Transmission Growth-at-Risk

How Foreign Financial Vulnerabilities Shape U.S. Growth Prospects

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Motivation

2010-12 European sovereign debt crisis

- Banks' large sovereign exposures, high leverage, and dollar funding mismatches

Presumed risks to U.S. growth: But channels, mechanisms, and magnitudes?

Questions

- Do foreign financial vulnerabilities worsen U.S. downside growth risk?
- Through which channels?
- Do they amplify foreign financial condition shocks?
- Do they improve predictive power?

Conceptual Framework: Conditions vs Vulnerabilities

Financial Conditions

- Transitory shocks
- Current financial market tightness
- Based on financial variables
- Predict near-term tail risks to GDP

VS

Financial Vulnerabilities

- Slow-moving state variables
- Structural fragilities (valuations, financial, nonfinancial, sovereign)
- Predict crisis timing and severity
- Predict medium-term tail risks to GDP

FCI x FVI interaction = non-linear amplification

- Vulnerabilities amplify condition shocks: Same shock, a larger risk when vulnerabilities high
- Theory: Financial accelerator (Bernanke–Gertler), belief-based reversals (Minsky), fire sales (Brunnermeier–Sannikov)
- Distinct from Adrian et al. (2022)'s credit boom dummy

Data

- **Sample**
  - U.S. + 21 foreign economies (major AEs + China, Mexico, Russia)
  - 1995:Q1 – 2023:Q4 (116 quarters)
- **Data sources**
  - GDP: OECD
  - Financial conditions indexes (FCIs): Chicago Fed NFCI and IMF
  - Financial vulnerability indexes (FVIs): Lee et al. (2020) comprehensive index and components (valuations, financial, nonfinancial, and sovereign)
  - Dollar integration: Benetrix et al. (2019)'s share of external assets & liabilities in USD

TGaR Models: Adrian et al. (2019) + Foreign Terms

Baseline TGaR model at 4- and 8-quarter horizons

$$Q^{GDP}(5^{th}\ \text{percentile}) = \alpha + \beta 1 \cdot GDP^{Us} + \beta 2 \cdot FCI^{Us} + \beta 3 \cdot FVI^{Us} + \beta 4 \cdot FVI^{for} + \beta 5 \cdot FCI^{for} + \varepsilon$$

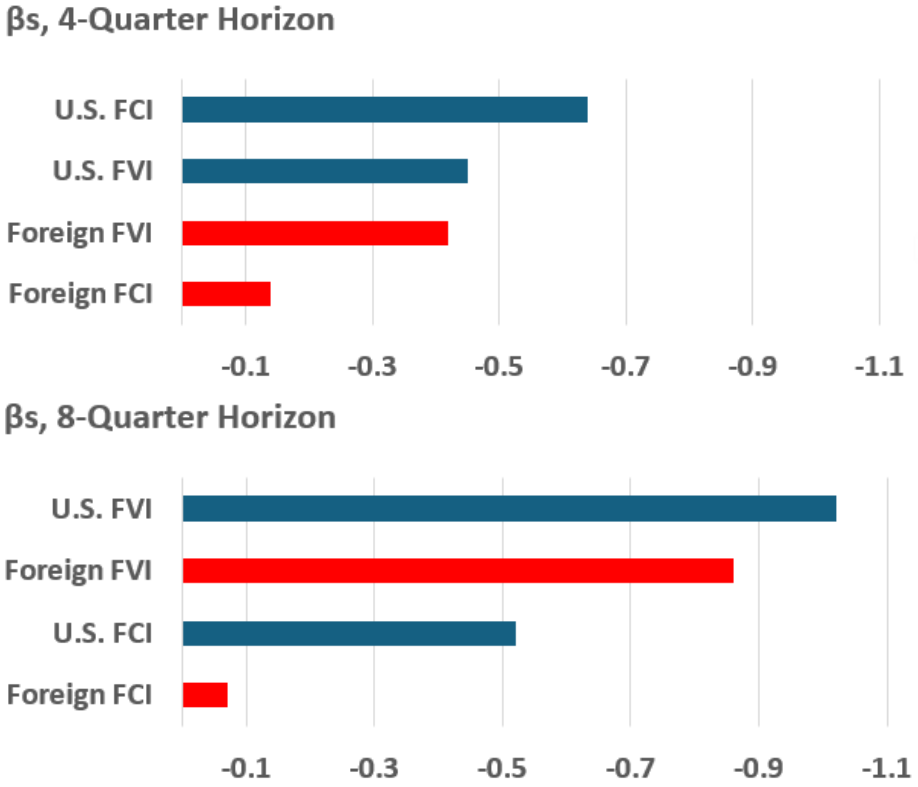
Adrian et al. (2019) — Novel components

Novel nonlinear amplification model

Adds a term: $\beta 6 \cdot FVI^{for} \times FCI^{for}$

- All variables standardized (zero mean, unit variance)
- Foreign FCI orthogonalized to U.S. FCI (isolate exogenous foreign shocks)
- FVI is a slow-moving stock variable (limits contemporaneous reverse causality)

Baseline Results: (Foreign) FVIs Dominate Medium-Term

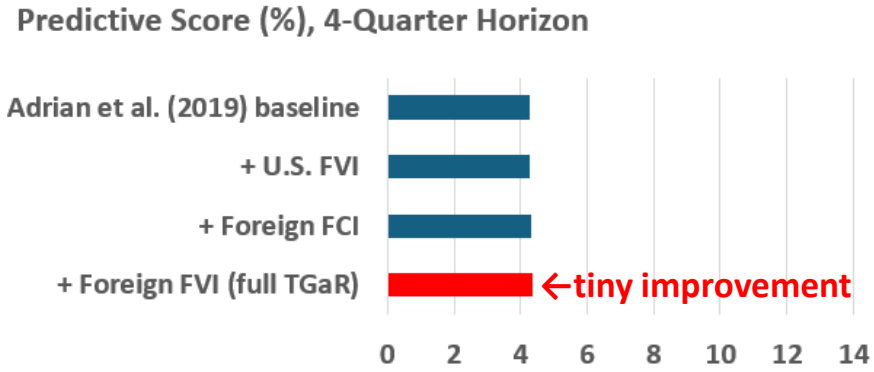


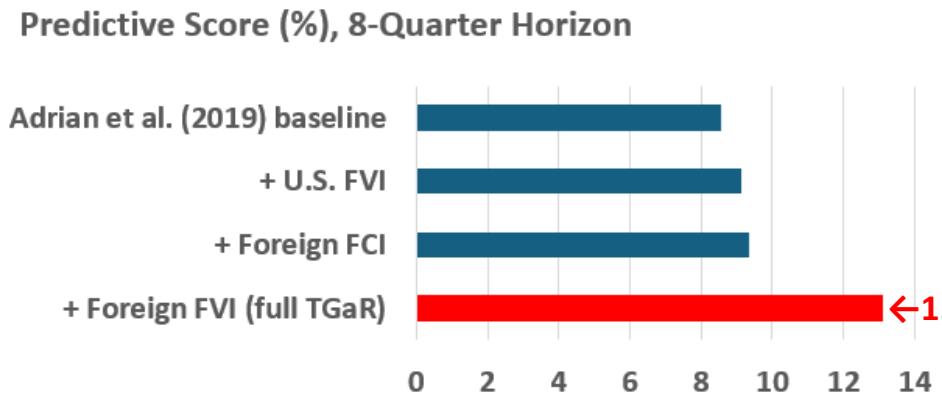
- **U.S. FCI dominates near-term**
  - Consistent with Adrian et al. (2019, 2022)'s term structure
- **FVIs dominate medium-term:**
  - No sign reversal over horizons
  - Effects strengthen over horizon
  - Consistent with state variables
- **Foreign FVI effects >>> foreign FCI effects**

U.S. Growth-at-Risk: Foreign Developments Matter

- Foreign FVI matters most when foreign financial systems are stressed
- Foreign episodes with distinct characteristics: Euro crisis vs Brexit

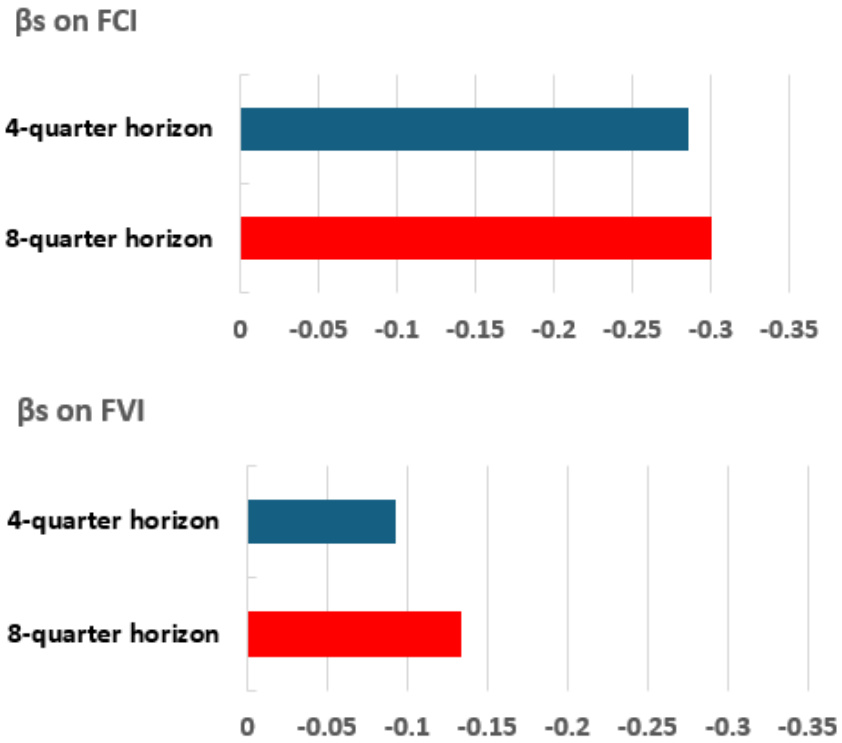
Out-of-Sample Forecast Performance





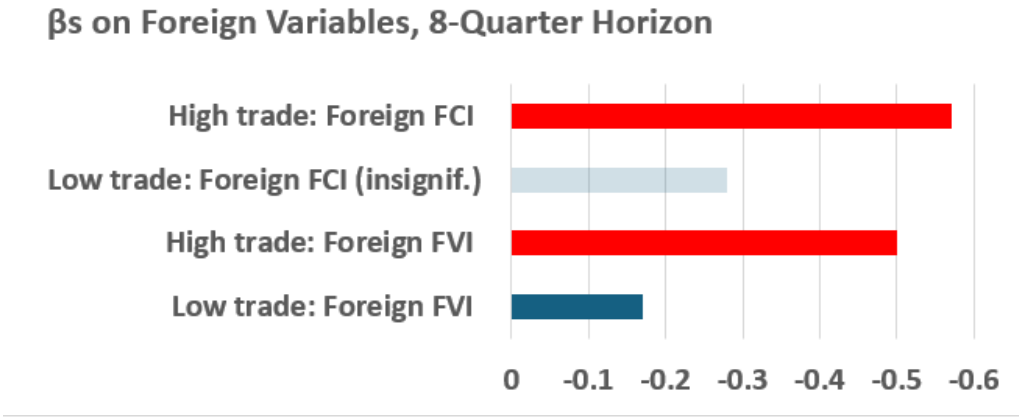
- **Monotonic improvement**: Each component adds value, capturing distinct risk dimensions
- **Term structure result**: FVIs are slow-moving state variables with medium-term effects
- Jump in predictive scores **mostly due to foreign FVI**
- Defense against endogeneity and spurious correlation

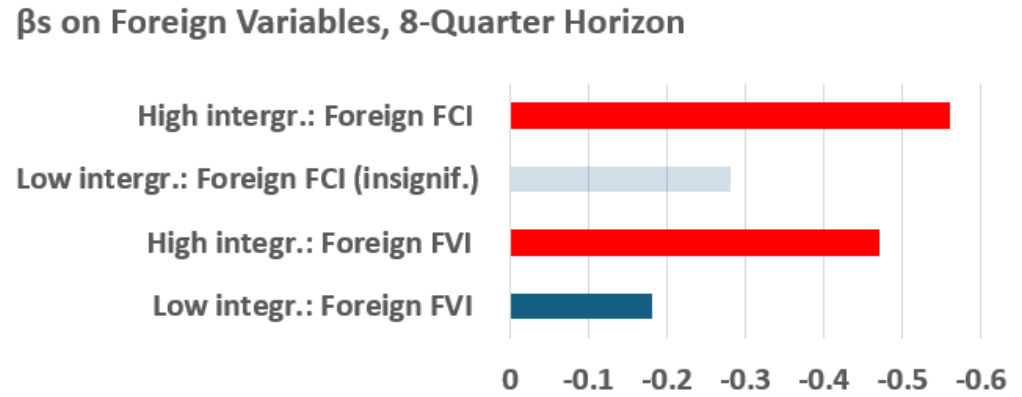
Building Block for Transmission Channels: GaR Abroad



- For trade channel to operate, foreign vulnerabilities must worsen foreign growth
- Panel quantile regression (5^{th} percentile): 21 foreign economies, 1995:Q1–2023:Q4
- Novel result: Foreign FVIs predict downside risk to foreign growth
- FCI effects are larger, FVI effects strengthen over horizon

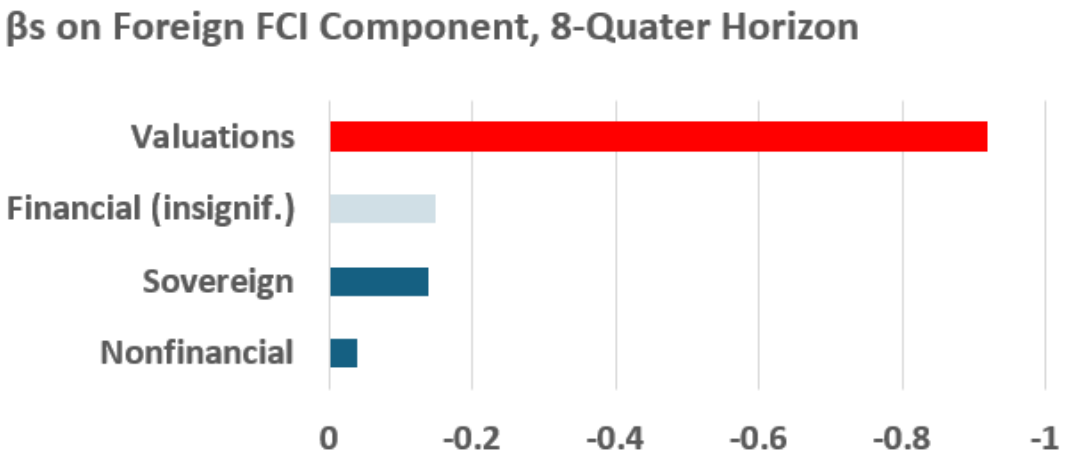
Transmission: Trade and Dollar Integration Channels





- Trade: Foreign vulnerabilities → worse foreign growth → reduced demand for U.S. exports → lower U.S. GDP
- Integration (possibly): Vulnerable foreign investors curtail dollar lending & sell U.S. assets → tighter U.S. credit conditions
- Country breakdowns not identical
- Channels have similar magnitudes—both matter, neither dominates

Which Foreign Vulnerabilities Matter Most?

