CHAPTER 2

# Geopolitical Risks: Implications for Asset Prices and Financial Stability

## Online Annex 2.1. Data Description and Sources

| Online Annex Table 2.1.1. Variable Description and Data Sources | | |
|---|---|---|
| **Variable** | **Description** | **Source** |
| **Geopolitical variables** | | |
| Geopolitical risk index | A measure of adverse geopolitical events and associated risks based on a tally of newspaper articles covering geopolitical tensions (index, 1985–2019=100), at both global and country levels. | Caldara and Iacoviello (2022), available at https://www.matteoiacoviello.com/gpr.htm |
| Bilateral sanction | Dummy variable equal to 1 if a financial/trade/other sanction has been imposed by a source country on a recipient country | Global Sanctions Database; and Kirilakha and others (2021) |
| **Global variables** | | |
| VIX | Chicago Board Options Exchange's options-implied volatility index for S&P 500 | Bloomberg Finance LP |
| WTI oil price | Spot price of West Texas Intermediate (WTI) crude oil, in US dollars per barrel | LSEG Datastream |
| Safe asset return | One-month US Treasury Bill rate (monthly yields) | Kenneth R. French - Data Library |
| **Macro-financial variables** | | |
| Stock market index | Country-aggregate stock market index | LSEG Datastream; and IMF staff calculations |
| Market return | Log difference of country-aggregate stock market index | LSEG Datastream; and IMF staff calculations |
| Policy rate | Monetary policy rate, in percent | IMF, World Economic Outlook database |
| Short-term rate | Short-term interest rate, in percent | IMF, World Economic Outlook database |
| Long-term sovereign bond yield | Long-term (10-year or nearest equivalent) government bond yield, in percent | IMF, World Economic Outlook database |
| Sovereign 5-year CDS premium | Financial derivative contract that allows investors to hedge or speculate on the creditworthiness of a sovereign country over a 5-year period. | Bloomberg Finance LP |
| GDP, real | Gross domestic product, at constant 2015 prices in national currency and in US dollars | IMF, World Economic Outlook database |
| GDP, nominal | Nominal gross domestic product, in US dollars | IMF, World Economic Outlook database |
| Real GDP growth | Real GDP growth, in percent | IMF, World Economic Outlook database |
| Real GDP per capita | Log of real GDP per capita | IMF, World Economic Outlook database |
| Industrial production index | Industrial production index | IMF, World Economic Outlook database |
| Consumer price index | Consumer price index | IMF, World Economic Outlook database |
| Inflation | Change in the consumer price index | IMF, World Economic Outlook database |
| Public Debt-to-GDP ratio | Central government gross debt-to-GDP ratio | IMF, World Economic Outlook database |
| Current account balance-to- GDP ratio | Ratio of current account balance to GDP, in percent | IMF, Balance of Payments |
| Nominal exchange rate | Local currency per US dollar | IMF, World Economic Outlook database |
| Real effective exchange rate (deviation from trend) | Log deviation of the real effective exchange rate from trend using an Hodrick-Prescott filter, with penalty parameter 100 | IMF, World Economic Outlook database |
| International reserves adequacy | International reserves-to-a combined metric of components reflecting potential drains on the balance of payments. | IMF, Assessing Reserve Adequacy – ARA database |
| Financial Markets Depth Index | A combined metric of stock market capitalization to GDP, stocks traded to GDP, sovereign debt securities to GDP, and total debt securities of financial and nonfinancial corporations to GDP. | IMF, Financial Development Index database |
| Exports | Bilateral total value of merchandise exports | IMF Direction of Trade Statistics |
| Imports | Bilateral total value of merchandise imports | IMF Direction of Trade Statistics |
| Cross-border banking claims | Total cross-border banking claims (including loans, debt securities or other debt instruments, equity or | Bank for International Settlements, Locational Banking Statistics |

