*(i')$ given $i < i'$, holding all exogenous variables constant. Note that $D_2^*(i)$ may or may not be a corner solution since credit constraint in this case might not bind.

The above implies that in the re-framed problem,

$$W_1(i') < W_1(i), \quad W_2(i') > W_2(i) \tag{C.2.7}$$

Computing first order condition over I_1, and substituting the constraints yield:

$$-\frac{1}{W_1 - I_1} + \beta\frac{A_2\alpha[(1-\delta)K_1 + I_1]^{\alpha-1}}{W_2} = 0$$
$$\implies \frac{1}{W_1 - I_1^*} = \frac{\beta\alpha A_2}{W_2[[(1-\delta)K_1 + I_1^*]^{1-\alpha}} \tag{C.2.8}$$

(C.2.7)-(C.2.8) together imply:

$$I_1^*(i') < I_1^*(i) \tag{C.2.9}$$

Given comparative fall in optimal investment, it immediately follows from (5.4) and (5.7) that:

$$Y_2^*(i') < Y_2^*(i) \tag{C.2.10}$$

For aggregate utility U^*, note that in both scenarios, the unique *unconstrained* optimal debt D_2^{**} is the same under Lemma 2's assumptions, and satisfies $D_2^{**} \geq D_2^*(i) > D_2^*(i')$. Consider a Lagrange Multiplier, μ, applied to the credit constraint. Through a standard complementary slackness argument, it easily follows that for all $D_2 \in [D_2^*(i'), D_2^*(i))$, $\mu(D_2) = \frac{\partial U}{\partial D_2} > 0$, and $\mu(D_2) \geq 0$ for $D_2 = D_2^*(i)$. As such, $U^*(i) - U^*(i') = \int_{D_2^*(i')}^{D_2^*(i)} \frac{\partial U}{\partial D_2} dD_2 > 0$, holding all exogenous variables constant, as desired.