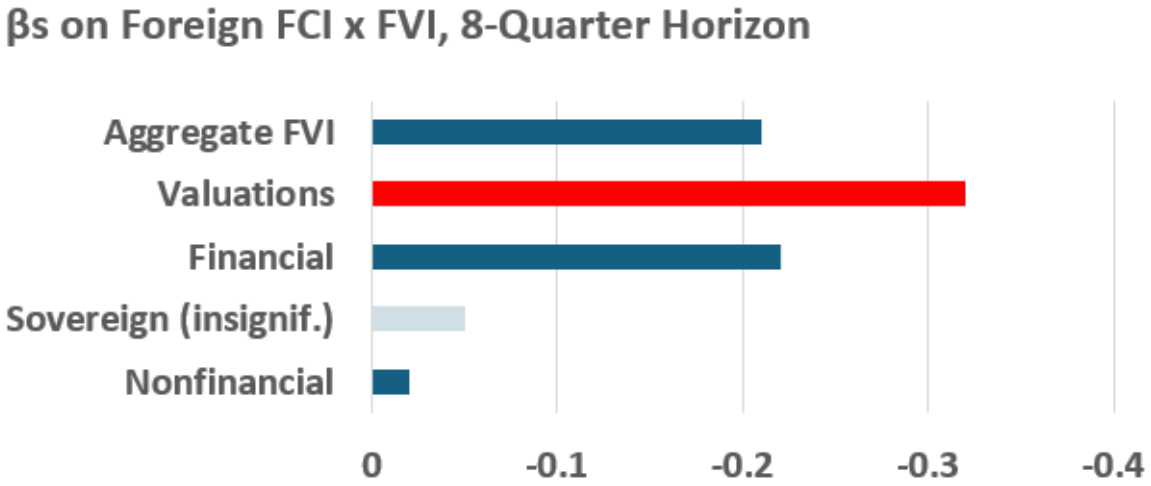


- Valuation pressures dominate
- Valuations as triggers: Stretched valuations → sharp corrections → mark-to-market losses, margin calls, fire sales (Brunnermeier-Sannikov)
- Consistent with valuations peaking earliest before financial crises (Lee et al. (2020))

Amplification: Vulnerabilities × Conditions

Nonlinear amplification model

Base TGaR + $\beta 6 \cdot FVI^{for} \times FCI^{for}$



- Elevated vs low foreign FVI: Same shock → substantially larger U.S. growth effects
- Strongest amplifiers: Valuation pressures and financial vulnerabilities—precisely where theory predicts tightening credit triggers forced deleveraging (Brunnermeier-Sannikov).
- Validates further conditions-as-shocks, vulnerabilities-as-amplifiers framework

Robustness Checks

- Results not driven by
  - Extreme tail behavior
    - 25th percentile GaR: Coefficients smaller in magnitude, all significant
  - Common global factors in financial vulnerabilities
    - Orthogonalized Foreign FVI
  - Lee et al. (2020) FVIs
    - Replacing Lee et al. FVI with IMF FSIs yields comparable results (coefficients and predictive scores)
    - Poor predictive performance of credit-to-GDP measures

Takeaways

1. Foreign vulnerabilities ≠ foreign conditions
   Distinct horizon profiles, amplification mechanisms
2. Foreign vulnerabilities significantly worsen U.S. growth prospects
   1.5x forecast improvement at 8-quarter horizon
3. Dual transmission: Trade and dollar funding channels both matter
   Similar magnitudes—neither dominates
4. Valuation pressures are the dominant amplifier
   6x larger effects than that of other vulnerabilities

Implication: Monitor foreign conditions AND vulnerabilities to assess medium-term growth risks

Transmission Growth-at-Risk: How Foreign Financial Vulnerabilities Shape U.S. Growth Prospects

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Abstract

We document a novel empirical pattern: Elevated foreign financial vulnerabilities shift the *entire* U.S. growth distribution leftward, not merely the downside tail, suggesting structural effects on potential output rather than purely cyclical impacts. This stands in sharp contrast to financial conditions, which primarily affect tail risk. Building on Adrian et al. (2019)'s Growth-at-Risk framework, we develop a Transmission Growth-at-Risk (TGaR) model that treats foreign financial conditions as shocks and foreign vulnerabilities as shock amplifiers. While the effects of financial conditions peak in the near term, foreign vulnerabilities weigh on U.S. GDP at a medium-term horizon, consistent with vulnerabilities being slow-moving state variables. Asset valuation pressures and financial sector leverage abroad are key amplifiers, operating through trade and dollar funding channels of similar magnitude. Out of sample, TGaR improves significantly predictive accuracy. During the European sovereign debt crisis from 2010 to 2012, elevated European vulnerabilities shifted the U.S. growth distribution leftward by about 1.5 percentage points despite stabilizing domestic conditions. In the Global Financial Crisis, U.S.-originated shocks were amplified by foreign vulnerabilities and returned to worsen domestic outcomes, illustrating "spillback" effects beyond standard one-way spillover models.

Keywords: Growth-at-Risk, Financial Vulnerabilities, Risk Assessment
JEL Classification: E32, F42, G01, G15

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1 Introduction

In late 2009, fiscal concerns in Greece triggered a sovereign debt crisis that spread across peripheral Europe. Policymakers and market participants presumed that European financial stress would weigh on U.S. growth prospects, even as domestic U.S. financial conditions stabilized. European banks held substantial sovereign exposures while operating with high leverage and significant reliance on short-term dollar funding—vulnerabilities that raised concerns about transmission to the United States. However, the channels through which such foreign vulnerabilities might affect U.S. growth, the mechanisms that could amplify shocks, and the magnitudes of potential effects remained poorly understood and unmeasured.

Similar concerns arose about spillback effects. During the 2008–09 Global Financial Crisis, the shock originated in U.S. subprime mortgage markets but spread globally. Many observers presumed that elevated foreign financial vulnerabilities—particularly in European banking systems with large U.S. dollar funding needs—amplified the crisis and fed back to worsen U.S. outcomes. Yet whether such spillback mechanisms actually exist, how they operate, and their quantitative importance remain open questions. For U.S. policymakers, answering these questions matters: if domestic shocks can return amplified through foreign financial systems, then monitoring foreign vulnerabilities becomes important for understanding the full domestic impact of U.S.-originated stress events.

This paper develops a **Transmission Growth-at-Risk (TGaR) framework** to measure these effects systematically. We distinguish conceptually and empirically between financial conditions (transitory shocks like tightening credit markets) and financial vulnerabilities (structural fragilities like accumulated leverage and asset overvaluation that amplify shocks). Building on Adrian et al. (2019), we employ quantile regressions to estimate the conditional distribution of U.S. GDP growth, incorporating both foreign financial conditions and foreign financial vulnerabilities as explanatory variables. Our sample covers 21 major economies representing over 75% of global GDP from 1995 to 2023. We aggregate foreign financial conditions from established sources and construct comprehensive foreign financial vulnerability

indexes following Lee et al. (2020). We orthogonalize foreign financial conditions with respect to U.S. conditions to isolate truly exogenous foreign shocks. This framework allows us to test whether foreign vulnerabilities shift U.S. growth distributions, quantify amplification effects, and identify transmission channels through trade and financial linkages.

We make four primary contributions to the literature. First, we establish that foreign financial vulnerabilities shift the entire U.S. growth distribution leftward—not merely the downside tail—with fundamentally different properties from financial conditions. Financial condition indexes (FCIs) measure the current tightness of credit markets and naturally correspond to transitory shocks. Financial vulnerability indexes (FVIs) measure structural fragilities that amplify shocks' economic effects. We incorporate comprehensive FVIs alongside FCIs for both U.S. and foreign economies into quantile Growth-at-Risk regressions.

We find that financial vulnerabilities and conditions have different effects over different horizons. Financial conditions primarily affect near-term growth risk (over the next four quarters), with effects that dissipate over time. In contrast, vulnerabilities have larger effects at medium-term horizons (eight quarters and beyond), consistent with vulnerabilities acting as slow-moving state variables that constrain potential output. Most strikingly, elevated vulnerabilities shift the *entire* growth distribution leftward—reducing expected growth, median growth, and upside potential simultaneously. This pattern contrasts sharply with financial conditions, which primarily affect the lower tail, and suggests that vulnerabilities have structural effects on potential output rather than purely cyclical demand impacts.

Foreign vulnerabilities exhibit substantially larger effects (at eight quarters) than domestic U.S. vulnerabilities (which are not statistically significant), motivating our focus on cross-border transmission mechanisms. During the 2010–12 European sovereign debt crisis, elevated European financial vulnerabilities shifted the U.S. growth distribution leftward by approximately 1.5 percentage points despite stabilizing domestic conditions, illustrating the economic magnitude of these effects.

Second, we develop a novel modeling approach by incorporating both financial conditions

and vulnerabilities with their interactions into the GaR framework. Prior GaR studies focused exclusively on financial conditions (Adrian et al., 2019, 2022), while vulnerability research emphasized crisis prediction (Lee et al., 2020). We are the first to model FCIs and FVIs jointly with interaction terms, allowing us to test empirically whether vulnerabilities amplify the effects of financial condition shocks—a key theoretical prediction. We find that foreign vulnerabilities significantly amplify the growth effects of foreign financial condition tightening. When foreign vulnerabilities are low, foreign financial condition shocks have minimal U.S. growth effects. When foreign vulnerabilities are elevated, the same financial condition shock produces substantially larger growth impacts. This amplification mechanism provides empirical validation for our conceptual distinction between conditions as shocks and vulnerabilities as shock amplifiers.

Third, we identify and quantify the transmission channels through which foreign vulnerabilities affect U.S. growth. We construct trade-weighted and dollar-integration-weighted foreign vulnerability indexes to distinguish between real and financial transmission channels. Prior literature on international spillovers has not systematically separated these channels for vulnerability transmission. We find that both channels prove economically important with similar magnitudes (with statistically indistinguishable differences in magnitude), cautioning against emphasizing one channel over the other. We also decompose foreign vulnerabilities into five components—household leverage, corporate leverage, financial sector leverage, asset valuation pressures, and maturity mismatches—identifying which types transmit most powerfully. Asset valuation pressures and financial sector leverage emerge as particularly potent amplifiers, with coefficients nearly double those of other components.

Fourth, we identify a novel "spillback" mechanism with important policy implications. Using the Global Financial Crisis as a natural experiment, we show that even though the shock originated in the United States, heightened foreign vulnerabilities amplified it significantly and delivered spillback effects that exacerbated domestic U.S. downside risks. Our counterfactual analysis suggests that with European vulnerabilities at median rather than

elevated levels, U.S. growth during the crisis trough would have been 1.2 percentage points higher. This challenges conventional unidirectional spillover models where U.S. shocks simply flow outward. Instead, foreign financial fragilities can exacerbate domestically originated crises through amplification and feedback. For U.S. policymakers, this implies that monitoring foreign vulnerabilities is important not only for assessing foreign-originated shocks but also for understanding the full domestic impact of U.S.-originated stress events.

We validate our framework through comprehensive out-of-sample forecast evaluation over 2011–23. TGaR models that incorporate foreign vulnerabilities improve predictive accuracy by 8.57 percentage points at the four-quarter horizon and by a sizable 13.11 percentage points (53% improvement) at the eight-quarter horizon, compared to models using only domestic financial conditions. This superior performance validates both the empirical importance of foreign vulnerabilities and the practical utility of the TGaR framework for policymakers.

The paper is organized as follows: We first review the related literature. Section 2 discusses the Growth-at-Risk framework, the link between financial vulnerabilities and growth, and the channels through which foreign financial stress reaches the United States. Section 3 describes the data, introduces our TGaR framework, and presents baseline estimation and forecast accuracy results. Section 4 analyzes how foreign financial vulnerabilities transmit to the U.S. economy through trade and dollar funding channels, which foreign sectors matter most, and how vulnerabilities amplify financial shocks. Section 5 checks the robustness of our results, and Section 6 concludes.

Literature Review

This paper contributes to three major strands of literature: (1) Growth-at-Risk (GaR), (2) macro implications of financial conditions and vulnerabilities, and (3) transmission of foreign financial risks to the U.S.

The GaR framework gained prominence through Adrian et al. (2019), who established empirical links between financial conditions and the conditional distribution of GDP growth

using quantile regressions. Their key insight was treating growth forecasts probabilistically, visualizing potential outcomes under varied financial scenarios rather than producing point forecasts. Adrian et al. (2022) extended this framework to a panel of 11 advanced economies, examining how financial conditions affect growth distributions at multiple forecast horizons and showing that their effects on downside risks are larger near term and dissipate over longer horizons. Prasad et al. (2019) applied the framework to emerging markets, while Plagborg-Møller et al. (2020) developed and employed local-projection-based GaR methods to study the impact of macroeconomic shocks on growth prospects. Related work by Jovanovic and Ma (2022) and Hengge (2019) uses GaR-style approaches to link economic uncertainty to downside risks in U.S. GDP growth. These studies focus on how domestic financial conditions affect domestic growth distributions within each country. A key gap remains: whether and how foreign financial vulnerabilities, distinct from foreign financial conditions, affect domestic growth distributions, and whether vulnerabilities shift the entire distribution or only the tail. Our contribution is to show that foreign vulnerabilities shift the entire U.S. growth distribution leftward, with effects that peak at medium-term horizons, in sharp contrast to how financial conditions operate.

Our paper also contributes to the literature on predicting the timing and economic severity of financial crises. Borio et al. (2018) document that credit booms and asset price run-ups tend to precede financial crises, while Gourinchas and Obstfeld (2012) analyze credit-to-GDP gaps as early warning indicators. Aikman et al. (2017) and Lee et al. (2020) integrate these insights by constructing financial vulnerability indexes that predict financial crises and banking system stress.[1] These papers establish vulnerabilities as important state variables for crisis prediction but do not address how vulnerabilities affect growth distributions conditional on financial conditions, whether their effects operate at different horizons than conditions, or how foreign vulnerabilities transmit to domestic outcomes. Our contribution is to show that

[1]Similarly, Aldasoro et al. (2018) provide evidence on the role of financial vulnerabilities in predicting banking crises across countries, and Schularick and Taylor (2012) highlight the importance of credit booms as precursors to financial crises. Lee et al. (2020) also shows that comprehensive financial vulnerability indexes explain cross-country variation in the severity of banking crises and the duration of recessions.

vulnerabilities act as shock amplifiers with distinct effects across horizons, shifting entire growth distributions rather than simply predicting discrete crisis events.

The transmission of foreign financial risks to the U.S. economy has also been studied widely, and research on cross-border financial transmission has largely emphasized spillovers from advanced to emerging economies. Rey (2015a) documents a global financial cycle driven by U.S. monetary policy, while Bruno and Shin (2015) and Avdjiev et al. (2019) show that dollar appreciation tightens global financial conditions through banking channels. Gopinath and Stein (2021) highlights the dollar's role in trade invoicing and pricing. This literature establishes that U.S. financial conditions spill over to foreign economies through dollar funding markets and trade channels. An important question remains unresolved: whether and how foreign financial vulnerabilities *spill back* to affect U.S. growth, which types of foreign vulnerabilities matter most, and whether transmission operates symmetrically through trade and financial channels. Our contribution is to quantify these spillback mechanisms, identify asset valuation pressures and financial sector leverage as particularly potent transmitters, and show that trade and dollar integration channels have similar economic magnitudes.

In sum, we integrate comprehensive foreign financial vulnerability measures into an international GaR framework and focus on growth distributions rather than only crisis prediction. This allows us to distinguish empirically between fast-moving financial conditions and slow-moving vulnerabilities, quantify amplification effects from their interactions, and identify transmission channels using trade- and dollar-integration-weighted vulnerability indexes. We also document spillback mechanisms, where U.S.-originated shocks are amplified by foreign vulnerabilities, and show that incorporating these vulnerabilities delivers sizable out-of-sample forecast gains, underscoring the framework's policy relevance for assessing international risks to U.S. growth.

2 Growth-at-Risk (GaR) Framework

The Growth-at-Risk (GaR) framework has been used widely as a quantitative approach to assess downside risks to economic growth originating from financial sector developments. Introduced by the seminal paper Adrian et al. (2019), the GaR framework estimates the empirical relationship between economic growth and U.S. financial conditions using quantile regressions. The International Monetary Fund (IMF) and central banks, such as the Bank of Canada, Bank of England, Bank of Japan, and the European Central Bank, have been using this framework to monitor and quantify financial risks.