| | | |
|---|---|---|
| | investment fund shares, and financial derivatives), on an immediate counterparty basis | |
| Cross-border banking liabilities | Total cross-border claims, as defined above, on a country by non-resident banking sectors | Bank for International Settlements, Locational Banking Statistics |
| Commodity exporter | A country is considered to be a commodity exporter if more than 60 percent of its total merchandise exports are composed of commodities. | UN Trade and Development |
| Institutional quality | Average of bureaucracy quality, corruption, democratic accountability, government stability and law and order scores. | The International Country Risk Guide database |
| **Firm-level variables** | | |
| Leverage | Total debt-to-total assets ratio | LSEG Datastream; and IMF staff calculations |
| Profitability | Return on assets | LSEG Datastream; and IMF staff calculations |
| Revenue exposure | Weighted average major foreign geopolitical risk event indicator variable, with weights proportional to the share of total revenue derived from each foreign country in the previous year | FactSet; and IMF staff calculations. |
| Size | Log of total assets of a firm | LSEG Datastream; and IMF staff calculations |
| Subsidiary exposure | Weighted average major foreign geopolitical risk event indicator variable, with weights proportional to the number of subsidiaries in each foreign country in the previous year | Orbis; and IMF staff calculations |
| Shareholder company presence | Weighted average major foreign geopolitical risk event indicator variable, with weights proportional to whether a firm has any shareholder company in each foreign country in the previous year | Orbis; and IMF staff calculations |
| **Bank-level variables** | | |
| Change in cost of funding | Change in total interest expense-to-average interest-bearing liabilities ratio | Fitch Connect; and IMF staff calculations |
| Change in equity | Change in equity-to-lagged total assets ratio | Fitch Connect; and IMF staff calculations |
| Loan growth | Log change in total outstanding gross bank loans | Fitch Connect; and IMF staff calculations |
| Non-Performing Loans Ratio | Nonperforming loans-to-outstanding gross loans | Fitch Connect; and IMF staff calculations |
| Size | Log of total assets | Fitch Connect; and IMF staff calculations |
| Capital ratio | Total equity-to-total assets ratio | Fitch Connect; and IMF staff calculations |
| Liquidity ratio | Liquid assets-to-total assets ratio | Fitch Connect; and IMF staff calculations |
| Profits | Operating profits normalized by total assets | Fitch Connect; and IMF staff calculations |
| **Fund-level variables** | | |
| Cash holding percentage | Cash as a percentage of fund portfolio | Lipper |
| Direct exposure | Weighted average of an indicator variable indicating if the security issuer is domiciled in country c' whereas the weights reflect the holding percentage of each security one quarter prior to the event | FactSet, Lipper, and IMF staff calculations |
| Exposure to companies impacted by tariffs | Weighted average of an indicator variable indicating if the security issuer operates in sectors impacted by a tariff announcement, whereas the weights reflect the holding percentage of each security one quarter prior to the event | FactSet, Lipper, and IMF staff calculations |
| Fund cumulative flow | Cumulative flow from event month t, in millions of US dollars | Lipper, and IMF staff calculations |
| Fund cumulative return | Cumulative return from event month t | Lipper, and IMF staff calculations |
| Fund size | Total assets under management, in millions of US dollars | Lipper |
| Revenue exposure | Weighted average of an indicator variable indicating if the security issuer derives revenues country c' at year T-1 and the revenue percentage is higher than the country-sectoral median, whereas the weights | FactSet, Lipper, and IMF staff calculations |

| | | |
|---|---|---|
| | reflect the holding percentage of each security one quarter prior to the event | |
| Subsidiary exposure | Weighted average of an indicator variable indicating if the security issuer has at least one subsidiary in country c' at year T-1, whereas the weights reflect the holding percentage of each security one quarter prior to the event | FactSet, Lipper, Orbis, and IMF staff calculations |
| **Stock-level variables** | | |
| Stock return | Log difference of firm i's stock return index, monthly | LSEG Datastream; and IMF staff calculations |
| Size factor | Logarithm of firm i's market capitalization (the sum of the share price multiplied by the number of ordinary shares in issue for each index constituent) | LSEG Datastream; and IMF staff calculations |
| Book-to-market factor | Stock i's price-to-book values. | LSEG Datastream; and IMF staff calculations |
| Momentum factor | Stock i's cumulative return for month t–12 to month t–1. | LSEG Datastream; and IMF staff calculations |
| Implied volatility | One month ahead put options for firm i's stock; across out-of-the-money deltas. | LSEG Datastream |
| Revenue exposure | Share of country c in total revenue exposure, percent | FactSet |
| Number of subsidiaries | The number of subsidiaries of a parent company in country c | Orbis |
| Subsidiary presence | The dummy variable that takes one if a firm has at least one subsidiary in country c, and zero otherwise | Orbis |
| Asset size of subsidiaries | Total assets of subsidiaries in country c | Orbis |

