

Online Annexes

Online Annex 1.1. Drivers of Emerging Market Spreads¹

This Online Annex estimates the key drivers of sovereign spreads in emerging market and developing economies (EMDEs), with emphasis on high-frequency dynamics. Machine learning techniques are used to identify a stable core set of global and domestic determinants of EMDE spreads, which are then complemented by parsimonious panel regressions to quantify the compression in spreads observed since late 2022.

Data

The analysis uses a monthly unbalanced panel of 35 EMDE sovereigns included in the JPMorgan Emerging Markets Bond Index Global during 2000–25. The initial explanatory set of variables is high-dimensional. It combines (1) more than 20 global financial variables capturing advanced economies’ monetary, exchange rate and funding conditions, global risk appetite, equity performance and (2) more than 25 domestic macroeconomic conditions, including economic activity, inflation, fiscal variables, reserves, and debt-related measures ([Online Annex Table 1.1.1](#)).

Online Annex Table 1.1.1 Variables Included in the Machine Learning Process

Panel A. Macro Fundamentals				Panel B. Global Conditions			
Variable	Source	Variable	Source	Description	Source	Description	Source
GDP (Nom/Real)	WEO	Industrial Prod.	Haver	EMBI Global (bps)	Bloomberg	S&P 500 Index	Bloomberg
Real GDP Growth	WEO	Governance Idx.	WGI	US 10y-3m Spread	FRED	US Dollar Index	Bloomberg
Inflation (Idx/%)	CEIC	Risk (E/F/P/D)	ICRG	US 10y Term Prem.	Bloomberg	Financial Cond.	FRED
Terms of Trade	WEO/CEIC	Gross Ext. Debt	WB	AAA vs 10y Spread	Bloomberg	Fed Funds Rate	CME
Current Acct (% GDP)	WEO/CEIC	IMF Program	IMF	CDS 5y/10y	Bloomberg	Global Growth	WEO
Exports (% GDP)	WEO/CEIC	Sovereign Default	Fitch	FRA-OIS Spread	Bloomberg	US Fed Deficit	FRED
Interest Exp.	WEO/CEIC	Fiscal Rule/Council	IMF	MOVE Idx (1/3/6m)	BofA	US Public Debt	FRED
Gross/Net Debt	WEO/CEIC	Domestic ST Interest Rate	CEIC	Stock Market Index	CEIC	WTI Spot Price	EIA
Reserves (% GDP)	WEO/CEIC	Pres/Legis Election	DPI	VIX / Oil Volat.	CBOE	Commodity Index	Bloomberg
FX Gross Debt	WEO/CEIC	Inflation Target	CB	Policy/World Uncertainty	EPU/WUI		
ST External Debt	WEO/CEIC	Trade (% GDP)	WEO/CEIC	Trade Uncertainty	WUI		
Inflation Expectations	Consensus	Growth Expected	Consensus				

Note: During the feature engineering and selection process for the machine learning algorithms (LASSO, Ridge, Stepwise OLS, and Random Forest), all variables were evaluated under multiple transformations. These include various horizon changes (h = 1, 3, 6, 12) applied as both log-differences and simple differences to ensure stationarity and capture dynamic effects.

Empirical Strategy and Results

Several machine learning (ML) techniques—including LASSO, Ridge, and Stepwise OLS—are employed for variable selection and regularization, ensuring a compact and robust set of predictors. These are complemented by Random Forest to capture potential nonlinearities and threshold effects (Hastie Tibshirani, and Jerome Friedman 2009). Each model is evaluated against simple benchmarks (training mean and pooled AR(1)) using out-of-sample root mean squared error (RMSE) and R^2 . Results are consistent across methods: monthly EMDE spread repricing is largely captured by a small, stable set of global factors, including equity risk (S&P 500 index), US dollar index strength (DXY), broad financial conditions (National Financial Conditions Index – NFCI), and commodity prices (Bloomberg Commodity Index – BCI). The domestic variables that most consistently appear as relevant are industrial

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production, international reserves, and domestic short-term interest rates. Measures of global stress (Treasury-EuroDollar – TED spread, yield-curve slope, CBOE Volatility Index – VIX) enter some specifications but do not add large incremental content. Random Forest confirms the same core drivers; inspection of partial effects indicates the leading predictors are largely monotonic and close to linear, implying limited gains from nonlinearities. [Online Annex Table 1.1.2](#) summarizes comparable coefficients and model-fit statistics across methods, including Random Forest pseudo-coefficients derived from permutation importance and ridge projection of fitted values.

Guided by the 10 core predictors consistently selected by the ML exercises in [Online Annex Table 1.1.2](#), the analysis estimates parsimonious panel regressions to obtain interpretable short-run elasticities and enable statistical inference in a standard sovereign-spread framework. Specifically, it models monthly repricing of spreads as:

$$\Delta \log(\text{spread}_{i,t}) = \alpha_i + \beta' \Delta X_t + \gamma' \Delta Z_{i,t} + \varepsilon_{i,t}, \quad (\text{Eq.1.1})$$

where α_i are country fixed effects; ΔX_t is the vector of global variables for month t which includes the dollar index; NFCI to capture the financial conditions; VIX to capture market volatility, and S&P 500 to proxy for global risk sentiment; $\Delta Z_{i,t}$ is the set of high-frequency domestic variables including the Industrial Production (IP) Index to proxy for local economic activity, international reserves, and short-term interest rate that captures the monetary policy stance.

Online Annex Table 1.1.2. Core Predictors of Monthly EMDE Spread Repricing: Coefficients across Methods

Dependent Variable	LASSO	Ridge	Stepwise OLS (AIC)	Random Forest (pseudo-coef.)
Global variables				
Equity risk appetite (S&P 500)*	-0.854	-0.665	-1.032***	-0.839
U.S. dollar (DXY)*	0.496	0.547	0.558.	0.528
Commodities Index (BCI)*	-0.278	-0.258	-0.320.	-0.340
U.S. financial conditions (NFCI)*	0.201	0.177	0.162*	0.263
Market volatility (VIX)*	0.031	0.058	–	0.064
Stress / funding variables				
TED spread*	0.035	–	0.109***	0.021
Yield curve spread (10y–3m)^	0.042	–	0.253**	0.074
Domestic fundamentals				
Industrial production (monthly activity proxy)*	-0.187	-0.215	–	-0.275
Domestic short-term interest rate*	0.033	0.029	0.337***	0.030
International reserves^	-0.033	-0.049	–	-0.033
Model statistics				
RMSE (test)	0.089	0.091	–	0.090
R^2 / Adj. R^2	0.202	0.167	0.382	0.158
λ_{\min}	0.00091	0.01670	–	–
N (train / test / OLS)	7426 / 803	7426 / 803	497	7426 / 803

Source: IMF staff estimation.

Note: Dependent variable: $\Delta \log(EMBIG)$. LASSO/Ridge report penalized coefficients at λ_{\min} ; Stepwise OLS (AIC) reports OLS estimates with significance codes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Random Forest (RF) column reports prediction based pseudo-coefficients from a projection of RF fitted values on standardized regressors and rescaling back to original units. By construction, no comparable p -values for LASSO, Ridge, and Random Forest coefficients. RMSE and R^2 for LASSO/Ridge/RF are out-of-sample (2024–25), while the Stepwise OLS Adj R^2 is in-sample.