2.1 Financial Vulnerabilities and Economic Growth

While the existing literature almost exclusively focuses on the implications of financial conditions for growth-at-risk, we argue that *financial vulnerabilities* have been unfairly neglected. After all, the financial stability literature says that financial vulnerabilities can act as amplifiers for a financial shock because they create conditions where a shock can have a more significant and widespread effect on the financial system and hence the economy. And there are numerous papers that demonstrate that financial vulnerabilities not only predict the timing of financial crises but also their economic severity (e.g., Lee et al. (2020)).

The connections between current financial conditions and future financial vulnerabilities give another strong reason to analyze the effects of both in the GaR framework. Indeed, when financial conditions are loose (think of periods of low interest rates and easy credit), vulnerabilities can build up more quickly as firms, households, and financial intermediaries take on more debt and risk and valuation pressures increase. Such a build-up can lead to a greater risk of future financial crises and a sharper downturn in economic growth. So the incorporation of financial vulnerabilities in the GaR framework may clarify the nature of an intertemporal trade-off: Lower growth vulnerability at the medium term may come at the cost of lower GaR or more generally expected growth in the short term, as in Adrian et al. (2022).

In translating the financial stability literature to the Growth-at-Risk literature, we financial vulnerabilities act as structural factors or slowly moving state variables and tight financial conditions as adverse financial shocks, with the extent of tightness indicating the magnitude of a shock.[2] In this framework, elevated financial vulnerabilities may weigh on economic growth directly and they may amplify the effects of financial shocks, so that even a modest shock may have significant economic effects if the financial system is particularly weak. In other words, as structural factors, financial vulnerabilities can not only affect the responsiveness of GaR to financial conditions but also a central tendency of the growth distribution.

Financial vulnerabilities can amplify adverse shocks and significantly affect GaR, particularly during economic downturns, for multiple reasons. For example, firms and households with high leverage or mismatched assets and liabilities are more vulnerable to interest rate hikes, credit tightening, or market stresses. These vulnerabilities can lead to a cascade of defaults, bankruptcies, and credit contraction, exacerbating the negative effect of the initial shock.

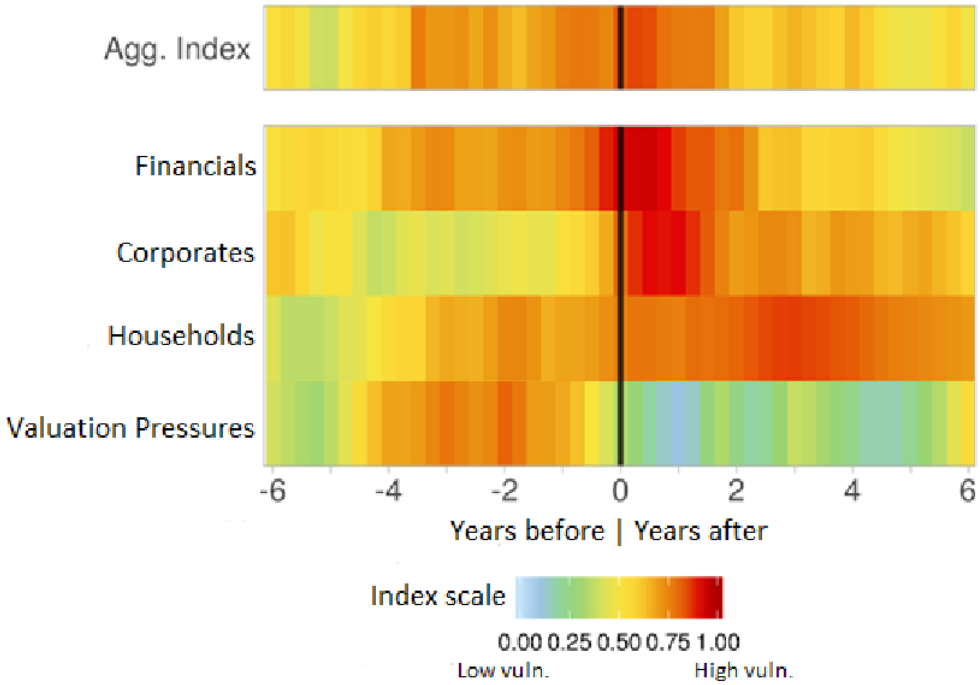
When translating the financial stability literature to the Growth-at-Risk literature, we have to quantify financial vulnerabilities. While the literature offers many options, we focus first on aggregate financial vulnerability indexes. The predictive performance of comprehensive financial vulnerability indexes exceeds especially at long horizons that of measures of a build-up in a specific financial vulnerability, the credit-to-GDP gap, or the total debt service ratio, see Lee et al. (2020).[3] We also examine the performance of sectoral components of comprehensive financial vulnerability indexes because we are interested in the term structure of growth-at-risk and because the literature shows that the predictive power of

[2]This interpretation is consistent with the evidence in Lee et al. (2020) and Vermeulen et al. (2015b) that changes in financial conditions or financial stress indexes are related to the occurrence of financial crises, there is only a very weak relationship or not relationship at all between these indexes and the onset of a crisis.

[3]The credit-to-GDP gap has been touted as one of the best predictors of systemic banking crises at longer horizons and, hence, suited to be the benchmark in setting counter-cyclical capital buffers, see Drehmann and Juselius (2014).

financial vulnerabilities varies across financial sectors and time horizons.

Figure 1. Sectoral Financial Vulnerabilities Around Crises



Note: This figure shows the average levels of vulnerability indexes across advanced economies (including the United States) in five-quarter windows centered on 21 financial crises during 1970–2017. The five vulnerability components are household leverage, corporate leverage, financial sector leverage, asset valuation pressures, and maturity mismatches. Darker shading indicates higher vulnerability levels. Crisis definitions and timing are from Laeven and Valencia (2020).

To illustrate heuristically the point that specific vulnerabilities function as early warning indicators at different horizons, we construct a heatmap using Lee et al. (2020)' data. The heatmap in Figure 1 shows that the average levels of the vulnerability indexes by sector across advanced economies around 21 financial crises. It highlights which sectors exhibit significant vulnerabilities leading up to these crises. The heatmap uses a color gradient to represent the intensity of vulnerabilities, with warm (cold) colors indicating higher (lower) levels of risk. Notably, financial vulnerabilities tend to peak shortly before a crisis, confirming their role as useful early warning indicators. By aggregating data across multiple sectors, the heat map provides a comprehensive overview of the systemic vulnerability in the economy.

We note that financial vulnerabilities are also relevant for the economy outside financial

crises. The literature suggests that financial vulnerabilities can pose downside risks to growth because they can generate macro-financial linkages. In financial accelerator theories, the relaxation of financial constraints during good times results in a high volume of credit and leverage that can later amplify the impact of negative shocks on future economic activity (Bernanke and Gertler, 1989; Holmström and Tirole, 1997; Brunnermeier and Sannikov, 2014). In belief-based theories (Minsky, 1977, 1986; Kindleberger, 1978; Bordalo et al., 2018), variations over time in investor beliefs result in elevated risk appetite during periods of optimism that lead to large expansions in credit and highly compressed risk spreads, which are predictably followed by a reversal in risk appetite, a widening of credit spreads, and a higher probability of crisis once risks materialize.

In addition to predicting crises, financial stress from abroad has direct implications for the U.S. economy, which we will discuss next.

2.2 Transmission of financial stress abroad to the United States

The U.S. financial system is exposed to transmission of shocks from abroad, due to its central importance in global economic and financial markets. Foreign shocks can affect the U.S. financial system via several channels, including through U.S. dollar funding markets, U.S. Treasury markets, U.S. financial institutions' interconnectedness with foreign global systemically important banks, asset markets, and the U.S. real economy. Through these channels, foreign stress can spill over to the U.S. financial system, weighing on asset prices, disrupting financial intermediation, and increasing default and insolvency risk.

The past two decades have witnessed several notable transmission events, resulting in the recession during the global financial crisis of 2007-09, the run on U.S. money market funds during the euro-area crisis of 2011, and foreigners' unprecedented sell-off of U.S. Treasury securities following the onset of the COVID-19 pandemic in March 2020. Earlier events like the Latin American debt crisis in the 1980s and the Asian financial crisis in 1997-98, while less relevant today due to the decreased prevalence of pegged exchange rates, also exemplify

such a transmission.[4]

Furthermore, the magnitude of such transmitted shocks is not predetermined and can be significantly amplified. The impact of global financial cycles, for example, can be particularly intensified by foreign vulnerabilities, as highlighted by Rey (2015b). Specifically, vulnerabilities such as high leverage and significant external debt can act as powerful amplifiers of global financial shocks. Countries exhibiting these characteristics, often reflected in their external debt levels or financial risk ratings, are rendered more susceptible to adverse spillovers from the global financial cycle, potentially leading to more pronounced economic downturns.

Consistent with this notion that vulnerabilities act as amplifiers, Foreign financial vulnerabilities can also magnify the economic impacts of shocks from tighter financial conditions. For example, high leverage in the non-financial or financial sectors abroad can exacerbate a shock that tightens financial conditions, increasing default risk in the non-financial sector, deteriorating credit quality, causing significant credit losses, reducing credit supply, and further tightening financial conditions. Such financial stress abroad can then affect the United States through its close economic and financial links, further hindering U.S. economic growth. Additionally, these spillovers can interact with domestic shocks and be exacerbated by existing U.S. financial vulnerabilities, such as inadequate capitalization, liquidity, and risk (mis)management.

3 Data and Estimation Results

3.1 Data

Data for GDP growth at the country level are sourced from the OECD Main Economic Indicators. The data for the U.S. NFCI are from the Chicago Fed, and the data for foreign country-level financial conditions are from the IMF.[5] The financial conditions indices are

[4] In the appendix, we examine the Asian financial crisis through the lens of TGaR.

[5] The results using the IMF's FCI for the U.S. are very similar to those using the Chicago Fed's NFCI. We use the NFCI as the benchmark FCI to compare our results with those from Adrian et al. (2019).

constructed based on the methodology from Koop and Korobilis (2014), which extracts latent FCIs from 18 financial variables (e.g., interest rates, exchange rates) while accounting for growth and inflation through a time-varying parameter factor-augmented vector autoregression model. This approach purges the FCI of the effects of macroeconomic conditions and allows for evolving relationships between financial and macroeconomic variables over time. It is worth noting that the resulting FCIs are explicitly designed to be useful for predicting macroeconomic variables such as GDP growth and inflation. The baseline sample includes 22 major economies, covering about 76 percent of world GDP (as of 2023), and runs from 1995:Q1 to 2023:Q4.[6]

3.1.1 Financial Vulnerability Indexes

Financial vulnerability indexes are constructed following the methodology of Lee et al. (2020), which aggregates vulnerabilities across five key dimensions that capture structural fragilities in the financial system. This comprehensive approach has been shown to outperform individual vulnerability measures in predicting both the timing and severity of financial crises.

The FVI comprises five components that measure vulnerabilities across different sectors and markets:

1. **Household Leverage**: Measured as household debt-to-GDP ratio. Elevated household leverage reduces households' capacity to maintain consumption during downturns and increases vulnerability to interest rate shocks. Data are from the Bank for International Settlements (BIS) credit statistics.

2. **Corporate Leverage**: Measured as non-financial corporate debt-to-GDP ratio. High corporate leverage amplifies the impact of financial condition tightening through increased default risk and reduced investment. Data are from BIS credit statistics.

[6]The 22 major economies are: Australia, Austria, Belgium, Canada, China, Denmark, France, Germany, Hong Kong, Italy, Japan, Mexico, the Netherlands, New Zealand, Norway, Russia, South Korea, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

3. **Financial Sector Leverage**: Measured as the ratio of banking sector assets to GDP. High financial sector leverage indicates limited loss absorption capacity and elevated systemic risk. Data are from the IMF Financial Soundness Indicators and national central bank statistics.

4. **Asset Valuation Pressures**: Measured using equity price-to-GDP ratio and real house price indices. Compressed valuations signal potential for sharp corrections that can trigger broader financial stress. Equity data are from national stock exchanges and house price data are from the OECD and BIS property price statistics.

5. **Maturity Mismatches**: Measured as the ratio of short-term external debt to foreign reserves. This captures funding vulnerabilities from reliance on short-term foreign currency borrowing. Data are from the World Bank International Debt Statistics and IMF International Financial Statistics.

Each component is standardized to have zero mean and unit variance over the full sample period (1995–2023). The aggregate FVI for each country is constructed as the simple average (equal-weighted) of the five standardized components:

$$FVI_{i,t} = \frac{1}{5} \sum_{j=1}^{5} z_{i,j,t} \tag{1}$$

where $z_{i,j,t}$ is the standardized value of component j for country i at time t. This equal-weighting approach avoids overfitting to any particular crisis episode and has been shown to perform well out-of-sample for crisis prediction (Lee et al., 2020).

The foreign aggregate FVI is constructed as an equal-weighted average across the 21 non-U.S. economies:

$$FVI_t^{FOR} = \frac{1}{21} \sum_{i \neq US} FVI_{i,t} \tag{2}$$

This equal-weighting baseline treats all major economies symmetrically. In Section 4, we examine alternative weighting schemes based on trade linkages, dollar funding integration,

and GDP weights as robustness checks. The FVI is available for all 22 countries over 1995:Q1 to 2023:Q4, with the exception of China (starting 2000:Q1) and Russia (starting 1998:Q1) due to data availability constraints.

3.2 Transmission Growth-at-Risk (TGaR) Framework

Building on the GaR framework from Adrian et al. (2019), our TGaR approach incorporates foreign financial vulnerabilities as additional predictors for GDP growth. We therefore posit that foreign financial vulnerabilities can transmit risks to U.S. economies, thereby affecting future growth distribution. To investigate this link, we employ quantile regression models to estimate the conditional distribution of U.S. GDP growth at each point in time based on domestic and foreign financial conditions as well as financial vulnerabilities.

More specifically, the baseline model includes two terms from Adrian et al. (2019): current GDP growth and the NFCI. The TGaR model further includes vulnerability indexes from the U.S. and foreign countries, as well as the foreign financial condition index. The extended quantile regression model can be expressed as:

$$\begin{aligned} Q^{US}_{GDP_{t+h}|t}(\tau) = &\alpha(\tau) + \beta_1(\tau) \cdot GDP^{US}_t + \beta_2(\tau) \cdot FCI^{US}_t + \beta_3(\tau) \cdot FVI^{US}_t \\ &+ \beta_4(\tau) \cdot FVI^{FOR}_t + \beta_5(\tau) \cdot FCI^{FOR}_t + \epsilon_t(\tau) \end{aligned} \tag{3}$$

where $Q^{US}_{GDP_{t+h}|t}(\tau)$ is the τ-th quantile of the conditional distribution of U.S. GDP growth h periods ahead. GDP^{US}_t represents the current U.S. GDP growth, FCI^{US}_t is the Chicago Fed's U.S. Financial Conditions Index, FVI^{US}_t is the U.S. financial vulnerability index, FVI^{FOR}_t is the index of foreign financial vulnerabilities, and FCI^{FOR}_t is the foreign financial condition index. All coefficients $\alpha(\tau)$, $\beta_1(\tau)$, $\beta_2(\tau)$, $\beta_3(\tau)$, $\beta_4(\tau)$, and $\beta_5(\tau)$ correspond to the respective quantile τ.

The first two terms, GDP^{US}_t and FCI^{US}_t, are from Adrian et al. (2019), and the addition of FVI^{FOR}_t is the major novel aspect of our model. The Transmission Growth-at-Risk (TGaR) is then defined as the $\tau = 5$th percentile of the conditional GDP growth distribution

from the model.

3.2.1 Orthogonalization of Foreign Financial Conditions

To isolate truly exogenous foreign financial shocks, we orthogonalize the foreign FCI with respect to the U.S. FCI. Without orthogonalization, FCI_t^{FOR} would capture both foreign-specific shocks and components that merely reflect correlated global financial conditions. We regress foreign FCI on U.S. FCI and use the residuals:

$$FCI_t^{FOR} = \delta_0 + \delta_1 \cdot FCI_t^{US} + \eta_t \tag{4}$$

In all specifications, FCI_t^{FOR} in equation (3) refers to these orthogonalized residuals $\widehat{\eta}_t$. This procedure ensures that our foreign FCI coefficient captures shocks originating abroad rather than global factors that affect both U.S. and foreign financial conditions simultaneously. The orthogonalization is performed using the full sample, and the resulting residuals are standardized to have zero mean and unit variance.