**Online Annex Table 2.1.2. Advanced Economies and Emerging Market and Developing Economies Included in the Analyses**

| *Advanced Economies (AEs)* | *Emerging Market and Developing Economies (EMDEs)* |
|---|---|
| Australia, Austria, Belgium, Canada, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong SAR, Ireland, Italy, Japan, Korea (South Korea), Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovakia, Slovenia, Spain, Sweden, Switzerland, Taiwan Province of China, United Kingdom, United States | Argentina, The Bahamas, Bangladesh, Botswana, Brazil, Bulgaria, Chile, China, Colombia, Czech Republic, Egypt, Hungary, India, Indonesia, Jamaica, Kazakhstan, Kenya, Lebanon, Liberia, Malaysia, Mauritius, Mexico, Morocco, Nigeria, Pakistan, Panama, Peru, Philippines, Poland, Russia, Saudi Arabia, South Africa, Sri Lanka, Thailand, Türkiye, Ukraine, United Arab Emirates, Venezuela, Vietnam, Zambia |

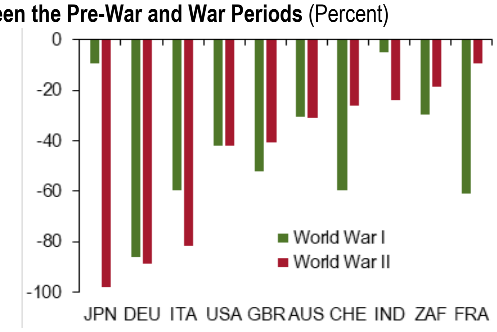
Source: IMF staff.
Note: The exact sample composition varies across empirical analyses based on data availability.

## Online Annex 2.2. Additional Stylized Facts

**Online Annex Figure 2.2.1. Stock Market Reaction During World Wars I and II**

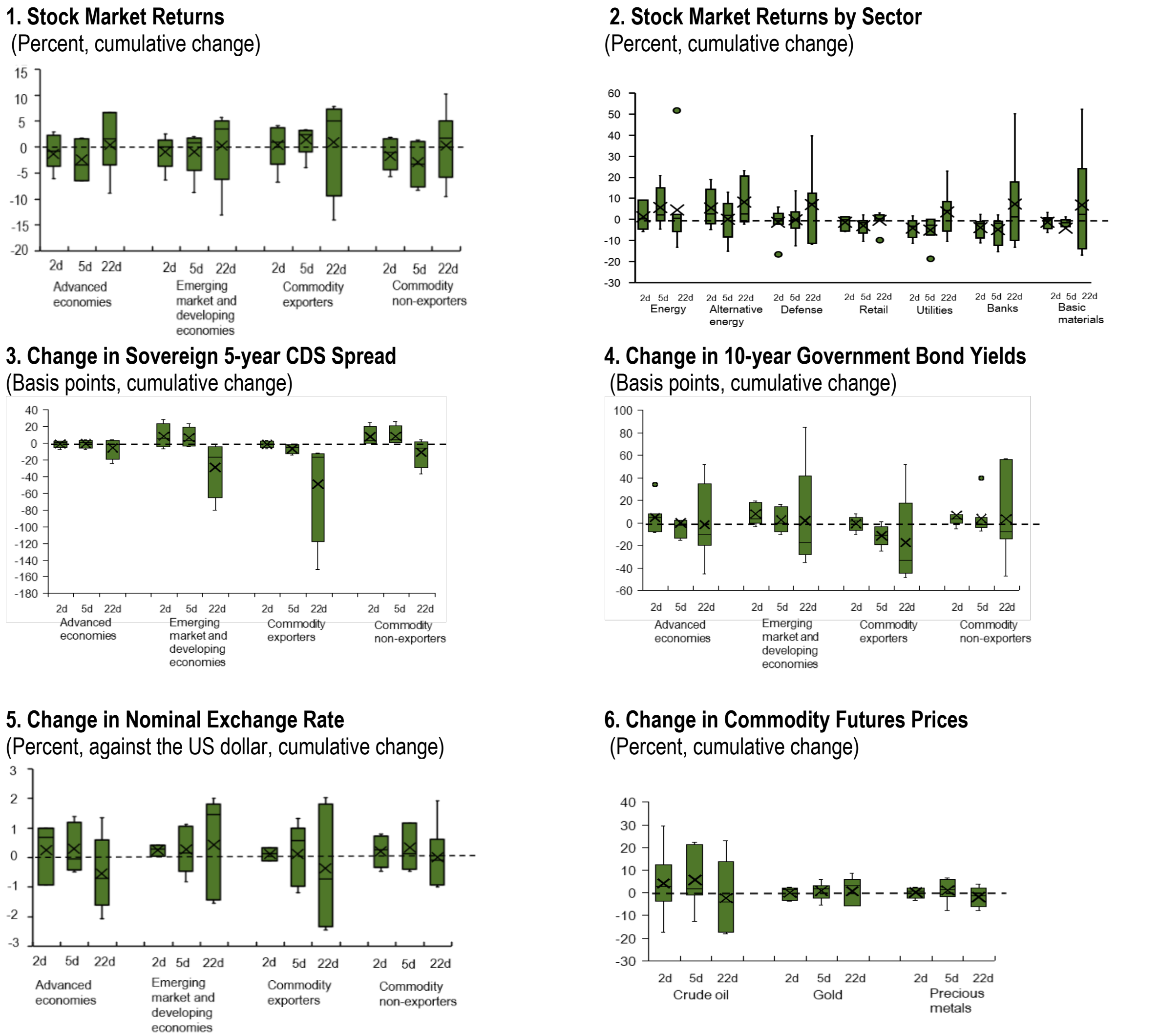
*During the World Wars, stock price declines were severe, both in the countries directly involved in the conflict and in others.*