* denotes contemporaneous $\Delta \log(\cdot)$ and ^ denotes lagged $L1 \Delta \log(\cdot)$.

[Online Annex Table 1.1.3](#) reports a sequence of specifications that gradually expands the global block (risk sentiment, dollar strength, and financial conditions) and the domestic block. The estimates show that global risk appetite and US financial conditions account for most of the short-run variation in spreads, while domestic activity and policy variables add secondary explanatory power. Consistent with overlap between commodity cycles and broader financial conditions, the commodity index becomes

statistically weaker once NFCI is included. International reserves are associated with lower spreads but the results become statistically weaker when the commodity index is included. Finally, the VIX generates a lower R^2 than the S&P 500 and becomes statistically insignificant when the S&P 500 is included. Therefore, the authors adopt specification (5) as the baseline given its stability and close alignment with the “core” set of predictors identified by the ML exercises.

Online Annex Table 1.1.3 to generate country-month predictions of factor contributions. Aggregate results are computed as cross-section medians, with a decomposition of monthly changes in EMDE spread compression since late 2022 into global, domestic, and residual components. Global factors account for nearly three-quarters of the average 240 basis point reduction in spreads between October 2022 and November 2025.

Online Annex Table 1.1.3. Short-Run EMDE Spread Repricing Pooled OLS Regressions

Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Global Variables										
Equity risk appetite (S&P 500)*	-1.828*** (0.120)	-1.820*** (0.124)	-1.728*** (0.150)	-1.126*** (0.103)	-1.100*** (0.0919)	-1.079*** (0.0977)				-1.017*** (0.120)
U.S. dollar (DXY)*	0.908*** (0.113)	0.851*** (0.115)	0.673*** (0.141)	0.514*** (0.138)	0.516*** (0.120)	0.461*** (0.123)	1.475*** (0.130)	1.395*** (0.146)	1.142*** (0.168)	0.491*** (0.137)
Commodities index (BCI)*			-0.340*** (0.0895)			-0.156 (0.108)			-0.481*** (0.0869)	-0.155 (0.108)
U.S. Financial conditions (NFCI)*				0.334*** (0.0591)	0.335*** (0.0565)	0.322*** (0.0617)				0.312*** (0.0621)
Market Volatility (VIX)*							0.289*** (0.0186)	0.289*** (0.0218)	0.264*** (0.0243)	0.0198 (0.0194)
Domestic Fundamentals										
Industrial Production (monthly activity proxy)*	-0.442*** (0.134)	-0.549*** (0.150)	-0.550*** (0.161)	-0.425*** (0.162)	-0.408** (0.162)	-0.405** (0.169)	-0.529*** (0.131)	-0.664*** (0.135)	-0.627*** (0.155)	-0.413** (0.169)
Domestic short-term interest rate*		0.0726*** (0.0225)	0.0719*** (0.0236)	0.0673*** (0.0184)	0.0684*** (0.0189)	0.0690*** (0.0197)		0.0677*** (0.0221)	0.0689** (0.0246)	0.0690*** (0.0198)
International reserves^			-0.157** (0.0685)	-0.0875 (0.0751)				-0.149* (0.0695)	-0.163** (0.0672)	
Observations	2863	2152	2051	2051	2152	2152	2863	2051	2051	2152
R-squared	0.291	0.296	0.309	0.336	0.330	0.332	0.240	0.251	0.263	0.332
Adjusted R-squared	0.286	0.290	0.303	0.330	0.325	0.325	0.235	0.243	0.256	0.325
AIC	-4233.1	-3237.3	-3063.8	-3145.4	-3344.1	-3346.1	-4033.0	-2898.0	-2930.2	-3345.0

Source: IMF staff estimation.

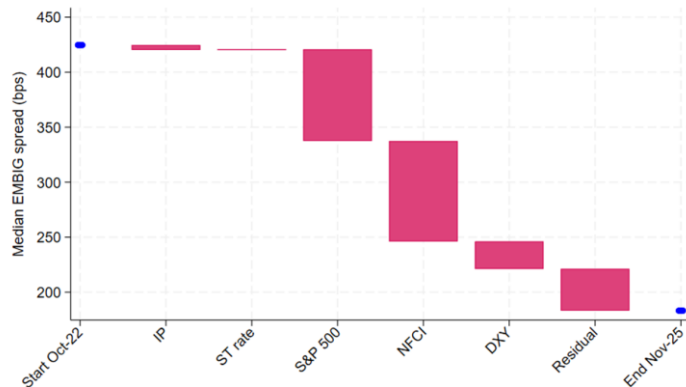
Note: Dependent variable: $\Delta \log(EMBIG)$. Entries are pooled OLS coefficients; standard errors (in parentheses) are clustered at the country level.

* denotes contemporaneous first-differences in logs while ^ denotes one-period lag.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Online Annex Figure 1.1.1. Median EMDE Spread Decomposition of the 2022–25 Compression

(Basis points)



Source: IMF staff calculations.

Robustness

Robustness is assessed along different technical dimensions. First, the analysis is repeated across alternative training windows (for example, excluding COVID-19 years, shifting the start date forward, and restricting to post-2014 subsamples) to verify that the selected drivers and their relative importance are not specific to a particular period. Second, the stability of estimated coefficients is evaluated using rolling or recursive estimations (and, where relevant, time-varying parameter diagnostics) and the findings indicate that the coefficients are stable over time. Third, the analysis tests whether the magnitude of key global factors is symmetric across tightening and easing regimes. The results indicate that tighter liquidity conditions—captured by positive changes in NFCI—have a markedly larger impact than comparable easing episodes: the implied tightening effect is about 0.5, versus about 0.1 under easing ([Online Annex Table 1.1.4](#)).

Online Annex Table 1.1.4. Asymmetries of Global Factors in EMDE Spread Decomposition

Dependent Variable	(1)	(2)	(3)	(4)
Industrial production*	-0.408** (0.162)	-0.409** (0.164)	-0.436** (0.158)	-0.410** (0.162)
Domestic short-term interest rate*	0.0684*** (0.0189)	0.0701*** (0.0200)	0.0711*** (0.0228)	0.0690*** (0.0185)
Equity risk appetite (S&P500)*	-1.100*** (0.0919)	-1.271*** (0.183)	-1.026*** (0.0909)	-1.088*** (0.0925)
U.S. financial conditions (NFCI)*	0.335*** (0.0565)	0.328*** (0.0545)	0.112** (0.0513)	0.338*** (0.0560)
U.S. dollar (DXY)*	0.516*** (0.120)	0.560*** (0.126)	0.629*** (0.120)	0.567 (0.326)
S&P500 upswing ($\Delta \log(\text{S\&P500}) > 0$) x $\Delta \log(\text{S\&P500})$ ^		0.450 (0.258)		
NFCI tightening ($\Delta \log(\text{NFCI}) > 0$) x $\Delta \log(\text{NFCI})$ ^			0.410*** (0.0825)	
USD appreciation ($\Delta \log(\text{DXY}) > 0$) x $\Delta \log(\text{DXY})$ ^				0.294 (0.263)
Observations	2152	2152	2152	2152
R-squared	0.330	0.332	0.344	0.331

Source: IMF staff estimations.

Note: Dependent variable: $\Delta \log(\text{EMBIG})$. Entries are pooled OLS coefficients; standard errors (in parentheses) are clustered at the country level.