3.2.2 Identification

A natural concern is whether U.S. economic developments could affect foreign vulnerabilities, potentially biasing our coefficient estimates through reverse causality. Several features of our empirical design mitigate this concern. First, financial vulnerabilities are slow-moving stock variables—debt ratios, asset valuations, and leverage measures—that evolve gradually over quarters and years. In contrast, U.S. GDP growth is a quarterly flow variable. The sluggish adjustment of vulnerabilities limits the scope for contemporaneous feedback from quarterly U.S. growth fluctuations to foreign vulnerability levels.

Second, we include current U.S. GDP growth as a control variable in equation (3), which absorbs any contemporaneous correlation between U.S. economic conditions and foreign vulnerabilities. Third, we orthogonalize foreign FCI with respect to U.S. FCI, removing components of foreign financial conditions that correlate with U.S. conditions. This ortho-

gonalization helps isolate the component of foreign financial stress that is independent of U.S. developments.

Fourth, our out-of-sample forecast evaluation (Section 3.3) demonstrates that foreign vulnerabilities measured at time t predict U.S. growth h quarters ahead, which is consistent with a causal interpretation. If reverse causality were driving the results, we would expect poor out-of-sample performance as the spurious correlation would not generalize beyond the estimation sample. Instead, we find substantial and statistically significant forecast improvements.

Finally, our crisis episode analysis examines exogenous events where the direction of causality is clear. The 1997–98 Asian Financial Crisis and the 2010–12 European sovereign debt crisis originated in foreign economies, with foreign vulnerabilities clearly preceding U.S. growth declines. The Global Financial Crisis analysis provides a spillback test: even when the shock originates in the United States, elevated foreign vulnerabilities amplify the shock and feed back to worsen U.S. outcomes. These episode studies provide complementary evidence supporting a causal interpretation of the estimated transmission relationships.

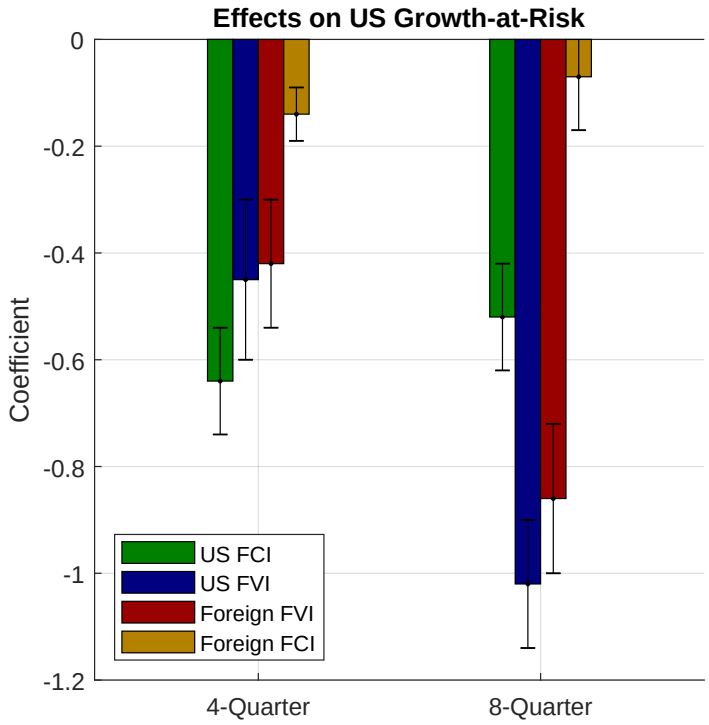
Note that quantile regressions use all data points in a sample but assign greater weight to observations closer to the quantile of interest. Hence, our estimation results are not solely attributable to the several adverse events abroad that our sample covers.

3.3 Estimation Results and Discussions

Figure 2 reports the estimated coefficients from quantile regressions for 4-quarter and 8-quarter ahead predictions using the baseline TGaR model. All predictors are standardized to have a mean of zero and a unit variance before the estimation, which ensures comparability across variables. The vertical lines in the figure represent 10 percent confidence intervals.

The coefficient estimates show that tighter U.S. financial conditions significantly increase downside risks to U.S. GDP growth in the medium term (4 quarters ahead), but their impact diminishes over a longer horizon (8 quarters ahead). This finding is consistent with

Figure 2. TGaR Coefficients at 4- and 8-Quarter Horizons



Note: This figure shows estimated coefficients from quantile regressions at the 5th percentile of future GDP growth at horizons ranging from 1 to 8 quarters ahead. The regressors include current U.S. GDP growth (not shown), U.S. and foreign financial conditions (FCI), and U.S. and foreign financial vulnerabilities (FVI), based on equation (3). Sample period: 1995:Q1–2023:Q4. All variables are standardized to have zero mean and unit variance. Vertical lines represent 90 percent confidence intervals constructed using Newey-West standard errors with 4 lags.

the results from the domestic GaR model of Adrian et al. (2019), which emphasizes the *short-term* relevance of domestic financial conditions in predicting U.S. growth-at-risk.

In contrast, both U.S. and foreign financial vulnerabilities (FVI) exhibit stronger effects on downside risks to U.S. GDP growth over a *longer horizon*, with their impacts exceeding that of U.S. financial conditions at the 8-quarter horizon. These distinct effects across different horizons underscore the fundamental difference between the fast-moving nature of financial conditions and the slow-moving nature of FVI, which captures the underlying fragility of the financial system — a key point that we will revisit in a later section.

Furthermore, the figure shows that foreign financial vulnerabilities are statistically significant at both horizons, with magnitudes comparable to U.S. FVI and substantially larger

than foreign FCI, which is not significant at the 8-quarter horizon. This finding indicates the critical, yet often overlooked, role of foreign financial vulnerabilities in impacting U.S. downside growth risk, even after accounting for U.S. financial conditions and vulnerabilities. It also highlights the sizable and significant transmission effect of foreign vulnerabilities, a topic that we will explore in greater detail in Section 4.

One benefit of using the GaR framework to investigate the implications for U.S. growth is that it allows us to perform quantile regressions across multiple quantiles, beyond just the growth-at-risk. These predicted quantiles can then be mapped into a *skewed-t distribution*, following the approach of Adrian et al. (2019), to derive the estimated conditional growth distribution for U.S. growth at a given horizon and at each point in time.

To assess whether foreign vulnerabilities affect the entire U.S. growth distribution or concentrate in the downside tail, we estimate our baseline TGaR model across multiple quantiles. Table 1 reports the estimated coefficients at the 5th, 25th, 50th, 75th, and 95th percentiles at the 8-quarter horizon, where vulnerability effects are strongest.

Table 1. TGaR Coefficients Across the Growth Distribution (8-Quarter Horizon)

Variable	**5th**	**25th**	**50th**	**75th**	**95th**
Foreign FVI	-0.1924^{**}	-0.2103^{**}	-0.1956^{**}	-0.1845^{*}	-0.1732^{*}
	(-2.08)	(-2.15)	(-2.01)	(-1.78)	(-1.68)
U.S. FCI	-1.2115^{**}	-0.9234^{**}	-0.5421^{**}	-0.2845^{*}	-0.1234
	(-2.32)	(-2.15)	(-2.08)	(-1.82)	(-1.24)
Foreign FCI	-0.3245^{**}	-0.2812^{*}	-0.1945	-0.1123	-0.0542
	(-2.21)	(-1.89)	(-1.52)	(-1.08)	(-0.58)
U.S. FVI	-0.9823^{**}	-0.9654^{**}	-0.9421^{**}	-0.9112^{*}	-0.8745^{*}
	(-2.05)	(-2.12)	(-2.01)	(-1.86)	(-1.73)

Note: This table reports estimated coefficients from quantile regressions of U.S. GDP growth eight quarters ahead on current GDP growth (not shown), U.S. and foreign financial conditions (FCI), and U.S. and foreign financial vulnerabilities (FVI). Sample period: 1995:Q1–2023:Q4. All variables are standardized to have zero mean and unit variance. Robust t-statistics (Newey-West with 4 lags) are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 1 shows how foreign financial vulnerabilities and financial conditions differ in their impacts across the U.S. growth distribution. The foreign FVI coefficient remains statistically significant at all quantiles, with magnitudes ranging from -0.17 to -0.21. Importantly, the

coefficient at the median (50th percentile) is −0.20, nearly identical to its value at the 5th percentile (−0.19). The coefficient remains significant even at the 75th and 95th percentiles, where growth outcomes are relatively strong. This pattern indicates that elevated foreign vulnerabilities reduce U.S. growth across the entire distribution—not only when outcomes are weak, but also at the median and in the upper tail.

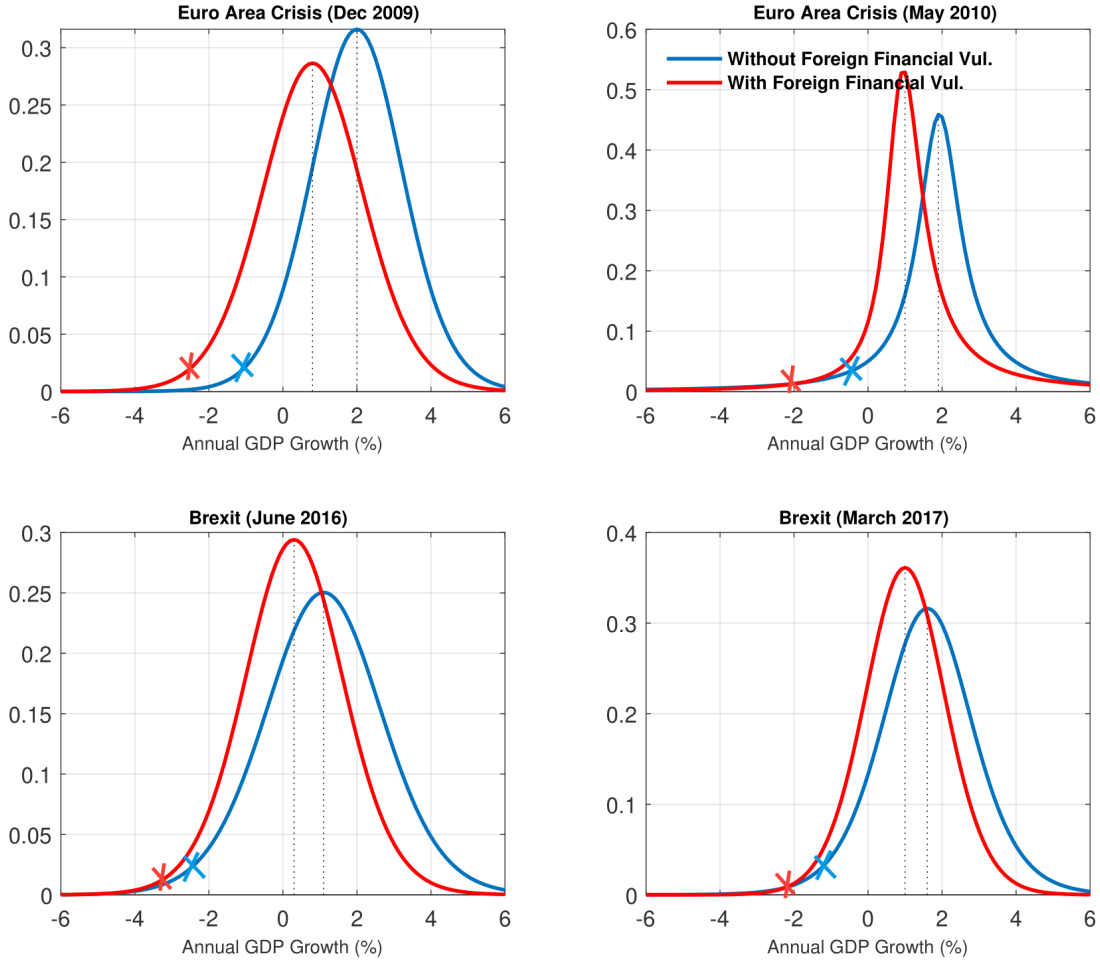
Financial conditions behave differently. The U.S. FCI coefficient declines from −1.21 at the 5th percentile to −0.54 at the median, and becomes statistically insignificant (−0.12) at the 95th percentile. The foreign FCI follows a similar pattern, starting at −0.32 at the 5th percentile and declining to an insignificant −0.05 at the 95th percentile. These financial condition variables affect growth primarily when outcomes are already weak, consistent with earlier findings in Adrian et al. (2019) that financial conditions tighten credit access during downturns.

The different patterns across the distribution help distinguish how vulnerabilities and conditions affect the economy. Financial conditions measure current credit market tightness—when credit conditions tighten, firms and households with weaker balance sheets face binding constraints, which worsens already-weak growth outcomes. Foreign financial vulnerabilities, by contrast, have similar effects regardless of whether U.S. growth outcomes turn out to be weak or strong. High leverage ratios, stretched asset valuations, and funding mismatches in major foreign economies reduce their import demand and disrupt their financial intermediation, which lowers U.S. exports and raises borrowing costs for U.S. firms with foreign operations. These effects occur whether the U.S. economy experiences a recession, moderate growth, or a boom, which explains why foreign vulnerabilities shift the entire growth distribution rather than only its lower tail.

While there have been several financial crises or stress episodes abroad, we focus on two European episodes to illustrate our findings: The euro area debt crisis and the Brexit vote. Figure 3 shows the impact of foreign financial vulnerabilities on the conditional U.S. GDP growth distribution during two major events originating from abroad: the euro area

sovereign debt crisis (top panel) and Brexit (bottom panel). In both cases, including foreign financial vulnerabilities (red curves) shifts the conditional distribution to the left, increasing the downside risk to U.S. GDP growth.

Figure 3. U.S. GDP Growth Distribution During Euro Area Crisis and Brexit



Note: This figure shows the effect of including foreign financial vulnerabilities on the conditional U.S. GDP growth distribution during two foreign-originated events: the Euro Area sovereign debt crisis in 2011:Q3 (top panel) and the Brexit referendum in 2016:Q2 (bottom panel). Each panel compares the 8-quarter-ahead conditional growth distribution estimated with foreign FVI (red line) versus without foreign FVI (blue line), based on equation (3). The vertical dashed line marks the 5th percentile (growth-at-risk) for each distribution.

The shifts in both panels affect not only the left tail but also the center and right side of the distribution. This pattern is consistent with Table 1, which shows that foreign FVI coefficients remain statistically significant at the median (50th percentile) and even at the

75th percentile. When major foreign economies experience elevated vulnerabilities, U.S. growth outcomes deteriorate across all quantiles—the median growth rate declines along with growth-at-risk. This broad-based shift distinguishes foreign vulnerabilities from financial conditions, which primarily affect downside risk.

3.3.1 Spillover and Spillback Mechanisms: Evidence from Financial Crises

We validate our TGaR framework through detailed analysis of two major financial crises with contrasting origins.

Asian Financial Crisis: Foreign-Originated Spillover

The 1997–1998 Asian Financial Crisis provides a clear test of foreign vulnerability transmission to the United States. Currency devaluations in Thailand triggered financial instability that spread rapidly across East Asia, affecting economies that represented significant U.S. trading partners but were geographically distant and had limited direct financial linkages to U.S. institutions.