**1. Change in Real Stock Price between the Pre-War and War Periods** (Percent)




Sources: Global Financial Database, IMF staff calculations.
Note: The war periods are World War I (July 28, 1914 – November 11, 1918) and World War II (September 1, 1939 – September 2, 1945). However, the dates extended for Japan and Germany during World War II, as Japan's stock market was closed from September 1945 to May 1949, and Germany imposed stock price limits on trading from January 1943 to June 1948.

**Online Annex Figure 2.2.2. Global Geopolitical Risk Events and Asset Classes**

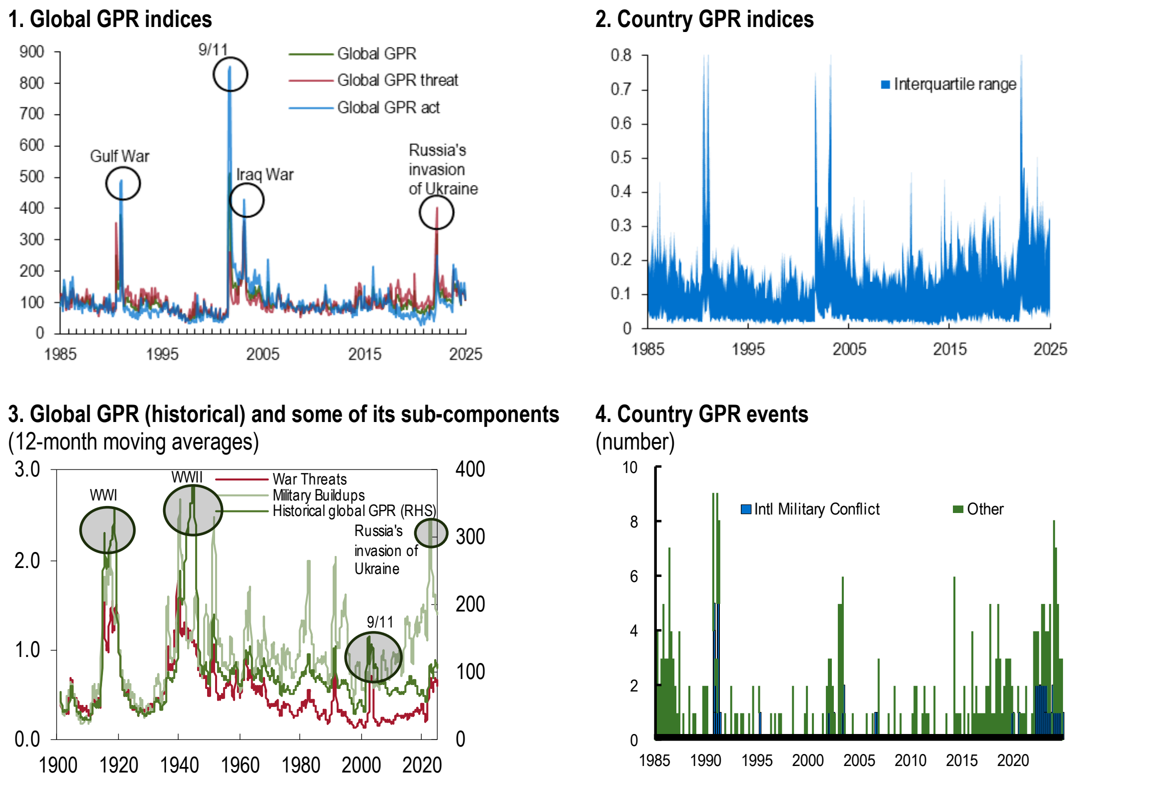



Sources: Bloomberg Finane L.P.; IMF; Global Financial Database, LSEG Datastrem; UN Trade and Development; IMF staff calculations.
Note: The panels show cumulative change in the indicated asset prices 2 days (2d), 5 days (5d), or 22 days (22d) after major global geopolitical risk events, defined as all events since 1985 that are more than two standard deviations above the average of the global geopolitical risk index of Caldara and Iacoviello (2022). The boxes indicate the interquartile ranges across events, and "x" and "–" denote the average and the median impact, respectively. Whiskers denote the whole range across events, excluding outliers. Outliers are shown by a dot outside the whiskers. See Online Annex Table 3.3.1 for the list of identified events and their start dates. The sample includes the largest 40 economies, classified as AEs and EMDEs based on the IMF's *World Economic Outlook,* and as commodity exporters and non–commodity exporters based on UN Trade and Development data from 2019 to 2021. Commodity-exporting countries are defined as those for which commodities constitute more than 60 percent of total merchandise exports. In panel 6, precious metals refer to the average prices of copper, palladium, platinum and silver futures (on a continuous contract basis). CDS = credit default swap.

## Online Annex 2.3. Measuring Geopolitical Risk

The chapter defines geopolitical risk as the potential for adverse geopolitical events, such as wars, terrorist acts, and tensions between states, which can disrupt international relations and economic stability. To measure geopolitical risk, it utilizes the news-based geopolitical risk (GPR) indices of Caldara and Iacoviello (2022). Based on a dictionary of words associated with geopolitical events and threats, the indices measure the share of articles in ten major news outlets in the US, the U.K. and Canada discussing rising geopolitical risks by dividing the number of such articles by the total number of published articles. The indices allow for differentiation between (i) geopolitical threats and realization or escalation of adverse geopolitical risk events, and (ii) countries, by counting joint occurrences of geopolitical terms and the name of the country (or its capital or another main city). The global and country-specific indices are available from 1985 onwards at daily and monthly frequencies, respectively (Online Annex Figure 2.3.1, panels 1 and 2). A historical global GPR index, which is based on fewer newspapers, starts from 1900 and provides further sub-components (Online Annex Figure 2.3.1, panel 3).