* denotes contemporaneous first-differences in logs.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

^ indicates the interaction of a dummy that equals 1 if $\Delta \log() > 0$ and 0 otherwise for every global determinant interacted with $\Delta \log()$ to capture the asymmetries between tightening and loosening regimes.

Online Annex 1.2. Treasury Auction Shock¹

This annex documents the data sources and econometric methodology underlying the Treasury auction shock analysis presented in Figures 1.29 and 1.30 of the main chapter. The analysis examines domestic and international spillovers from US bond supply shocks to financial markets and economic activity, using daily and monthly data with panel local projections.

Empirical Strategy

This annex presents an empirical framework that uses high-frequency–identified US Treasury supply shocks to estimate (1) domestic yield responses, (2) spillovers to foreign sovereign yields and how the spillover effects vary by foreign investor participation in recipient bond markets, and (3) domestic and international effects on economic activity.

The empirical strategy proceeds in two steps. First, high-frequency–identified shocks originating in the US Treasury market are used to estimate the dynamic response of sovereign bond yields at daily frequency, both domestically and abroad. The use of daily data reflects the higher volatility of financial markets and the need for high-frequency observations to detect responses in asset prices. Second, the same shocks are aggregated to monthly frequency to study their effects on economic activity, as measured by industrial production, again assessing international spillovers and cross-country heterogeneity.

Data Sources and Coverage

The baseline sample spans the period from October 21, 1998 to January 23, 2020, to match the available sample span of the shock series that is based on the published announcements of the Treasury auctions. The unbalanced panel for foreign economies covers 66 advanced and emerging market economies, with some data becoming available later in the sample ([Online Annex Table 1.2.1](#)).

Online Annex Table 1.2.1. Data Availability

Country code	First year of data			Country code	First year of data			Country code	First year of data		
	10-year bond yield	Industrial Production	Foreign investors share		10-year bond yield	Industrial Production	Foreign investors share		10-year bond yield	Industrial Production	Foreign investors share
ARG		2016	1989	GBR	1998	1998	1989	NOR	1998	1998	2003
AUS	1998	1998	2003	GRC	2018	1998	2003	NZL		1998	1993
AUT	1998	2005	1995	HKG	2010			PER	2005		1996
AZE		2012	1993	HRV		1998	1995	PHL	2011		1989
BEL	1998	2000	1995	HUN	1999	1998	1989	POL	1999	1999	1989
BGR		2000	1994	IDN	2010		1989	PRT	1998	2005	1995
BIH		2006	1999	IND	1998	1998	1997	QAT		2016	1989
BLR		2008	1993	IRL	1998	1998	2002	ROU		2000	1996
BRA	2006	2002	1989	ISR	2002		1998	RUS		2005	1992
CAN	1998	1998	1998	ITA	1998	1998	1989	SGP	1998		
CHE	1998	2004	1999	JOR		2002	1989	SLV		2005	1989
CHL	2004	2009	2003	JPN	1998	2008	2003	SRB		1998	1997
CHN	2006	1998	1989	KAZ		1998	1992	SVK		1998	1995
CYP		2000	1995	KOR	2013	1998	1994	SVN		1998	1995
CZE	2000	2000	1995	LKA		2010	1989	SWE	1998	2000	1995
DEU	1998	1998	1991	LTU		1998	1995	SYC		2013	1989
DNK	1998	2000	1995	LUX		1998	1995	THA	2001		1989
EGY		2013	2001	LVA		2000	1992	TUR	2012	1998	1989
ESP	1998	1998	1995	MEX	2007		1989	TWN		1998	
EST		2000	1995	MNE		2001	2005	UKR		2006	1995
FIN	1998	1998	1995	MYS	2019	2015	1989	USA	1998	1998	1989
FRA	1998	1998	1995	NLD	1998	2000	1995	ZAF	2019	1998	1998

Sources: Haver Analytics; and IMF, International Financial Statistics database.

Note: Data labels in the figure use International Organization for Standardization (ISO) country codes.

¹ Prepared by Danila Smirnov based on several working papers (Bi, Phillot, and Zubairy 2025; Carrière-Swallow, Kindberg-Hanlon, and Smirnov 2025; Miranda-Agrippino and Rey 2020).

Daily zero-coupon or benchmark 10-year sovereign bond yields are obtained from Haver Analytics. For the United States, the 10-year Treasury yield is used as the benchmark domestic yield. For foreign economies, the analysis covers 38 economies with sufficiently liquid sovereign bond markets. All yield series are expressed in percentage points and aligned to US trading days; nontrading days are excluded.

Monthly industrial production indicators are obtained from Haver Analytics. The series are seasonally adjusted and expressed in logarithms; growth rates are computed as log differences. The monthly panel includes 58 countries over the same period, with some countries entering the sample at a later date.

Data on the share of sovereign debt held by foreign investors are compiled from the Arslanalp and Tsuda (2012, 2014) database and cover 63 countries. The foreign investor share is measured as the fraction of outstanding general government marketable debt held by nonresidents. The series are available at annual frequency.

The analysis follows Phillot (2025) to identify US Treasury supply shocks based on narrow-window price changes around public Treasury auction announcements. The identifying assumption is that within a 30-minute window bracketing each announcement, markets have no time to receive or process new macroeconomic information: any price movement therefore reflects the market's reassessment of bond supply conditions rather than a response to fundamentals. This timing restriction provides a credible exclusion restriction, isolating variation in yields that is orthogonal to contemporaneous monetary policy, macroeconomic news, and financial conditions.

The validity of the timing restriction is supported by Phillot (2025), who documents that Treasury auction windows do not systematically overlap with scheduled US macroeconomic data releases, US Federal Reserve communications, or other high-impact publications. This ensures that within-window price movements are not contaminated by concurrent news unrelated to debt supply. As a further check on exogeneity, the authors conduct Granger causality tests examining whether the debt expansion shock is predicted by a broad set of daily US and foreign financial and economic conditions, including the US 10-year yield, the German 10-year yield, the Japanese 10-year yield, US term premiums at the 2-, 5-, and 10-year horizons, US 10-year breakeven inflation, the VIX, the NASDAQ, the S&P 500, and the oil price. The shock is not Granger-caused by any of these variables at the 5 percent significance level, with one exception: the Japanese 10-year yield enters with marginal predictive power at the 10 percent level. To address this, the contemporaneous value and two lags of the Japanese 10-year yield are included as controls in both the daily and monthly local projection regressions throughout the analysis.

At daily frequency, each auction generates a price change in Treasury futures across multiple maturities within the event window. Because auctions vary in their maturity composition, the cross-maturity yields responses conflate two conceptually distinct shocks: a pure increase in overall stock of public debt, and a shift in the maturity structure of outstanding supply. To separate these, we apply principal component analysis to the vector of within-window yield changes across 2-, 5-, 10, 30-year maturities. The first principal component which loads equally positively across all maturities, captures the pure debt supply shock. The second principal component, which loads with opposing signs at short and long maturities, so that the sum of the loadings is zero, captures maturity extension shocks that redistribute the supply along the yield curve without changing the total size. The analysis retains the first component as a baseline shock, signed so that the positive value corresponds to an upward surprise in yields.²

² This decomposition aligns the shock series with the identification in Bi, Phillot, and Zubairy (2025), who isolate the pure debt supply component and distinguish it from maturity extension whose effects on US economy differ substantially. Additionally they show that a one-standard-deviation debt expansion shock that leads to an increase of debt-to-GDP ratio by 0.9 percent after two years.