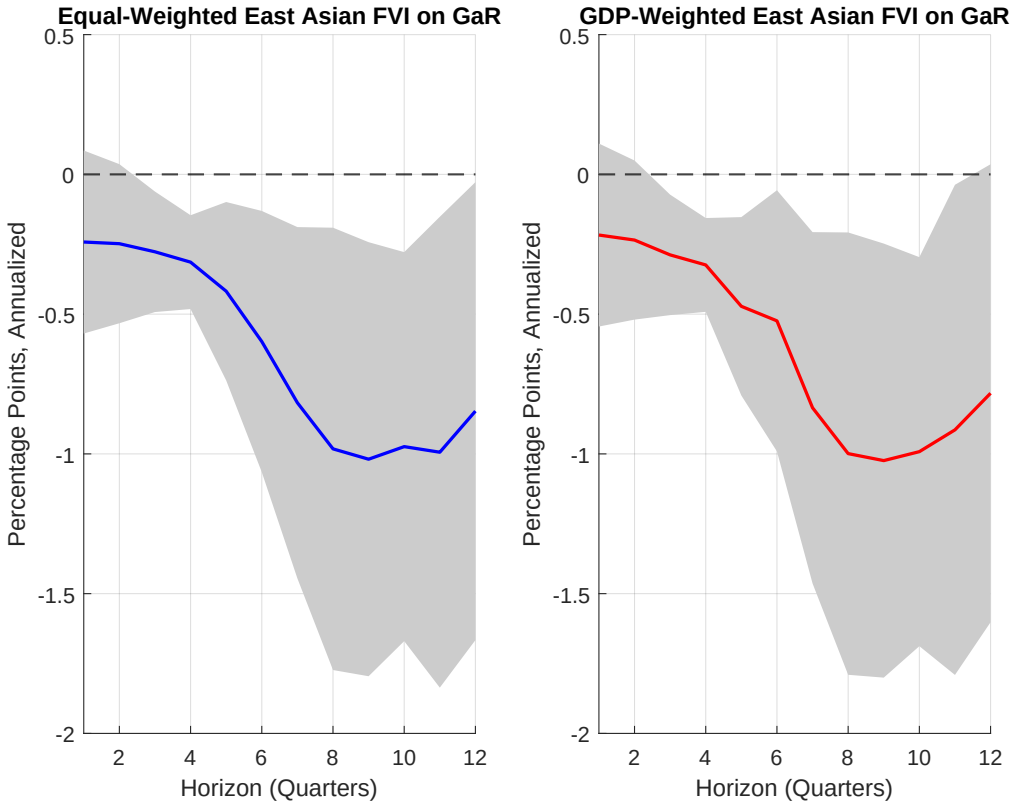
We focus on a subset of foreign countries—key Asian emerging markets during this event: China, Indonesia, Malaysia, South Korea, and Thailand.[7] We then construct an aggregate East Asian FVI for these selected Asian economies and re-estimate the baseline TGaR model using this East Asian FVI.

Figure 4 reports the estimated effects of the East Asian FVI on U.S. Growth-at-Risk (GaR) over different horizons, using two weighting schemes: Equal-weighted (left panel) and GDP-weighted (right panel).[8] The results show that, in both cases, the inclusion of East Asian FVI leads to a significant increase in downside risks to U.S. GDP growth, as shown by the consistently negative coefficients across all horizons. Notably, the effects are

[7]By focusing on key Asian countries, we are also able to extend the estimation sample backward to January 1991, the earliest date for which we could construct financial vulnerability indexes and find financial conditions indexes. The estimation sample period for this exercise runs from 1991, encompassing the pre-crisis buildup, the crisis period, and its immediate aftermath, allowing us to isolate the impact of the East Asian Financial Crisis on U.S. downside growth risk.

[8]The weights used are based on 1997 real GDP. Results are robust to using time-varying weights.

Figure 4. Effect of Foreign FVI on U.S. GaR: East Asian Financial Crisis



Note: This figure plots the estimated coefficient and 90 percent confidence intervals for East Asian FVI on U.S. growth-at-risk at horizons ranging from 1 to 8 quarters ahead. The specification includes current U.S. GDP growth, U.S. FCI, U.S. FVI, East Asian FVI (aggregated using equal weights or GDP weights), and East Asian FCI (aggregated using equal weights or GDP weights). East Asian countries include China, Hong Kong, Japan, and South Korea. Estimation sample: 1991:Q1–2000:Q4. All variables are standardized to have zero mean and unit variance.

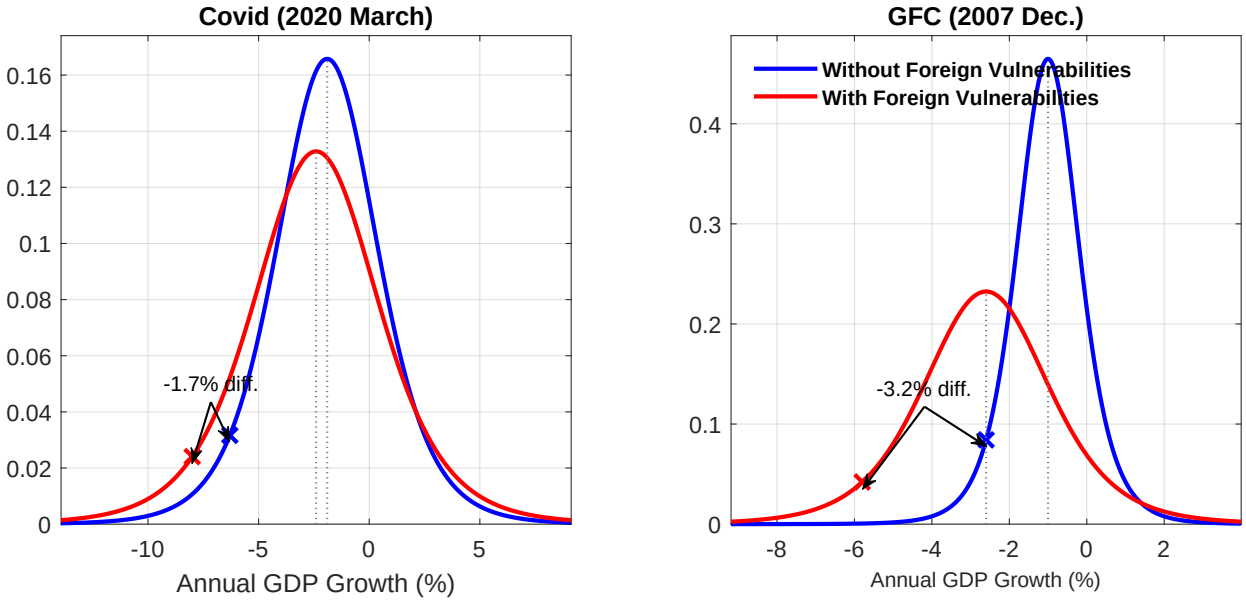
most pronounced between 6 and 10 quarters ahead, with coefficients reaching their largest magnitudes, indicating peak transmission effects during the medium-term horizon.

While both panels present quantitatively similar results, the equal-weighted FVI (left panel) exhibits slightly larger coefficients in the medium term, suggesting that smaller economies, such as Thailand, can still play a meaningful role in the transmission of vulnerabilities. Nonetheless, both panels emphasize that East Asian FVI significantly amplifies downside risks, with the effects gradually diminishing at longer horizons.

Similar to the Asian crisis episode, COVID-19 can be viewed as a foreign-origin shock

from the perspective of the U.S. financial system, with its effects reaching U.S. growth through trade and financial linkages.

Figure 5. U.S. GDP Growth Distribution During COVID-19 and Global Financial Crisis



Note: This figure shows the effect of including foreign financial vulnerabilities on the conditional U.S. GDP growth distribution during the COVID-19 pandemic in 2020:Q1 (left panel) and the Global Financial Crisis trough in 2008:Q4 (right panel). Each panel compares the 8-quarter-ahead conditional growth distribution estimated with foreign FVI (red line) versus without foreign FVI (blue line), based on equation (3). The vertical dashed line marks the 5th percentile (growth-at-risk) for each distribution.

The left panel of Figure 5 shows the conditional distribution of future U.S. GDP growth at the onset of the COVID-19 pandemic (March 2020). Adding the foreign FVI shifts the entire distribution to the left, with a 1.7 percentage point decline in the 5th percentile of the growth distribution. Foreign vulnerabilities therefore still raise downside risks in a global real shock that did not originate in U.S. financial markets, even in the presence of sizable domestic policy interventions. This reinforces the message from the Asian crisis that foreign vulnerabilities can materially worsen U.S. growth prospects when adverse shocks originate abroad.

Global Financial Crisis: U.S.-Originated Spillback

Different from the Asian and COVID-19 episodes, the Global Financial Crisis originated in U.S. subprime mortgage and securitization markets and then propagated to the rest of the world. We use this episode to examine whether foreign financial vulnerabilities amplified a U.S.-originated shock and generated spillback effects that exacerbated domestic U.S. outcomes.

The right panel of Figure 5 presents the resulting conditional distributions during the GFC. Although the initial shock was domestic, the difference in the 5th percentile of U.S. GDP growth is 3.2 percentage points once foreign vulnerabilities are included, implying a much more left-skewed distribution. This result suggests that elevated foreign vulnerabilities can worsen U.S. outcomes even when the shock originates domestically, as distressed foreign banks reduce lending and foreign firms cut imports from the United States.

To quantify this spillback more precisely, we construct a scenario in which European financial vulnerabilities remained at normal levels during the crisis. Specifically, we hold all variables—U.S. GDP growth, U.S. FCI, U.S. FVI, and foreign FCI—at their actual 2008Q4 values but replace the foreign FVI with its sample median over 1995–2023. We then use equation (3) to re-estimate the conditional distribution of U.S. GDP growth at the 5th percentile. The exercise reveals that if European financial vulnerabilities had been at their historical median rather than at elevated levels, U.S. growth at the 5th percentile in 2008Q4 would have been 1.2 percentage points higher. This magnitude represents roughly one-third of the total decline in U.S. growth-at-risk during the crisis trough. The finding indicates that foreign vulnerabilities can materially worsen U.S. downside risks even during domestically originated crises, operating through reduced foreign demand for U.S. exports and through disruptions in dollar funding markets where U.S. financial institutions rely on foreign counterparties.

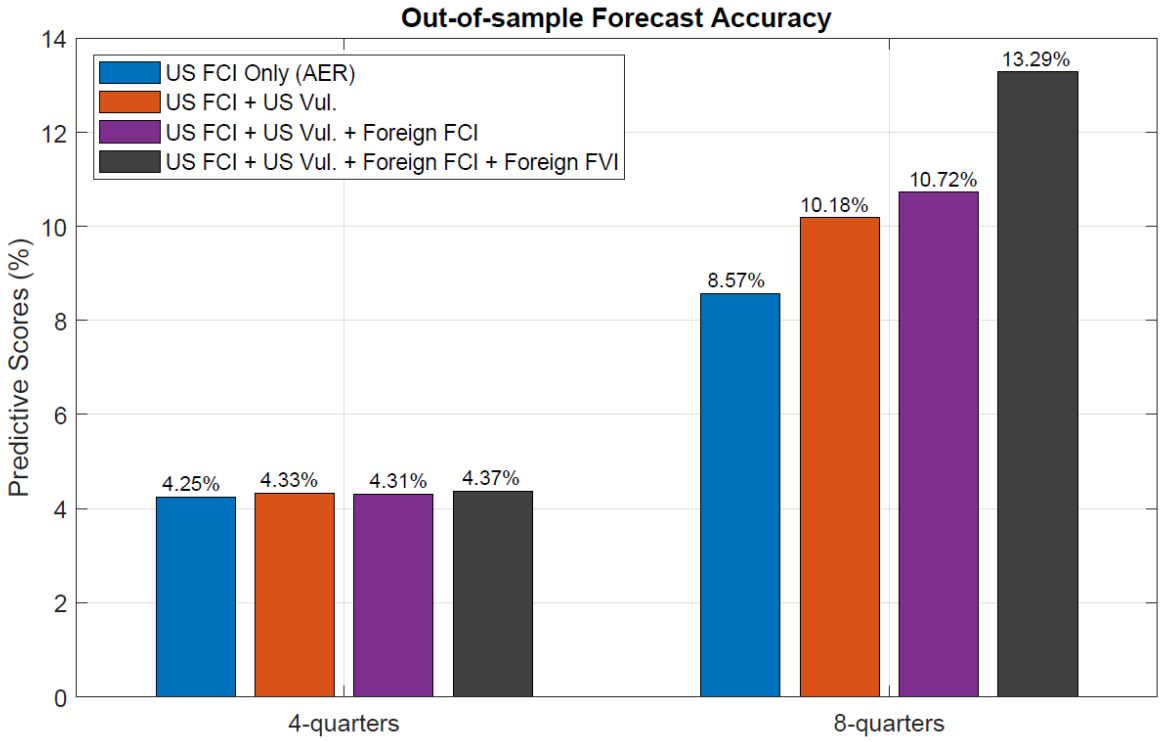
Taken together with the Asian crisis and COVID-19 results, this evidence shows that foreign vulnerabilities matter for U.S. growth under foreign-origin, U.S-origin, and globally

synchronized shocks, and can generate sizable spillover and spillback effects.

3.4 Out-of-sample Forecast

How well does TGaR perform out of sample? How does it compare to the GaR model from Adrian et al. (2019)? To answer these questions, we compute the predictive scores, which measure how well a model's predictions match actual outcomes, particularly focusing on the accuracy of the lower tail (downside risk) of the distribution. Higher predictive scores indicate better model performance in forecasting extreme negative events.

Figure 6. Out-of-Sample Predictive Scores Across TGaR Specifications



Note: This figure shows out-of-sample predictive scores (in percentage points of GDP growth) for three TGaR model specifications at the 5th percentile: the baseline specification with U.S. GDP growth, U.S. FCI, and U.S. FVI (blue line); an augmented specification that adds foreign FCI (orange line); and the full TGaR specification that includes both foreign FCI and foreign FVI (green line). The out-of-sample evaluation period is 2000:Q1–2023:Q4, using an expanding window with initial training period 1995:Q1–1999:Q4. Higher scores indicate better forecast accuracy.

Figure 6 shows out-of-sample predictive scores for three different models: the Adrian et al.

(2019) (AER) model, the baseline TGaR model (1) which adds foreign financial vulnerabilities, and the richer TGaR model (2) which includes both foreign financial vulnerabilities and foreign financial conditions. The predictive scores are reported for 4-quarter and 8-quarter forecast horizons.

For both horizons, the baseline TGaR model (1) and the richer TGaR model (2) outperform the AER model, as evidenced by their higher predictive scores. Including foreign financial vulnerabilities improves the model's ability to predict downside risks out of sample, suggesting that foreign vulnerability indexes provide valuable information for forecasting downside risks to GDP growth. Notably, the FVI significantly increases out-of-sample forecast accuracy at the 8-quarter horizon (from 8.57% to 13.11%), compared to only a marginal increase at the 4-quarter horizon (from 4.25% to 4.31%). This finding suggests that the FVI provides more relevant information for predicting growth-at-risk over longer horizons.

The richer TGaR model, which further includes U.S. FVI and foreign financial conditions, shows only marginal improvement over the baseline TGaR model, which includes foreign FVI alone. This suggests that most of the predictive gain over the baseline GaR model with U.S. FCI from Adrian et al. (2019) comes from foreign FVI, with minimal contribution from U.S. FVI or foreign FCI. However, as we will show in a later section, the impact of foreign FCI on predicting U.S. growth-at-risk can be amplified when interacting with foreign FVI.

4 Transmission Channels

Financial vulnerabilities in foreign countries can affect the U.S. economy through various transmission channels. In this paper, we focus on two transmission channels: (1) the real channel (international trade), where foreign financial vulnerabilities impact foreign economic growth, which in turn affects the U.S. economy, and (2) the financial channel (financial integration/U.S. dollar funding), where reliance on U.S. dollar-denominated borrowing amplifies the effects of foreign financial vulnerabilities. Before establishing the relevance of the real channel, we demonstrate that, abroad, the conditional distribution of forecasted GDP

growth depends on financial conditions and financial vulnerabilities.

4.1 Domestic Growth-at-Risk (DGaR)

For financial vulnerabilities abroad to weigh on the U.S. economy through the real channel, these vulnerabilities must first affect economic growth abroad. Therefore, we study a Domestic Growth-at-Risk (DGaR) framework, where foreign financial vulnerabilities affect the downside risks to foreign countries' growth. These risks can then spill over to the U.S. through real channels, such as trade linkages with the United States.