At monthly frequency, shocks are constructed by summing daily shocks over a rolling 31-day window, following the aggregation approach of Gertler and Karadi (2015), where each daily shock is weighted by the number of days remaining in the window at the time it occurs. This weighting reflects the intuition that an older shock has had more time to influence the monthly outcome variable and therefore receives a higher weight than a shock occurring close to the end of the window.

Econometric Methodology

The dynamic response of sovereign bond yields is estimated using the local projection method. For each horizon $h = 0, 1, \dots, H$, the following regression is estimated:

$$\Delta_h Y_{i,t} = \beta_h s_t + \phi_h \Delta Y_{i,[t-1,t-2]} + \delta_h' D_t + \alpha_{i,h} + \lambda_{t,h}^{Year} + \mu_{t,h}^{DOW} + u_{i,t+h}, \quad (\text{Eq.2.1})$$

where $\Delta_h Y_{i,t}$ denotes the change in the 10-year sovereign yield of country i at horizon h , s_t is the US Treasury supply shock; $\alpha_{i,h}$ are country fixed effects; $\Delta Y_{i,[t-1,t-2]}$ is the control for the past two changes of the yield; D_t includes two US 10-year yields lags, two US short-term rate lags, two lags of the shock, and contemporaneous and up to two lags of control variables that were selected based on Granger causality tests; and $\lambda_{t,h}^{Year}, \mu_{t,h}^{DOW}$ are the year and day of the week fixed effects. Standard errors are Heteroskedasticity and Autocorrelation Consistent (HAC) (Newey–West). Impulse responses are constructed by plotting the sequence β_h . For the US domestic response, the regression is estimated without country fixed effects, setting $i = U.S.$

For the purpose of comparing the effects of international transmission, the daily analysis also estimates spillovers using an instrumental variables (IV) approach in which the day-0 response of the US 10-year yield to the Treasury supply shock is used as an instrument for changes in US yields and foreign yields. This design offers a direct estimate of the spillover elasticity—that is, the response of foreign yields to a 1 percentage point change in the US 10-year yield induced by the Treasury supply shock.

The first stage estimates the on-impact US yield response to the Treasury supply shock. The second stage estimates the same regression, with the only difference that the shock is replaced by the fitted estimate from the first stage. The coefficient β_h can be interpreted as the spillover elasticity: the change in the yield of the recipient country at horizon h in basis points associated with a 1 basis point shock-induced increase in the US 10-year yield on the day of the shock.

At monthly frequency, the response of economic activity is estimated using an analogous local projection framework:

$$\Delta_h IP_{i,t} = \beta_h^{PAN} s_t + \gamma_h \Delta \log(IP_{i,t-1}) + \alpha_{i,h} + \delta_h' X_t + u_{i,t+h}, \quad (\text{Eq.2.2})$$

where $IP_{i,t}$ denotes Industrial Production; s_t denotes the monthly aggregated US bond supply shock; and the set of controls $\alpha_{i,h}$ are country fixed effects, X_t include lagged industrial production and Granger causality suggested controls, following the same approach as the daily specification.

To assess heterogeneity in spillovers, the baseline specification is augmented with interactions between the US shock and the foreign investor share of the recipient country:

$$\Delta_h y_{i,t} = \beta_h^{Foreign} x_t \tau_{i,t} + \beta_h^{Domestic} x_t (1 - \tau_{i,t}) + \gamma_h \Delta y_{i,t-1} + \delta_h' D_{i,t} + \alpha_{i,h} + \lambda_{t,h} + \eta_{i,t+h} \quad (\text{Eq.2.3})$$

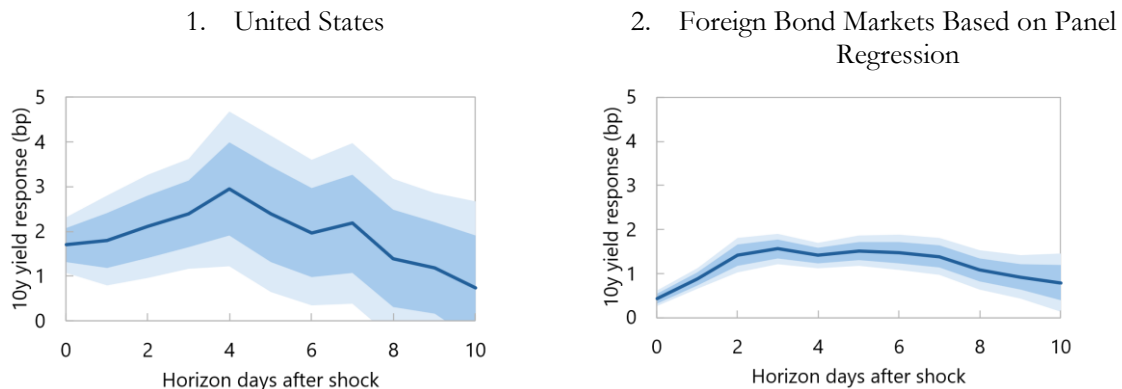
The specification allows two interactions of x_t , which is the US Treasury supply shock or the fitted 10-year US yield from the first stage IV regression, with $\tau_{i,t}$ representing the share of sovereign debt held by

foreign investors and $(1 - \tau_{i,t})$ representing the share of domestic investors. The set of controls $D_{i,t}$ additionally includes the share $\tau_{i,t}$. Notice that since we include time fixed effects $\lambda_{t,h}$, the regression equation is overidentified. Hence we report only the $\beta_h^{Foreign}$ and scale it by interquartile range of the exposure variable (the difference between 75th and 25th percentiles of foreign holdings). The scaled coefficient can be interpreted as the additional spillover effect for countries at the 75th percentile of foreign sovereign bond holdings compared to the country at the 25th percentile.

Results

Domestic yield response. A one-standard-deviation US Treasury supply shock raises the US 10-year yield by approximately 1–2 basis points on impact, with the effect building over the first four trading days and persisting through the nine-day horizon (Online Annex Figure 1.2.1, panel 1). The gradual ramp-up is consistent with information diffusing across market participants beyond the initial auction announcement window.

Online Annex Figure 1.2.1. Response of 10-Year Sovereign Yield to a One-Standard-Deviation Contractionary Shock on US Treasury Supply



Sources: Shocks from Phillot 2025; and IMF staff calculations.

Note: Responses are in basis points per one-standard-deviation shock. Shaded areas: 68 percent and 90 percent confidence bands. Standard errors: Newey–West (Heteroskedasticity and Autocorrelation Consistent – HAC). Daily OLS local projections are estimated over horizons of up to 10 business days. The dependent variable is $Y_{i,t+h} - Y_{i,t-1}$ for the US 10-year Treasury yield and $Y_{i,t+h} - Y_{i,t-1}$ for foreign 10-year sovereign yields. The shock is a contractionary Treasury-supply shock identified on auction announcement days as the first principal component raising the yield curve and residualized ex ante with respect to fixed effects (year, day-of-week, and country, where applicable), auction related dummies, and controls selected based on Granger-causality tests.

Spillovers to foreign sovereign yields. The same shock transmits to foreign bond markets, though at a smaller magnitude. Panel estimates indicate that foreign 10-year sovereign yields rise by roughly 1.5 basis point within two days of the shock, with the response stabilizing thereafter (Online Annex Figure 1.2.1, panel 2). When normalized by the contemporaneous US yield movement using the IV approach described above, the spillover elasticity reaches approximately 0.9 by day three, implying that foreign yields absorb close to 90 percent of the shock-induced US yield increase over a short horizon (Online Annex Figure 1.2.2). The first-stage HAC F -statistic of 26.0 indicates instrument strength.

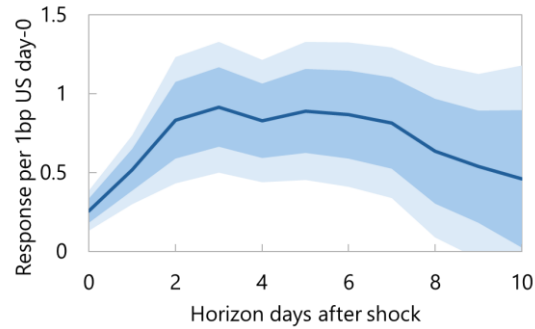
Effects on economic activity. At monthly frequency, the Treasury supply shock has transitory effect on US industrial production. The cumulative response peaks at about –0.2 percent 8 months after the shock and then gradually returns back to zero (Online Annex Figure 1.2.3, panel 1). The 90 percent confidence bands for the US are wide and include zero at most horizons, though the point estimates are persistently

negative through the first year. Foreign economies experience a stronger and more statistically significant decline in industrial production, with the cumulative response reaching roughly -0.4

percentage point about 6–12 months after the shock before partially reverting (Online Annex Figure 1.2.3, panel 2). The larger magnitude of the foreign response relative to the domestic US response reflects the compounding of direct and indirect transmission channels: in addition to the tightening of financial conditions through higher global long-term rates, foreign economies are also affected indirectly through the slowdown in US demand and exchange rate adjustments. Because these channels operate simultaneously and can reinforce one another, the total spillover effect need not be bounded by the size of the domestic impact.

Role of external financing exposure. The magnitude of international spillovers varies substantially with the recipient country's reliance on foreign investors. Moving from the 25th to the 75th percentile of foreign investor participation in the sovereign bond markets, countries at the higher end of the exposure distribution experience yield increases of

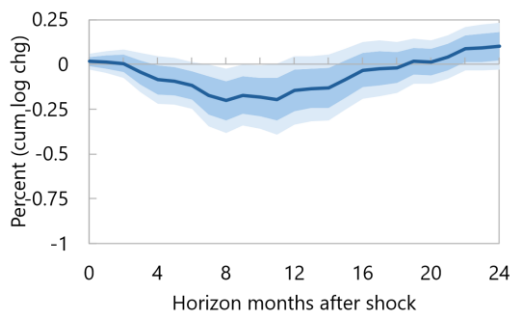
Online Annex Figure 1.2.2. Spillover 10-Year Yield Response Normalized by US 10-Year Response



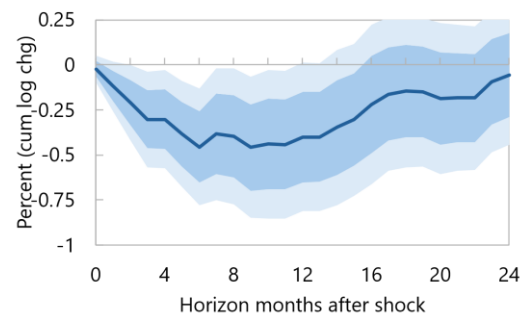
Sources: Shocks from Phillot 2025; and IMF staff calculations. Note: First-stage Heteroskedasticity and Autocorrelation Consistent (HAC) F -statistic is 26.0, indicating instrument strength. Shaded areas: 68 percent and 90 percent confidence bands. Standard errors: Newey–West (HAC). Daily OLS local projections are estimated over horizons of up to 10 business days. The first stage dependent variable is $Y_t - Y_{t-1}$ for the US 10-year Treasury yield and second stage is $Y_{i,t+h} - Y_{i,t-1}$ for foreign 10-year sovereign yields. The shock is a contractionary Treasury-supply shock identified on auction announcement days as the first principal component raising the yield curve and residualized ex ante with respect to fixed effects (year, day-of-week, and country, where applicable), auction related dummies, and controls selected based on Granger-causality tests.

Online Annex Figure 1.2.3. Domestic Response and Spillovers to Industrial Production from US Bond Supply Shocks (Cumulative change in percent)

1. United States



2. Spillover Effects on Other Countries



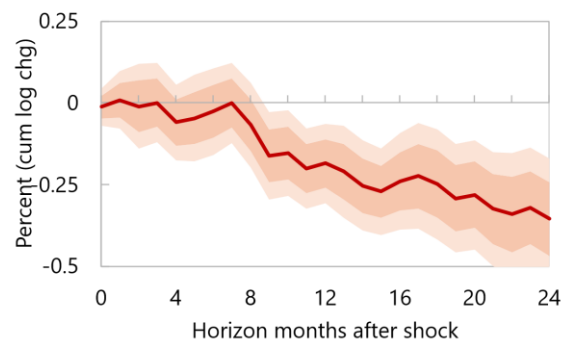
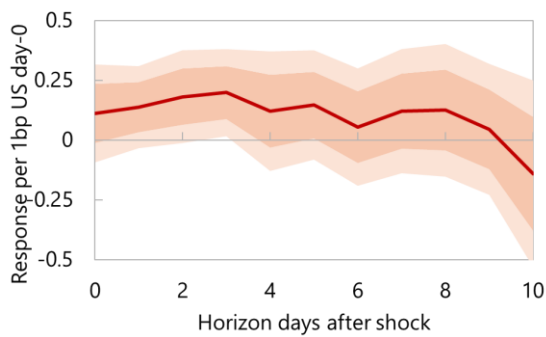
Sources: Phillot 2025; and IMF staff calculations.

Note: The figures show the cumulative responses $100 \cdot (\log IP_{i,t+h} - \log IP_{i,t-1})$ to a US Treasury supply shock based on the monthly panel local projections. Shaded areas denote the 68 percent and 90 percent confidence bands. The shock is constructed by aggregating high-frequency event-day Treasury supply surprises within each month and set to zero in non-event months. To facilitate interpretation, the impulse responses are scaled by one-day response of the US 10-year yield, so that the estimated effects can be read as the response to the same Treasury shock that causes 1 basis point increase in the US 10-year yield. Panel estimates exclude the United States and include country fixed effects and controls. Standard errors are clustered by month.

roughly 0.15 basis point larger within the 10-day horizon (Online Annex Figure 1.2.4, panel 1). A similar pattern emerges for industrial production: a country at the 75th percentile of foreign holdings sees output declines of approximately 0.2 percentage points larger after 12 months, compared to a country at 25th percentile of distribution (Online Annex Figure 1.2.4, panel 2). These results suggest that the portfolio rebalancing channel, whereby foreign investors adjust their holdings across markets in response to shifts in US Treasury supply conditions, is a key mechanism through which US fiscal shocks propagate internationally.