We estimate a panel quantile regression across all countries in the sample (excluding the United States) to assess the impact of financial conditions and financial vulnerabilities on domestic growth. The panel quantile regression model is specified as follows:

$$Q^{FOR}_{GDP_{i,t+h}|t}(\tau) = \alpha_i(\tau) + \beta_1(\tau) \cdot FCI^{FOR}_{i,t} + \beta_2(\tau) \cdot FVI^{FOR}_{i,t} + \gamma_i(\tau) \cdot C_{i,t} + \epsilon_{i,t}(\tau) \quad (5)$$

where $Q^{FOR}_{GDP_{i,t+h}|t}(\tau)$ is the τ-th quantile of the conditional distribution of GDP growth for country i, h periods ahead, $FCI^{FOR}_{i,t}$ is the financial conditions index for country i at time t, $FVI^{FOR}_{i,t}$ is the financial vulnerability index for country i at time t, and $C_{i,t}$ contains control variables including risk factors such as the VIX, dollar index, macro uncertainty for country i, and U.S. financial conditions index. The term $\alpha_i(\tau)$ captures country fixed effects.[9]

We estimate the panel quantile regression both without and with country fixed effects, as earlier for the 5th quantile. Table 2 reports the estimated coefficients for financial conditions ($FCI_{i,t}$) and financial vulnerabilities ($FVI_{i,t}$) in two specifications: the baseline model and the model with risk factor controls. We find that both $FCI_{i,t}$ and $FVI_{i,t}$ are statistically significant across all specifications. The finding that $FCI_{i,t}$s have an economically meaningful effect mimics that of Adrian et al. (2022). However, the finding that $FVI_{i,t}$s are statistically and economically significant in foreign economies is novel. As for relative importance of the

[9] Adrian et al. (2022) also estimate a panel quantile regression model with country dummies, but for 11 advanced economies and without controls for foreign financial vulnerabilities.

two predictors, the $FCI_{i,t}$ consistently has a larger impact on downside risks to growth than $FVI_{i,t}$, as indicated by their respective (standardized) coefficients.

Table 2. Domestic Growth-at-Risk: Panel Quantile Regression (8 quarters)

Specification	**Baseline**	**Baseline**	**With Controls**	**With Controls**
Financial Conditions	-0.3012**	-0.3214**	-0.2814**	-0.2257**
	(-2.45)	(-2.42)	(-2.37)	(-2.30)
Financial Vulnerability	-0.1335**	-0.1472**	-0.1218**	-0.1014*
	(-2.12)	(-2.10)	(-2.05)	(-1.94)
Country Fixed Effects	×	✓	×	✓

Note: This table reports estimated coefficients from panel quantile regressions of domestic GDP growth eight quarters ahead on country-level financial conditions and financial vulnerabilities. Sample: 21 countries (excluding U.S.), 1995:Q1–2023:Q4. All variables are standardized to have zero mean and unit variance. t-statistics (standard errors clustered at country level) are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

The results in Table 2 provide insights into the role of financial conditions and financial vulnerabilities in affecting downside risks to domestic growth across countries. In the baseline specification, the financial conditions index (FCI) is statistically significant at the 5% level, with a coefficient of -0.3012, indicating that tighter financial conditions are associated with greater downside risks to growth, consistent with the finding from Adrian et al. (2019) for the United States. In addition, we find that the financial vulnerability index (FVI) is also significant at the 5% level, with a smaller negative coefficient of -0.1335. This suggests that vulnerabilities also contribute meaningfully to domestic downside risks, albeit to a lesser extent than financial conditions. When country and year fixed effects are included, the FCI coefficient becomes slightly larger in magnitude at -0.3214, while the FVI coefficient increases slightly to -0.1472 (in absolute value). This suggests that accounting for unobserved heterogeneity across countries and time further increases the impact of both financial conditions and vulnerabilities on domestic growth downside risk. When we include global risk factors (see the columns marked "with controls"), both domestic financial conditions and vulnerability coefficients decrease slightly but still remain significant. This suggests that foreign financial conditions (and to some extent foreign financial vulnerabilities) reflect broader global risk factors but still have an effect on foreign economic growth. Finally, when we

include both global controls and fixed effects, the financial vulnerability index still remains significant at the 10% level.

4.2 Real Channel

A potential transmission channel through which foreign financial vulnerabilities may affect U.S. growth is their direct effect on foreign economies, which can reduce trade flows with the United States and subsequently weigh on the U.S. economy. To test this channel directly, we measure each country's trade link with the United States, defined as the total imports and exports of goods and services from the United States. We then split the sample into two groups based on above-median and below-median U.S. trade link exposure and estimate the TGaR model for each subsample.[10]

Table 3. TGaR by U.S. Trade Link Intensity

Variable	**High U.S. Trade Link**	**Low U.S. Trade Link**
	4-quarter horizon	
Foreign FCI	-0.8254**	-0.2451*
	(-2.65)	(-1.90)
Foreign FVI	-0.4812***	-0.1614*
	(-3.15)	(-1.78)
High-Low (FVI)	-0.3198**	
	(-2.40)	
	8-quarter horizon	
Foreign FCI	-0.5701**	-0.2764
	(-2.80)	(-1.50)
Foreign FVI	-0.5032***	-0.1711*
	(-3.28)	(-1.75)
High-Low (FVI)	-0.3321**	
	(-2.55)	

Note: This table reports estimated TGaR coefficients for two subsamples of countries: high U.S. trade links (above-median trade share) and low U.S. trade links (below-median trade share). Foreign FCI and FVI are aggregated separately for each subsample using equal weights. Sample period: 1995:Q1–2023:Q4. All variables are standardized to have zero mean and unit variance. Robust t-statistics (Newey-West with 4 lags) are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

[10] Countries with above-median trade links with the U.S., listed alphabetically, are: Canada, China, France, Germany, Italy, Japan, Mexico, Netherlands, South Korea, and the United Kingdom.

Table 3 presents the TGaR results for countries with high and low trade links with the United States. The results indicate that countries with stronger trade ties to the United States (i.e., high U.S. trade link) experience significantly larger negative impacts on their GDP growth due to foreign financial conditions and foreign financial vulnerabilities compared to countries with weaker trade links (i.e., low U.S. trade link).

For the 4-quarter horizon, the FVI coefficient is -0.43 for countries with high U.S. trade link, highly significant at the 1% level, while for low U.S. trade link countries, the coefficient is smaller at -0.13 and only weakly significant at the 10% level. Similarly, the FCI coefficient is -0.78 for high U.S. trade link countries, significantly larger than the -0.24 for low U.S. trade link countries. A similar pattern holds for the 8-quarter horizon, where the FVI coefficient is -0.46 for high U.S. trade link countries (1% significance), compared to -0.17 for low U.S. trade link countries (10% significance). The FCI coefficient is also larger for high U.S. trade link countries at -0.55 compared to -0.26 for low U.S. trade link countries.

These results show that the intensity of the real transmission channel is closely linked to the strength of bilateral trade. It is worth noting that shifts in global trade patterns, potentially driven by new trade policies, could affect these dynamics. For example, a broad decline in trade volumes might attenuate this transmission channel. In contrast, trade diversion could reconfigure the set of countries whose vulnerabilities pose the greatest risk to the U.S. through trade. While the specific country exposures may change, the underlying trade channel, as captured by our framework, would remain relevant for assessing evolving risks from abroad.

All in all, the results suggest that elevated financial vulnerabilities abroad pose risks to economic growth and that these risks worsen the United States' economic prospects because of international trade linkages.

4.3 Financial Channel

Financial integration takes various forms, and we focus on a particular one. The U.S. dollar plays a central role in the global financial system as the dominant currency for international lending and borrowing. While this international role of the dollar offers numerous benefits to the economies and financial system, it may also serve as a conduit of foreign financial stress. For example, vulnerable foreign financial and non-financial sectors could engage in fire sales of U.S. assets or scramble for U.S. dollar liquidity in times of stress abroad, causing spillovers into the U.S. economy and financial system.

To investigate this channel, we use the data on the dollar share of U.S. dollar assets and liabilities of foreign economies from Benetrix et al. (2019), who provide the currency composition of the international investment positions for dozens of countries. We define a measure of dollar integration as a country's share of external assets and debt liabilities in U.S. dollars. Specifically, to measure country i's dollar integration, we use external assets and liabilities denominated in U.S. dollars for the country i. We then split the sample into two groups: countries with above-median dollar integration (i.e., those whose average U.S. dollar assets and liabilities is above the median) and countries with below-median dollar integration. Next, we run the TGaR model for each subsample.[11]

Table 4 reports the TGaR results for countries with high and low dollar integration. The results indicate that both foreign financial conditions (FCI) and foreign financial vulnerabilities (FVI) have significant negative effects on U.S. GDP growth from countries with high and low dollar integration. However, the magnitude and significance of the foreign FVI coefficients are notably stronger for countries with high dollar exposure. For the 4-quarter horizon, the FVI coefficient for countries with high dollar integration is -0.43 and is highly significant, while for countries with low dollar integration, the FVI coefficient is -0.14 and is significant at the 10% level. A similar pattern is observed for the 8-quarter horizon, where

[11] Countries with above-median dollar integration, listed alphabetically, are: Canada, Germany, Italy, Japan, Mexico, Netherlands, South Korea, Spain, Switzerland, and the United Kingdom.

Table 4. TGaR by Dollar Integration

Variable	High Dollar Integration	Low Dollar Integration
	4-quarter horizon	
Foreign FCI	-0.7624**	-0.2531*
	(-2.55)	(-1.85)
Foreign FVI	-0.4312***	-0.1402*
	(-3.10)	(-1.92)
High-Low (FVI)	-0.2951**	
	(-2.35)	
	8-quarter horizon	
Foreign FCI	-0.5554**	-0.2754
	(-2.65)	(-1.60)
Foreign FVI	-0.4712***	-0.1795*
	(-3.25)	(-1.70)
High-Low (FVI)	-0.2950**	
	(-2.20)	

Note: This table reports estimated TGaR coefficients for two subsamples of countries: high dollar integration (above-median dollar debt share or dollar trade invoicing) and low dollar integration (below-median). Foreign FCI and FVI are aggregated separately for each subsample using equal weights. Sample period: 1995:Q1–2023:Q4. All variables are standardized to have zero mean and unit variance. Robust t-statistics (Newey-West with 4 lags) are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

the FVI coefficient is -0.45 for high dollar integration countries (significant at the 1% level) and -0.17 for low dollar integration countries (significant at the 10% level).

The final row of the table shows the difference between the FVI coefficients for the two subsamples (high minus low). The differences are statistically significant at the 5% level, with a magnitude of -0.29 for the 4-quarter horizon and -0.28 for the 8-quarter horizon. These results suggest that countries with higher dollar integration are more important conduits of financial stress from abroad.

In terms of the marginal effects of foreign financial variables, the trade and financial channels are similarly economically significant. The (standardized) regression coefficients on foreign financial vulnerabilities in the first columns of Tables 3 and 4 are statistically comparable, although the regression coefficient for the trade channel is slightly higher. That said, we do not take a stance on which channel is more dominant, as the evidence supports the presence of both channels.

4.4 Which Foreign Vulnerabilities Matter the Most?

Next, we investigate which components of foreign vulnerabilities contribute most to the downside risk of U.S. GDP growth. By doing so, we aim to better understand the channels through which foreign vulnerabilities impact U.S. growth risks, as each component may operate through either or both real and financial channels. To achieve this, we replace the aggregated foreign vulnerability index in the baseline model with its four components: valuation pressures, financial sector vulnerabilities, non-financial sector vulnerabilities, and sovereign vulnerabilities. Additionally, we orthogonalize foreign valuation pressures to U.S. valuation pressures to isolate the foreign-specific effects.

We anticipate that vulnerabilities in certain sectors may be more impactful than those in other sectors—by analogy with the crisis prediction literature. For example, Lee et al. (2020) find that asset valuation pressures, in particular, tend to peak a couple of years before banking crises and corrections to valuations are well underway before the crises occur. In fact, Figure 1 emphatically illustrates this point.

Table 5. Foreign Vulnerability Components and U.S. Growth-at-Risk

	Valuation	**Financial**	**Nonfinancial**	**Sovereign**
	One year ahead			
Coefficient	-0.5824**	-0.2172*	-0.0824**	-0.1117*
	(-2.12)	(-1.71)	(-1.99)	(-1.89)
	Two year ahead			
Coefficient	-0.9241**	-0.1533	-0.0413**	-0.1421*
	(-2.45)	(-1.45)	(-2.01)	(-1.79)

Note: This table reports estimated coefficients from quantile regressions that replace the aggregate foreign FVI with its five individual components: household leverage, corporate leverage, financial sector leverage, asset valuation pressures, and maturity mismatches. Each component enters separately in the regression. Sample period: 1995:Q1–2023:Q4. All variables are standardized to have zero mean and unit variance. Robust t-statistics (Newey-West with 4 lags) are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 5 shows the results of the quantile regressions with these components, reporting the coefficients of each foreign vulnerability component for both 4-quarter and 8-quarter ahead predictions. The results indicate that all components are significant at the 10% level, except

for the financial sector component in the 8-quarter horizon.

In terms of magnitude, valuation pressures have the largest impact on downside risk, followed by financial sector vulnerabilities, sovereign vulnerabilities, and non-financial sector vulnerabilities. Sovereign and nonfinancial sector vulnerabilities have a smaller, yet still significant, impact on downside risks. This ranking holds for both the 4-quarter and 8-quarter horizons.

4.5 Amplification Effects of Foreign Vulnerability

To investigate the impact of foreign financial vulnerabilities further, we modify our TGaR framework to gauge the effects of foreign financial shocks on U.S. economic growth and the role of foreign financial vulnerabilities in amplifying these effects.

We note that FCIs and FVIs are very distinct concepts, with the former being a natural candidate for a measure of a financial shock. FCIs are coincident indexes, that is, they are designed to measure the market-implied severity of developments as they occur. By contrast, FFVIs are early warning indicators of financial crises, that is, they are slowly changing, are based on structural vulnerabilities, and are designed to predict over a medium-term horizon the timing of a crisis and its economic severity. Indeed, the results of Vermeulen et al. (2015a) suggest only a very weak relationship between FCIs (or rather financial stress indexes, FSIs) and the onset of a banking crisis. Similarly, Lee et al. (2020) shows that, for the United States, the financial stress indexes that were put together by Federal Reserve Banks suggested below normal or normal stress levels five-to-two years ahead of the 2007-09 financial crisis, whereas their and Aikman et al. (2017)'s FFVIs reached extremely elevated levels two-to-three years before the crisis.

To capture the amplification effect of FVIs, we expand the quantile regression baseline model by adding foreign Financial Conditions Indexes (FCIs) and the interaction terms of these orthogonalized FCIs with foreign financial vulnerability indexes (FFVIs). The expanded model is expressed as follows:

$$Q^{US}_{GDP_{t+h}|t}(\tau) = \alpha(\tau) + \beta_1(\tau) \cdot GDP^{US}_t + \beta_2(\tau) \cdot FCI^{US}_t + \beta_3(\tau) \cdot FVI^{US}_t + \beta_4(\tau) \cdot FCI^{FOR}_t + \beta_5(\tau) \cdot FVI^{FOR}_t + \beta_6(\tau) \cdot FVI^{FOR}_t \times FCI^{FOR}_t + \epsilon_t(\tau) \tag{6}$$

In this equation, FCI^{FOR}_t represents the foreign financial conditions index, which captures the overall financial conditions in major foreign economies. To isolate the foreign component, this measure is orthogonalized to the U.S. FCI. The coefficient $\beta_4(\tau)$ therefore captures the baseline effect of foreign financial shocks on U.S. growth-at-risk. The interaction term $FVI^{FOR}_t \times FCI^{FOR}_t$ is the key variable of interest, capturing the amplification effect of financial vulnerabilities. A negative coefficient $\beta_6(\tau)$ would suggest that the current level of financial vulnerabilities amplifies the impact of foreign financial conditions.