Online Annex Figure 1.2.4. International Spillovers from US Treasury Supply Shocks by External Financing Exposure

1. Differential 10-year Yield Response in Foreign Markets to the US Treasury Supply Shock
2. Differential Response of Industrial Production in Other Countries to the US Treasury Supply Shock



Sources: Shocks from Phillot 2025; IMF staff calculations. Note: The figure represents the estimated differential response between countries at 75th percentile of foreign holdings (71 percent) and those at the 25th percentile (33 percent). First-stage Heteroskedasticity and Autocorrelation Consistent (HAC) *F*-statistic is 26.0, indicating instrument strength. Shaded areas: the 68 percent and 90 percent confidence bands. Standard errors: Newey–West (HAC). Daily OLS local projections are estimated over horizons of up to 10 business days. The first stage dependent variable is $Y_t - Y_{t-1}$ for the US 10-year Treasury yield and second stage is $Y_{i,t+h} - Y_{i,t-1}$ for foreign 10-year sovereign yields. The shock is a contractionary Treasury-supply shock identified on auction announcement days as the first principal component raising the yield curve and residualized ex ante with respect to fixed effects (year, day-of-week, and country, where applicable), auction related dummies, and controls selected based on Granger-causality tests.

Sources: Phillot 2025; and IMF staff calculations. Note: The figure represents the estimated differential response between countries at 75th percentile of foreign holdings (71 percent) and those at the 25th percentile (33 percent). It shows the cumulative response $100 \cdot (\log IP_{i,t+h} - \log IP_{i,t-1})$ to a US Treasury supply shock based on the monthly panel local projections. Shaded areas denote the 68 percent and 90 percent confidence bands. The shock is constructed by aggregating high-frequency event-day Treasury supply surprises within each month and set to zero in non-event months. Panel estimates exclude the United States and include country fixed effects and controls. Standard errors are clustered by month.

Online Annex 1.3. A Dynamic Stochastic General Equilibrium Model with Long- And Short-Term Debt¹

This annex presents a New Keynesian Dynamic Stochastic General Equilibrium model to analyze the macroeconomic implications of government debt with different maturity structures (Figure 1.28). The framework incorporates imperfect substitutability between short- and long-term government bonds. The model is calibrated to assess how debt levels and maturity structures interact with financing conditions under baseline and stressed scenarios, including heightened rollover risk concerns.

Model Description

The model is a New Keynesian framework with a representative household that derives utility from not only from consumption but also holding government bonds, following the *bonds-in-utility* specification of Alpanda and Kabaca (2020) and Mian, Straub, and Sufi (2025). The household consumes, supplies labor, and allocates its portfolio between short- and long-term government bonds. Liquidity services are generated by an aggregator with constant elasticity of substitution over short- and long-term bonds, allowing imperfect substitutability across different maturities. The elasticity of substitution governs how household responds to relative returns, while portfolio weights determine the steady-state maturity structure.

Household optimization yields standard Euler equations augmented by liquidity premia. As a result, bond demand depends on not only expected real returns but also the household's marginal utility of liquidity. Labor supply is chosen subject to disutility of work, with the labor wedge pinned down in steady state by a target level of hours.

In the model, firms operate under monopolistic competition with quadratic price adjustment costs à la Rotemberg (1982). Output is linear in labor and productivity, with a fixed-cost normalization ensuring zero steady-state profits. Inflation dynamics are governed by a forward-looking New Keynesian Phillips curve that links inflation to expected future inflation and real marginal costs.

Monetary policy follows a Taylor rule with interest rate smoothing, responding to deviations of inflation and output from steady state. The short-term borrowing cost depends on the policy rate as well as a risk premium, which is sensitive to changes in short-term government debt. This captures the sensitivity of investors to rollover concerns (deactivated in the baseline but introduced in the stressed scenario). Long-term interest rates are linked to bond prices through a coupon-based maturity structure.

Fiscal policy features government spending, non-distortionary lump-sum taxes, and debt issuance at multiple maturities. The government budget constraint accounts explicitly for the servicing costs of short- and long-term debt. Taxes respond to total government debt, allowing for fiscal feedback rules and temporary tax constraints.

¹ Prepared by Anh Dinh Minh Nguyen

Calibration

Online Annex Table 1.3.1 summarizes the key parameter values.

Online Annex Table 1.3.1 Selected Model Parameters

Parameter	Value	Source/Notes
Share of short-term bonds	80%/20%	Simulation objective
Elasticity of substitution (short-term/long-term bonds)	0.4259	Alpanda and Kabaca (2020) (AK)
Discount factor	0.987^4	AK (annual frequency)
Portfolio level in utility	0.06	AK
Price adjustment cost (Calvo equiv.)	0.83^4	Adjusted to annual frequency
Inverse labor supply elasticity	1.5	Between Smets and Wouters (2007) (SW) and Christiano, Eichenbaum, and Evans (2005)
Labor level in utility	21.6	Steady-state hour of 0.32
Gross markup	1.25	AK
Coupon rate for long-term bonds	0.84	5-year maturity for long-term bonds
Taylor rule persistence	0.8^4	Standard value, for example, SW, Born and Pfeifer (2014) (BP) (annual frequency)
Taylor rule inflation coefficient	1.5	Standard value (for example, AK, BP)
Taylor rule output gap coefficient	0.1	Standard value (for example, SW, BP)
Tax rule debt response	0.1	Traum and Yang (2015)
Short-term borrowing cost sensitivity to short-term debt	0.1	Rollover stress scenario

Scenarios and Simulations

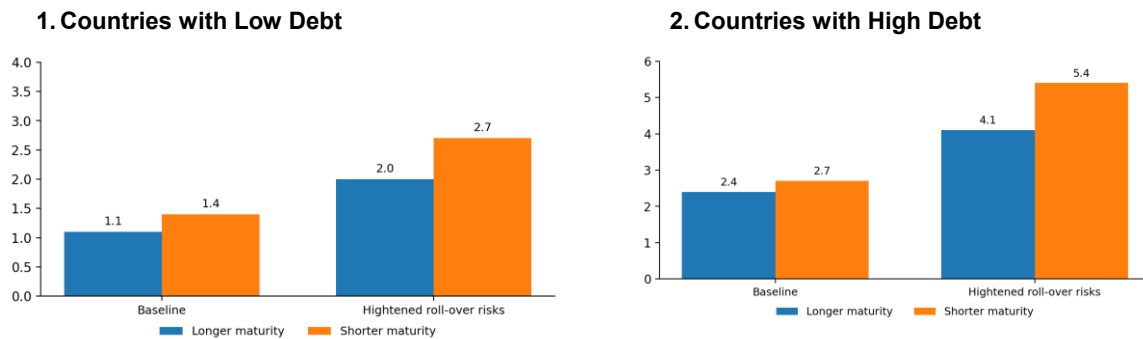
The simulations are calibrated for two public debt levels: a low-debt case (60 percent of GDP) and a high-debt case (100 percent of GDP). For each debt level, two alternative debt compositions are considered: a short-maturity structure, in which 80 percent of outstanding debt is short term, and a long-maturity structure, in which 80 percent of debt is long term (Online Annex Figure 1.3.1). These assumptions are illustrative.

Baseline Scenario. The baseline scenario features a temporary increase in short-term borrowing costs of 2 percentage points, with a half-life of 1.6 years. The shock can be interpreted as a moderate tightening in financial conditions, similar to the magnitude of rate increase for Italy in 2011, resulting in an increase in risk premiums. The macroeconomic impact is mitigated by two stabilizing forces: an endogenous

monetary policy response and household preference for safe and liquid assets, captured through the inclusion of government bonds in agents’ utility. This scenario serves as a benchmark in which markets function normally.

Heightened Rollover Risk Scenario. The shock is identical to the baseline, but the scenario is designed to capture heightened concerns about debt rollover risks, leading investors to demand higher premiums, particularly on short-term debt nearing maturity. The scenario jointly features higher short-term risk premiums (by 2 percentage points as in the baseline), a lower convenience yield by halving the portfolio preference level in utility to 0.03 (that is, investors attach less value to the safety or liquidity services of government debt, potentially reflecting heightened fiscal risks or increased uncertainty), and impaired contemporaneous monetary policy impact on short-term yields (that is, no immediate reduction in the borrowing cost when central bank lowers policy interest rate in response to the shock, reflecting constraints on policy effectiveness, such as credibility challenges and financial market segmentation). The interaction of these channels disproportionately affects short-maturity debt structures and high-debt economies, underscoring the potential vulnerabilities associated with unfavorable debt compositions under stressed financial conditions. High-debt countries experience roughly double the increase in the debt-to-GDP ratio (from 1.1 to 2.4 percentage points) in response to the financial shock, while greater reliance on short-term financing and the presence of rollover risks further amplifies these effects (Online Annex Figure 1.3.1).

Online Annex Figure 1.3.1. Changes in Government Debt-to-GDP Ratio in Response to a Tightening of Global Financial Conditions
(Deviation from steady state in percentage points)



Sources: IMF staff calculations.

Note: The figure shows the change in the contemporaneous debt-to-GDP ratio following a tightening in global financial conditions (that is, a risk premium shock). Each bar represents a different scenario, varying along three dimensions: country indebtedness, debt maturity structure, and rollover risk.

Online Annex 1.4. Impact of Social Unrest on Government Budgets¹

This annex outlines the data and methodology used to assess the budgetary impact of social unrest. The analysis examines whether social unrest is associated with worsening fiscal balances through two potential channels: (1) social unrest reduces economic growth, which is often related to weaker fiscal outcomes, and (2) social unrest shifts political equilibria that could shape public demand and fiscal policy. Using panel vector autoregression (PVAR) techniques, the annex quantifies the magnitude and persistence of these effects.

Methodology

The analysis employs a PVAR framework with three variables: real GDP growth, the Reported Social Unrest Index, and fiscal balances. The model is estimated at annual frequency. Given that economic theory does not prescribe a clear contemporaneous ordering, the model is estimated for all six possible Cholesky orderings to assess robustness with results consistent across all permutations. The estimation focuses on correlation rather than establishing a causal relationship between social unrest and fiscal outturns.

Data

The sample covers an unbalanced panel of countries from 1990 to 2024. The social unrest measure is the RSUI developed by Barrett and others (2022), which captures media reports of social unrest events. Fiscal variables and GDP growth rates are obtained from the World Economic Outlook database. The number of countries rises over time from about 90 countries in the mid-1990s to about 130 countries in the 2010s.

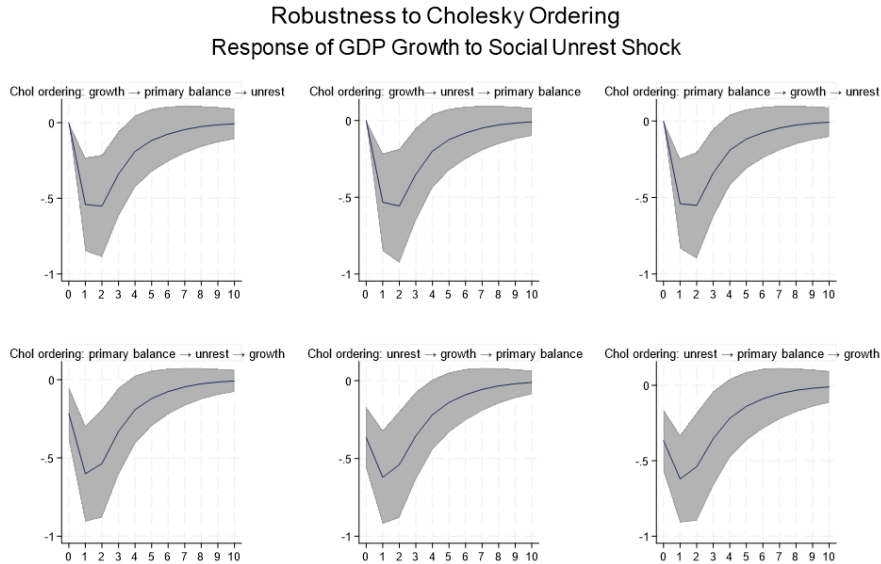
Results

Empirical results show that a one-standard-deviation increase in the social unrest index is associated with a statistically significant decline in real GDP growth of approximately 0.5 percentage point in the first year and the negative effects tend to be persistent over next five years. This result holds for the full sample as well as for advanced and emerging market economies separately ([Online Annex Figure 1.4.1](#)).

In addition, a one-standard-deviation increase in social unrest is associated with a deterioration in the primary fiscal balance of approximately 0.2 percentage points in the first year alone.

¹ Prepared by Carlos Goncalves

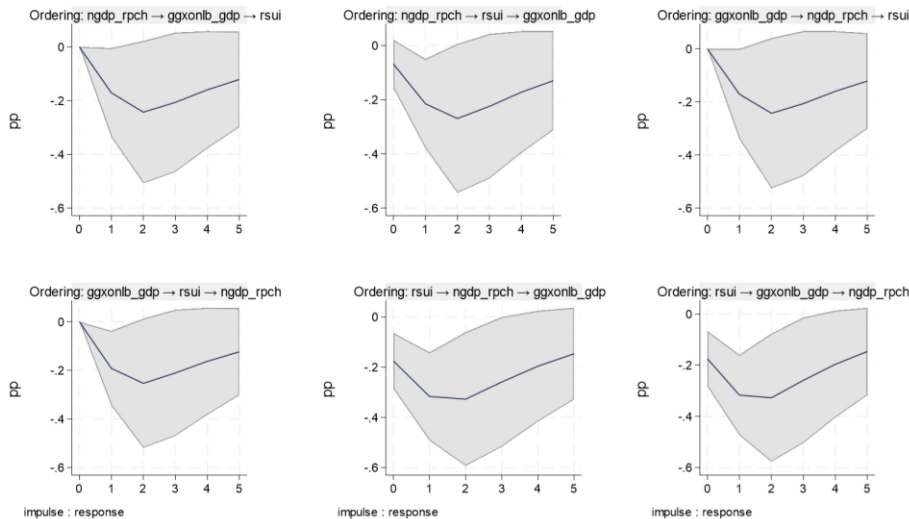
Online Annex Figure 1.4.1. Impulse Response of GDP Growth to a One-Standard-Deviation Social Unrest Shock
(Percentage deviation)



Source: IMF staff calculations.

Note: Panel VAR (PVAR) estimation using the Stata PVAR package. Shaded areas denote 90 percent confidence intervals. Each panel represents a different Cholesky ordering.