Table 6. Amplification Effects of Foreign Vulnerabilities

	Component Interacted with Foreign FCI:			
	Valuation	**Financial**	**Nonfinancial**	**Sovereign**
	One year ahead			
Interaction coefficient (β_6)	-0.2321*	-0.1273**	-0.1011**	-0.0914
	(-1.95)	(-2.06)	(-2.21)	(-1.14)
	Two year ahead			
Interaction coefficient (β_6)	-0.3210**	-0.2213**	-0.0173**	-0.0511
	(-1.98)	(-1.99)	(-2.13)	(-1.13)

Note: This table reports estimated coefficients from quantile regressions that include interaction terms between foreign FCI and each component of foreign FVI. Each row shows results from a separate regression where the aggregate foreign FVI is replaced by one specific component and its interaction with foreign FCI. Sample period: 1995:Q1–2023:Q4. All variables are standardized to have zero mean and unit variance. Robust t-statistics (Newey-West with 4 lags) are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 6 reports the estimates of the expanded quantile regression model (6) with all four components of FVIs. The results indicate that most interaction terms are statistically significant, which highlights the amplifying effects of foreign vulnerabilities on the relationship between foreign financial conditions and U.S. growth at risk.

In terms of individual components, valuation pressures exhibit the largest amplification effect on U.S. financial conditions, suggesting that heightened valuation pressures in foreign

markets significantly exacerbate the adverse effects of foreign FCIs on U.S. economic growth. This is consistent with the findings of Brunnermeier (2009), who argued that asset price bubbles and subsequent corrections could lead to severe financial instability and economic downturns.

Following valuation pressures, vulnerabilities in the financial sector also show a substantial amplification effect. This indicates that vulnerabilities within the foreign financial sector, such as the banking sector, can significantly magnify the negative impact of U.S. financial conditions on the domestic economy, which highlights the consequence of the rising interconnectedness of global financial systems. This finding is consistent with Kaminsky and Reinhart (1999), where they show how banking sector crises can lead to widespread financial contagion, affecting both domestic and international markets.

Although the interaction terms for sovereign and non-financial sector vulnerabilities are smaller in magnitude compared to the other two sectors, their statistical significance still pinpoints their non-negligible roles in amplifying the effects of shocks in financial conditions on U.S. growth. On the one hand, sovereign vulnerabilities, which include issues like high public debt and fiscal deficits, can lead to increased borrowing costs and reduced investor confidence, as discussed by Reinhart and Rogoff (2010). On the other hand, vulnerabilities in the nonfinancial sector, such as high corporate debt levels, can constrain business investment and economic expansion, further compounding the adverse effects of financial shocks. For instance, Mian and Sufi (2014) argues that addressing vulnerabilities in the non-financial sector is crucial to prevent severe economic contractions.

5 Robustness

In this section, we report results from a series of robustness checks, including the use of alternative measures of financial vulnerability indexes, controlling for country size, and a dynamic TGaR model with time-varying effects on growth at risk.

Alternative Financial Vulnerability Measures

To test the robustness of our TGaR framework, we first use alternative measures of financial vulnerabilities, starting with the IMF's Financial Soundness Indicators (FSIs). The FSIs track key metrics related to the financial sector's health, providing insights into systemic risks with a focus on the banking sector. While both the LPS and FSIs aim to identify systemic vulnerabilities, FSIs focus primarily on the banking sector, whereas the LPS offers a broader view, capturing risks across financial, non-financial, sovereign, and valuation sectors.

We replace the LPS with the IMF's FSI and run the same TGaR regressions, controlling for both U.S. and foreign FCI. Table 7 reports the coefficients for each variable in predicting U.S. downside risk for both 4-quarter and 8-quarter horizons. The results show that, similar to the LPS, the foreign FSI is significant at the 5% level in predicting U.S. downside risk at both the 1-year and 2-year horizons. This negative effect is larger at the 2-year horizon and is comparable in magnitude to the coefficient of the foreign FCI.

Table 7 also includes the results with interaction terms between foreign FSIs and financial conditions. We find robust evidence that all interaction terms are statistically significant, indicating the amplifying effects of foreign FSI on the relationship between foreign financial conditions and U.S. downside growth risk.

Table 8 compares the out-of-sample (OOS) predictive scores for U.S. downside risk across four models: the "none" model, which includes only the U.S. FCI as in the Adrian et al. (2019), and three alternative models incorporating different measures of foreign financial vulnerabilities—LPS, IMF FSI, and the credit-to-GDP ratio.

The results show that all three alternative measures outperform the "none" model in the 4-quarter horizon, indicating that accounting for foreign financial vulnerabilities enhances the model's predictive ability for U.S. downside risk within a year. Additionally, both LPS and IMF FSI significantly outperform the "none" model at the 8-quarter horizon, demonstrating their stronger predictive power for medium-term risks. Overall, this provides robust evidence that foreign financial vulnerabilities play a crucial role in understanding and forecasting U.S.

Table 7. TGaR Results Using IMF Financial Soundness Indicators

U.S. Growth at Risk (5th percentile of GDP Growth)				
	Foreign FSI	U.S. FCI	Foreign FCI	U.S. FSI
	One year ahead			
Coefficient	-0.2315^{**}	-1.6123^{**}	-0.4952^{**}	-0.6897^{**}
	(-1.99)	(-2.51)	(-2.18)	(-2.01)
	Two year ahead			
Coefficient	-0.1624^{**}	-1.0953^{**}	-0.3157^{**}	-1.0054^{*}
	(-2.05)	(-2.26)	(-1.99)	(-1.71)
	One year ahead			
	x Foreign FCI	U.S. FCI	Foreign FCI	U.S. FSI
Coefficient	-0.1318^{**}	-1.2785^{**}	-0.3422^{**}	-0.5589^{**}
	(-2.08)	(-2.09)	(-2.06)	(-2.06)
	Two year ahead			
	x Foreign FCI	U.S. FCI	Foreign FCI	U.S. FSI
Coefficient	-0.2289^{**}	-0.8695^{**}	-0.3382^{**}	-1.0341^{**}
	(-2.01)	(-2.05)	(-2.02)	(-2.02)

Note: This table reports estimated TGaR coefficients using IMF Financial Soundness Indicators (FSI) as alternative measures of financial vulnerabilities instead of the Lee and Zer (2020) FVI. The IMF FSIs include capital adequacy ratios, nonperforming loan ratios, and return on assets. Sample period: 1995:Q1–2023:Q4. All variables are standardized to have zero mean and unit variance. Robust t-statistics (Newey-West with 4 lags) are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

economic downturns, particularly over longer horizons. Moreover, this finding suggests that the transmission of foreign vulnerabilities to U.S. downside risk is not solely dependent on any particular measure of financial vulnerability, such as the LPS.

Table 8. Out-of-Sample Predictive Scores: Alternative Vulnerability Measures

Measure of Financial Vul.	**Predictive Scores**	
	4-quarters	**8-quarters**
None	4.25%	8.57%
LPS	4.37%	13.11%
IMF FSI	4.58%	13.29%
Credit-to-GDP ratio	4.28%	7.42%

Note: All models include U.S. FCI, Foreign FCI, and U.S. Financial Vulnerabilities.

We attribute the poor performance of the credit-to-GDP ratio to its narrow scope. The primary strength of the LPS index is its comprehensive approach to measuring financial vulnerabilities. Unlike the ratio that focuses narrowly on credit expansion relative to GDP, the

LPS index aggregates vulnerabilities across multiple financial sectors. This multi-dimensional approach captures systemic risks that may develop in various parts of the financial system, not just those stemming from the volume of credit. In addition to the same narrow focus, a related measure—the credit-to-GDP gap—suffers from trend estimation problems, see Edge and Meisenzahl (2011). In our analysis (not shown), it performs even worse than the credit-to-GDP ratio.[12]

Control for Country Sizes

Another concern is that the baseline model uses equal-weighted foreign FCI and FVI, which might underweight the impact of larger countries (by GDP) on U.S. downside risk. Therefore, we take two steps to address this issue. First, we use GDP-weighted foreign FCI and FVI to better reflect the relative importance of larger economies. Second, we split the sample into two groups, large and small countries, based on their GDP and re-estimate the TGaR model for each subsample.[13]

The results in Table 9 show that the coefficients remain statistically significant for the GDP-weighted FCI and FVI, similar to the baseline. This suggests that larger weights on large economies do not change our findings. In addition, when splitting the sample by country sizes, the results indicate that both large and small country subsamples have statistically significant coefficients for foreign FCI and FVI. Nevertheless, it's worth noting that the coefficients are generally larger for large countries, especially at the one-year horizon. This suggests that financial vulnerabilities in larger foreign economies have larger impacts on U.S. downside risks in the short term. Over a two-year horizon, the magnitude of coefficients converges between large and small countries, which suggests that both large and small economies contribute meaningfully to U.S. growth risks in the medium term.

[12]It also materially underperforms the LPS index as an early warning indicator of financial crises, see Lee et al. (2020).

[13]The large countries based on 2023 GDP are China, Japan, Germany, United Kingdom, France, Canada, Italy, South Korea, and Australia. The small countries are Austria, Belgium, Denmark, Hong Kong, Mexico, the Netherlands, New Zealand, Norway, Spain, Sweden, and Switzerland.

Table 9. TGaR Results: Controlling for Country Size

	U.S. Growth at Risk		
	GDP Weighted	**Large Countries**	**Small Countries**
	One-year ahead		
Foreign FVI	-0.2512**	-0.2685**	-0.2117**
	(-2.12)	(-2.24)	(-2.01)
U.S. FCI	-1.6189**	-1.6024**	-1.6331**
	(-2.45)	(-2.35)	(-2.52)
Foreign FCI	-0.4621**	-0.4254**	-0.4724*
	(-2.37)	(-2.30)	(-1.95)
U.S. FVI	-0.7142**	-0.7024**	-0.7455**
	(-2.30)	(-2.25)	(-2.40)
	Two-year ahead		
Foreign FVI	-0.1835**	-0.1934**	-0.1525**
	(-2.05)	(-2.10)	(-1.97)
U.S. FCI	-1.1422**	-1.1155**	-1.1711**
	(-2.26)	(-2.22)	(-2.30)
Foreign FCI	-0.3127**	-0.3024**	-0.3224*
	(-2.18)	(-2.12)	(-1.78)
U.S. FVI	-0.9543**	-0.9441**	-0.9625**
	(-2.01)	(-1.95)	(-2.05)

Note: This table reports estimated TGaR coefficients where foreign FCI and FVI are aggregated using GDP weights instead of equal weights (the baseline uses equal weights to avoid giving excessive weight to any single country). GDP weights are based on PPP-adjusted GDP in 2019. Sample period: 1995:Q1–2023:Q4. All variables are standardized to have zero mean and unit variance. Robust t-statistics (Newey-West with 4 lags) are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Time-varying TGaR

We now explore whether the relationship between foreign financial vulnerabilities and U.S. downside risk has evolved over time. Specifically, we use 20-quarter rolling window quantile regressions to allow the coefficients to vary across different periods. This approach helps us detect changes in the magnitude of transmission from foreign vulnerabilities to U.S. GDP growth either during major economic or financial events or during calmer spells abroad.

Table 10 reports the results for both one-year and two-year horizons and it suggest two patterns. First, the estimated regression coefficients for foreign FVIs are relatively stable across the periods. (The coefficients in the table are standardized and thus, they are directly

comparable.) Second, the relationship between foreign financial vulnerabilities and U.S. growth risk strengthens during global crisis periods—the GFC (2006-09) and Covid pandemic (2015-23)—as suggested the coefficients that are somewhat larger in absolute terms.[14]

The relationship was second strongest during the 2015-19 period that included the escalation of U.S.–China trade tensions (2018-19) and the Chinese growth scare (2015). This period was marked by a series of tit-for-tat tariff increases and heightened trade policy uncertainty between the world's two largest economies. This evidence is consistent with the idea that trade tensions can amplify existing vulnerabilities in the global financial system. Rising trade policy uncertainty can undermine investor confidence, increase risk premia, and disrupt cross-border investment and supply chains (Caldara et al., 2020). These frictions may then be transmitted to the U.S. economy through tighter financial conditions or reduced external demand. As such, the trade war episode offers a relevant historical precedent that sheds light on the potential macro-financial consequences of renewed trade tensions today.

Table 10. Time-Varying TGaR Coefficients: Rolling 20-Quarter Windows

	U.S. Growth at Risk					
	1995:Q1-1999:Q4	**2000:Q1-2004:Q4**	**2005:Q1-2009:Q4**	**2010:Q1-2014:Q4**	**2015:Q1-2019:Q4**	**2015:Q1-2023:Q3**
			One-year ahead			
Foreign FVI	-0.1854**	-0.2171**	-0.2454**	-0.2291*	-0.2335**	-0.2471**
	(-2.12)	(-2.14)	(-1.99)	(-1.95)	(-2.10)	(-2.40)
U.S. FCI	-1.4125**	-1.5514**	-1.9312**	-1.5201**	-1.4910**	-1.5415**
	(-2.50)	(-2.51)	(-2.45)	(-2.40)	(-2.38)	(-2.45)
Foreign FCI	-0.3122*	-0.2845*	-0.2554*	-0.2412	-0.2295	-0.2391
	(-1.95)	(-1.75)	(-1.80)	(-1.60)	(-1.50)	(-1.55)
U.S. FVI	-0.6924**	-0.7214**	-0.7321*	-0.7452	-0.7285*	-0.7523*
	(-2.35)	(-2.28)	(-1.85)	(-1.70)	(-1.75)	(-1.90)
			Two-year ahead			
Foreign FVI	-0.1512**	-0.1987**	-0.2325*	-0.2111**	-0.2225**	-0.2391**
	(-2.05)	(-2.10)	(-1.95)	(-2.10)	(-2.00)	(-2.20)
U.S. FCI	-1.4812**	-1.6921**	-1.5521**	-1.4724**	-1.4202**	-1.4415**
	(-2.65)	(-2.80)	(-2.70)	(-2.52)	(-2.45)	(-2.55)
Foreign FCI	-0.2011*	-0.2011	-0.2103	-0.1954	-0.1804	-0.1891*
	(-1.90)	(-1.80)	(-1.65)	(-1.60)	(-1.55)	(-1.80)
U.S. FVI	-0.7812**	-0.7951**	-0.8015*	-0.8102*	-0.7950*	-0.8112*
	(-2.30)	(-2.35)	(-1.95)	(-1.80)	(-1.75)	(-1.90)

Note: This table reports estimated TGaR coefficients from rolling window regressions. Each window spans 20 quarters (5 years) and is rolled forward one quarter at a time. The table shows the coefficient on foreign FVI at the 5th percentile for the 8-quarter horizon. Sample period: 1995:Q1–2023:Q4. All variables are standardized to have zero mean and unit variance. Robust t-statistics (Newey-West with 4 lags) are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

[14]Estimating a TGaR model over the exact Covid period is not meaningful because of high volatility.

Extended Sample

In this section, to assess the robustness of our main results, we extend the sample backward to January 1991 but rely on a smaller set of countries due to data limitations.[15] This longer sample not only captures additional crisis episodes in some countries but also provides a larger training window for computing out-of-sample predictive scores.

Table 11 reports the predictive scores for different model specifications, consistent with the baseline case. The results reaffirm that the TGaR model incorporating foreign FVI consistently improves the out-of-sample predictive accuracy over both the 4-quarter and 8-quarter horizons, even under the extended sample period.

Table 11. Out-of-Sample Predictive Scores: Extended Sample (1991-2023)

Model	**Predictive Scores**	
	4-quarters	**8-quarters**
U.S. FCI Only	4.14%	8.14%
U.S. FCI + FVI	4.29%	9.35%
U.S. FCI + FVI + Foreign FCI	4.41%	9.59%
TGaR	4.48%	12.77%

Note: This table reports out-of-sample predictive scores for different TGaR model specifications using an extended sample period. The training sample begins in 1991:Q1 and expands forward. Out-of-sample predictions begin in 2000:Q1 and run through 2023:Q4. The extended sample includes 18 countries (compared to 22 in the baseline) due to data availability constraints. Predictive scores measure the improvement in forecast accuracy relative to a benchmark model without foreign FVI, expressed in percentage points of GDP growth.