Online Annex Figure 1.4.2. Impulse Response of Fiscal Balances to a One-Standard-Deviation Increase in Social Unrest Shock
(Deviations in percentage points of GDP)



Source: IMF staff calculations.

Note: Panel VAR vector autoregression (PVAR) estimation using the Stata PVAR package. Shaded areas denote 90 percent confidence intervals. Each panel represents a different Cholesky ordering.

Online Annex 1.5. Impact of Official Development Assistance Cuts on Government Budgets¹

This annex outlines the data and methodology to assess the fiscal impact of official development assistance (ODA) on low-income developing countries.

Methodology

To analyze how ODA declines have historically affected government budgets, the following specification is estimated:

$$y_{i,t+h} - y_{i,t-1} = \beta_{ph} * I_{it}[\Delta x_{i,t} > 0](\Delta x_{i,t}) + \beta_{nh} * I_{it}[\Delta x_{i,t} < 0](\Delta x_{i,t}) + \phi_h c_{i,t} + \delta_{N,i} + \delta_{T,t} + e_{i,t+h}^h, \quad (\text{Eq.5.1})$$

where i denotes the country; t denotes the fiscal year; h denotes the time horizon over which the cumulative change in the outcome variable y is estimated; y is the budget item including government revenues (including grants), government expenditures, primary balance, and spending by type, that is, public investment, expenditures on health and social benefits; Δx is change in ODA disbursements; $c_{i,t}$ is a vector of control variables including two lags of x and y , lagged values of real GDP growth rate, growth forecast, inflation, foreign direct investment flows, GDP per capita as a proxy for institutional quality as well as indices for regulatory quality and government effectiveness, and an indicator for incidence of a disaster; $\delta_{N,i}$ and $\delta_{T,t}$ are country and time fixed effects respectively. y and x variables are expressed as percent of nominal GDP. Standard errors are clustered by year. Results present coefficient estimates with 90 percent confidence intervals.

The analysis distinguishes between historical episodes of ODA increases ($I_{it}[\Delta x_{i,t} > 0]$) and ODA decreases ($I_{it}[\Delta x_{i,t} < 0]$), to allow for asymmetric impact of changes in ODA. The asymmetry may arise from different adjustment costs (for example, it may be easier to cut spending on an existing project than to start spending on a new project due to startup costs). Coefficient estimates based on historical decreases in ODA (β_{nh}) are presented, to correspond with the current and projected declines in ODA.

Data and Sample

The country sample consists of an unbalanced panel (subject to data availability) of 56 countries identified as low-income countries based on the IMF *World Economic Outlook* classification. Data on gross ODA disbursements are taken from the Organisation for Economic Co-operation and Development; disbursements related to humanitarian aid, technical cooperation, and food aid are excluded, since these categories are likely to be endogenous to country-specific events. Data on fiscal aggregates and macroeconomic control variables are taken from the World Economic Outlook database. Indices of regulatory quality and government effectiveness are taken from the World Bank World Governance Indicators, and the indicator for natural disasters is developed from the Emergency Events database.²

Results

Online Annex Figure 1.5.1 shows the impulse-responses (that is, the estimates of β_{nh}), scaled to reflect a 1 percentage point of GDP decrease in ODA flows.³ Results show that a decrease in ODA flows is

¹ Prepared by Salma Khalid with assistance from Victoria Haver.

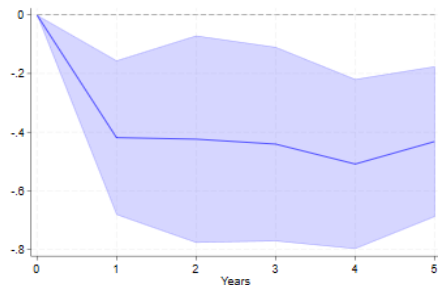
² See <https://www.emdat.be>.

³ Coefficient estimates are multiplied by -1 to reflect a decrease in ODA flows.

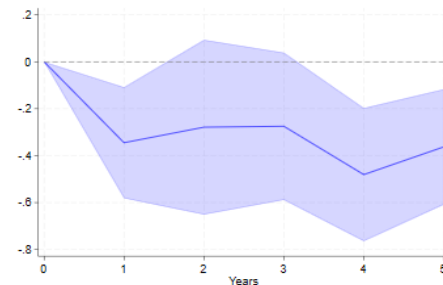
associated with a persistent decrease in total government revenues over the subsequent four years, and a commensurate decrease in total government expenditures though near-term expenditures tend to be stickier and the decline is less pronounced than that of revenues. Consequently, the primary balance deteriorates in the near term, but the effect dissipates in the medium term. The short-term impact on government investment is not statistically significant, reflecting expenditure stickiness, but the medium-term impact is negative and statistically significant at the 5 percent level. Health expenditures (the sector most closely tied to ODA flows) show a similar permanent decline over the medium term, while social benefit expenditures decline in the near term.

Online Annex Figure 1.5.1. Impulse-Responses of Macro Variables on Official Development Aid Decline
(Percent of GDP)

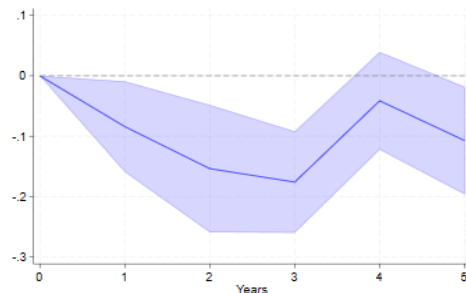
1. Government Revenues (including grants)



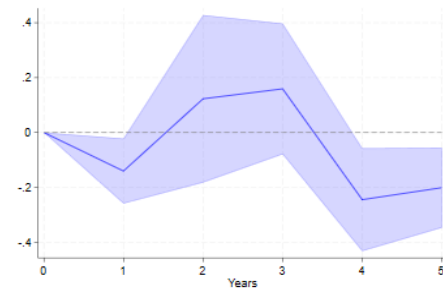
2. Government Expenditures



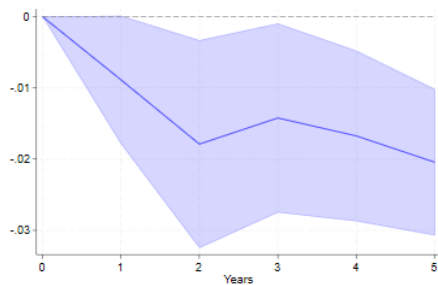
3. Government Primary Balance



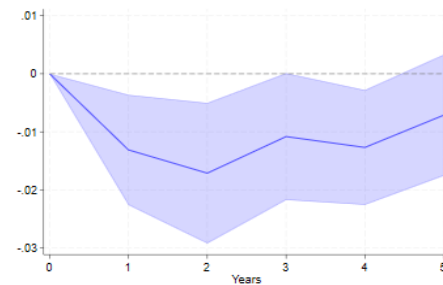
4. Public Gross Fixed Capital Formation



5. Government Expenditures: Health



6. Government Expenditures: Social Benefits



Sources: IMF staff calculations.

Note: The charts in the figure show estimates of parameter $\beta_{nh}^* - 1$, to reflect the change in the outcome variable with respect to a 1 percentage point of GDP decline in official development assistance flows. The shaded areas show the 90 percent confidence intervals using standard errors that allow for dependence across years.

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