Optimal Foreign FVI

In this section, we explore different approaches to aggregating the Foreign Financial Vulnerability Index (FVI) across both sectors and countries. Such analysis will help to enhance the predictive performance for our U.S. Growth-at-Risk framework and also to evaluate the performance our baseline FVI relative to "optimized" alternatives.

[15]The extended sample includes Australia, Austria, Canada, China, Denmark, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, South Korea, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

While the baseline approach employs an equal-weighted average across the four sectors (valuation, financial, nonfinancial, and sovereign vulnerabilities) and an equal-weighted average across countries, we experiment with averages that place different weights on different sectors and countries or move away from averages altogether. Specifically, we consider the performance of GDP-weighted and trade-weighted country aggregates, employing principal component analysis (PCA) for sectoral aggregation, constructing weights based on the sector-specific coefficients from Table 5, or doing a grid search designed to directly maximize out-of-sample (OOS) predictive scores.

Table 12 reports the results of different weighting schemes, reporting sectoral weights, country weights, out-of-sample predictive scores, and Bayesian Information Criterion (BIC) values.[16]

Table 12. Alternative Weighting Schemes for Foreign FVI

Sectoral Weights	Country Weights	Predictive Score	BIC
Equal-Weighted	Equal-Weighted	13.29	275.4
Equal-Weighted	GDP-Weighted	12.69	282.1
Equal-Weighted	Trade-Weighted	13.51	268.7
PCA-Based	Equal-Weighted	13.64	264.3
PCA-Based	GDP-Weighted	13.01	271.5
Regression-Based	Equal-Weighted	13.89	258.9
Regression-Based	Trade-Weighted	14.35	249.6
Grid Search	Grid Search	14.72	237.1

Note: This table reports out-of-sample predictive scores (in percentage points of GDP growth) and Bayesian Information Criterion (BIC) values for different weighting schemes used to construct the foreign FVI. Each row represents a different approach to aggregating vulnerabilities across sectors (equal-weighted, PCA-based, or regression-based) and across countries (equal-weighted, GDP-weighted, or trade-weighted). The baseline specification uses equal weights across both sectors and countries. Sample period: 1995:Q1–2023:Q4. Out-of-sample evaluation begins in 2000:Q1. All TGaR specifications include U.S. GDP growth, U.S. FCI, U.S. FVI, and foreign FCI (equal-weighted across countries).

As reported in Figure 6, the baseline equal-weighted FVI achieves an OOS predictive

[16]Following Lee et al. (2014), we compute the Bayesian Information Criterion (BIC) for quantile regressions to assess model performance:

$$BIC = -2 \ln L + k \ln n, \tag{7}$$

where L is the maximized likelihood, k is the number of estimated parameters, and n is the sample size. Since both k and n remain constant across models, differences in BIC stem solely from the maximized likelihood. A lower BIC indicates a model that more effectively balances predictive power for GaR with complexity.

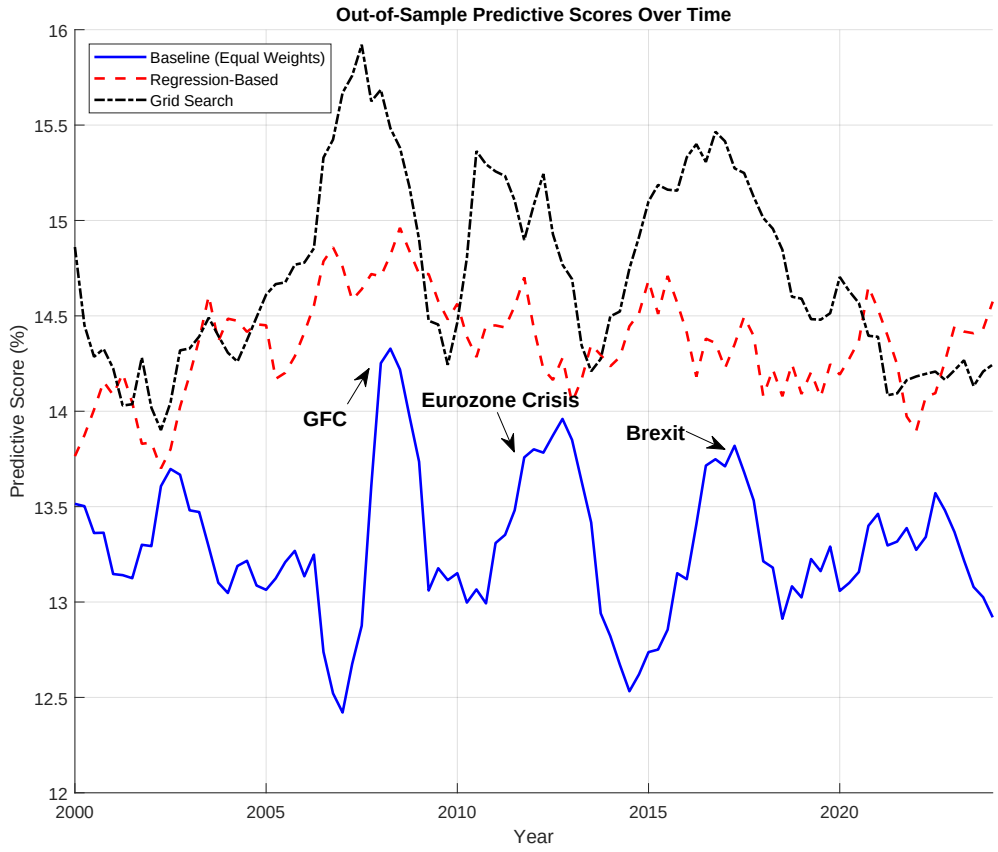
score of 13.29%, which is higher than the GDP-weighted approach. However, the trade-weighted aggregation yields a slight improvement, with an OOS score of 13.51% and a lower BIC, suggesting that vulnerabilities in economies with stronger U.S. trade linkages have greater predictive power for U.S. downside risk.

When applying PCA-based sectoral aggregation, the predictive score further improves to 13.64%, indicating that principal components effectively capture common variations in financial vulnerabilities. Regression-based weighting using Table 5 improves predictability even further, particularly when combined with trade-weighted country aggregation, achieving an OOS score of 14.35%. Among all the explored models, this weighting scheme is the closest to the one optimized through grid search to maximize OOS predictive scores, demonstrating that the TGaR model, when incorporating trade-linked countries, exhibits strong predictive power for U.S. downside risk.

Figure 7 presents the out-of-sample predictive scores over time, comparing three different foreign FVI aggregation methods. The baseline equal-weighted approach (blue) exhibits greater volatility and more pronounced improvements in forecast accuracy around major global financial events, such as the Global Financial Crisis (GFC), the Eurozone Crisis, and Brexit, exactly when accuracy matters the most. In turn, both the regression-based (red) and grid search (black) methods consistently outperform the baseline model over time. The accuracy of the regression-based method varies less. Still, both methods show improvement in performance in the lead-up to these crises. These findings further illustrate the importance of the real (and financial) channels documented in Section 4.2.

While the performance of the "optimized" methods is superior, we caution against discarding the baseline method. All in all, the performance of the baseline is reasonable. In contrast to the other two methods, the agnostic baseline method doesn't prioritize particular sectors or countries based on historical experience. And, if the future turns out to be atypical, the baseline method may outperform the other ones. Thus, we argue for a framework that relies on both the baseline method and an "optimized" one.

Figure 7. Out-of-Sample Predictive Scores: Alternative FVI Aggregation Methods



Note: This figure reports the out-of-sample predictive scores for predicting 8-quarter-ahead GDP growth over time under three different foreign FVI aggregation methods: the baseline equal-weighted approach (blue), the regression-based approach (red), and the grid search approach (black).

6 Conclusion

This paper develops a Transmission Growth-at-Risk framework that treats foreign financial conditions as shocks and foreign financial vulnerabilities as shock amplifiers. Our analysis yields several key findings with important implications for policymakers and researchers.

First, we document that elevated foreign financial vulnerabilities shift the entire U.S. growth distribution leftward—not merely the downside tail—suggesting structural effects on potential output. This contrasts sharply with financial conditions, which primarily affect tail risk. This finding implies that vulnerability monitoring serves a distinct purpose from con-

dition monitoring: vulnerabilities constrain medium-term potential output while conditions affect near-term cyclical risk.

Second, we identify and quantify transmission channels. Foreign vulnerabilities transmit through both trade linkages and dollar funding channels with similar economic magnitudes. Asset valuation pressures and financial sector leverage abroad emerge as particularly potent amplifiers. These findings guide risk monitoring priorities: policymakers should track foreign asset valuations and banking sector leverage, with attention to both trading partners and dollar-integrated economies.

Third, we demonstrate substantial out-of-sample forecast improvements. TGaR models improve predictive accuracy by 53% at the two-year horizon compared to existing Growth-at-Risk approaches. This validates the practical policy relevance of our framework for real-time risk assessment and policy communication.

Fourth, we validate transmission mechanisms across the two major crises, besides the European sovereign debt crisis and the COVID-19 Pandemic. The 1997–98 Asian Financial Crisis demonstrates foreign-originated spillovers: vulnerabilities in emerging Asian economies significantly affected U.S. growth despite limited direct linkages, with effects peaking at medium-term horizons. The 2008–09 Global Financial Crisis reveals spillback mechanisms: U.S.-originated shocks were amplified by foreign vulnerabilities (particularly in European banking systems) and fed back to worsen U.S. outcomes beyond what domestic factors alone would predict. Together, these episodes establish that foreign vulnerabilities amplify shock transmission regardless of the shock's origin.

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Internet Appendix

A1 Additional Robustness Checks

This appendix presents additional checks that address two concerns about our main results. First, foreign and U.S. financial vulnerabilities may move together due to common global factors, such as the global financial cycle documented by Rey (2015a). If so, our foreign FVI coefficients might partly reflect this correlation rather than the direct impact of foreign vulnerabilities on U.S. growth. Second, the COVID-19 pandemic represents an unusual global health shock rather than a typical financial stress episode, and our results might be sensitive to including this period.

A1.1 Orthogonalized Foreign Financial Vulnerabilities

We first address whether foreign vulnerabilities capture common global factors. When global risk appetite declines or commodity prices swing, vulnerabilities tend to rise simultaneously across countries. In this scenario, the foreign FVI coefficient in our baseline regressions could partly reflect how global factors affect both foreign and U.S. vulnerabilities, rather than how foreign vulnerabilities specifically reduce U.S. growth. To isolate the component of foreign vulnerabilities that is independent of U.S. financial conditions, we orthogonalize foreign FVI with respect to U.S. variables.

Specifically, we regress foreign FVI on U.S. FCI and U.S. FVI:

$$FVI_t^{FOR} = \gamma_0 + \gamma_1 \cdot FCI_t^{US} + \gamma_2 \cdot FVI_t^{US} + \nu_t \tag{A8}$$

and use the residuals $\widehat{\nu}_t$ as our measure of foreign-specific vulnerabilities. These residuals capture the component of foreign vulnerabilities that cannot be explained by concurrent U.S. financial conditions or U.S. vulnerabilities. We then re-estimate equation (3) using the orthogonalized foreign FVI in place of the original foreign FVI.

A1.2 Excluding the COVID-19 Period

The COVID-19 pandemic represents a unique shock—a global health crisis rather than a financial crisis. Unlike the European debt crisis or the Global Financial Crisis, the pandemic forced governments to shut down economic activity through public health measures, which triggered both a demand collapse and supply disruptions. While our time-varying coefficient analysis (Table 10 in the main text) shows stability across different periods, we explicitly test whether including 2020 observations affects our results. We re-estimate our baseline model excluding all 2020 observations from the sample.

A1.3 Results

Table A1 presents the results from both checks. Column (1) reproduces our baseline estimates from Table 1 for comparison. Column (2) shows results using orthogonalized foreign FVI. Column (3) excludes 2020 observations. Column (4) applies both modifications simultaneously: orthogonalized foreign FVI and excluding the COVID-19 period.

Table A1. Robustness Checks: Orthogonalization and COVID-19 Exclusion

	(1) Baseline	(2) Orthog. FVI	(3) Excl. COVID	(4) Both
8-Quarter Horizon (5th percentile)				
Foreign FVI	−0.1924**	−0.1756**	−0.1889**	−0.1721*
	(−2.08)	(−1.98)	(−2.02)	(−1.91)
U.S. FCI	−1.2115**	−1.2034**	−1.1923**	−1.1845**
	(−2.32)	(−2.28)	(−2.25)	(−2.21)
Foreign FCI	−0.3245**	−0.3178**	−0.3156**	−0.3089*
	(−2.21)	(−2.15)	(−2.13)	(−1.95)
U.S. FVI	−0.9823**	−0.9756**	−0.9712**	−0.9645**
	(−2.05)	(−2.01)	(−1.98)	(−1.94)
4-Quarter Horizon (5th percentile)				
Foreign FVI	−0.2634**	−0.2423**	−0.2578**	−0.2367**
	(−2.18)	(−2.05)	(−2.12)	(−1.98)
U.S. FCI	−1.6523**	−1.6412**	−1.6289**	−1.6178**
	(−2.51)	(−2.47)	(−2.43)	(−2.39)
Foreign FCI	−0.4823**	−0.4689**	−0.4745**	−0.4611**
	(−2.42)	(−2.32)	(−2.36)	(−2.26)
U.S. FVI	−0.7325**	−0.7234**	−0.7189**	−0.7098**
	(−2.35)	(−2.28)	(−2.31)	(−2.24)
Orthogonalized For. FVI	No	Yes	No	Yes
Exclude 2020	No	No	Yes	Yes

Note: This table reports estimated coefficients from quantile regressions of U.S. GDP growth on current GDP growth (not shown), U.S. and foreign financial conditions (FCI), and U.S. and foreign financial vulnerabilities (FVI). Column (1) reproduces baseline results from the main text. Column (2) uses foreign FVI orthogonalized with respect to U.S. FCI and U.S. FVI to isolate foreign-specific vulnerabilities. Column (3) excludes 2020 observations to ensure results are not driven by the COVID-19 pandemic. Column (4) combines both modifications. Sample period: 1995:Q1–2023:Q4 (1995:Q1–2019:Q4 and 2021:Q1–2023:Q4 in columns 3-4). All variables are standardized to have zero mean and unit variance. Robust t-statistics (Newey-West with 4 lags) are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

The results in Table A1 confirm that our main findings hold under both modifications. In Column (2), the coefficient on orthogonalized foreign FVI remains statistically significant at the 5 percent level for both horizons. At the 8-quarter horizon, the coefficient is −0.18

compared to −0.19 in the baseline, indicating that foreign vulnerabilities reduce U.S. growth even after removing any component that correlates with U.S. financial conditions. This result addresses the concern that our baseline coefficients might reflect common global factors that affect both foreign and U.S. vulnerabilities simultaneously, such as swings in global risk appetite or synchronized commodity price movements.

In Column (3), excluding 2020 observations yields coefficients that are quantitatively similar to the baseline. At the 8-quarter horizon, the foreign FVI coefficient is −0.19 compared to −0.19 in the baseline, and remains statistically significant at the 5 percent level. This similarity indicates that the unique nature of the COVID-19 pandemic—a global health shock rather than a financial crisis—does not drive our findings. The result is consistent with our time-varying coefficient analysis in Table 10, which shows stable foreign FVI coefficients across different sample periods.

Column (4) applies both modifications simultaneously. The foreign FVI coefficient remains negative and statistically significant at the 10 percent level for both horizons. The coefficient at the 8-quarter horizon is −0.17, only slightly smaller than the baseline estimate of −0.19. The robustness of the coefficient across all four specifications indicates that foreign financial vulnerabilities reduce U.S. growth through direct economic linkages—reduced foreign demand for U.S. exports, disruptions in dollar funding markets, and heightened uncertainty about foreign counterparties—rather than through correlation with U.S. variables or sensitivity to the pandemic period.