**Online Annex Figure 2.3.1. Geopolitical Risk Indices and Events**




Sources: Caldara and Iacoviello (2022); and IMF staff calculations.
Note: Panel 4 shows the total number of major geopolitical risk events per month, where "major" is defined as country GPR index values that are above the country-specific average by more than 2 standard deviations. Events are cross-verified using publicly available sources. GPR = geopolitical risk.

The chapter employs both global and country GPR indices and their various sub-components (e.g., acts and threats). It defines "major geopolitical risk events" as extreme observations in the country GPR indices that are more than two standard deviations above the country-specific average.

Extreme observations in the country GPR indices are cross-checked with publicly available news sources. Extreme values that correspond to multi-national summits (for example, protests amid various G7, APEC, ASEAN, NATO, or World Economic Forum summits; bilateral summits), climate policy protests, drug/cartel crackdowns or economics-related protests, are excluded from the major geopolitical risk events series. For global-scale events, extreme GPR values of countries not directly involved in the conflict are excluded—their exposure to such events is taken into account through their trade or financial linkages with the countries afflicted by conflict.

A total of 452 country-month observations are identified as major events. Those include international military conflicts, diplomatic tensions, domestic unrest, and terrorist attacks. On average, about 2.5 percent of country-specific observations are identified as major geopolitical risk events. International military conflicts occur less frequently than other types of geopolitical risk events, comprising about 15 percent of the major geopolitical risk events (Online Annex Figure 2.3.1, panel 4).

**Online Annex Table 2.3.1. Major Global Geopolitical Risk Events (post WWII)**

| | Event | Start Date | Size of the shock (in terms of standard deviation) In the event month (1) | At the onset of the event (2) | Maximum during the event (3) |
|---|---|---|---|---|---|
| WW II | Germany invades France | 5/9/1940 | 5.5 | -- | -- |
| WW II | Pearl Harbor | 12/6/1941 | 11.4 | -- | -- |
| WW II | D-Day | 6/6/1944 | 12.2 | -- | -- |
| Post WW II | Korean War* † | 6/23/1950 | 4.8 | -- | -- |
| Post WW II | Suez Canal Crisis* † | 10/30/1956 | 2.5 | -- | -- |
| Post WW II | USSR invasion of Hungary* | 11/4/1956 | 2.5 | -- | -- |
| Post WW II | Nuclear test* | 7/12/1958 | 2.1 | -- | -- |
| Post WW II | Lebanon crisis* | 7/15/1958 | 2.1 | -- | -- |
| Post WW II | Berlin Crisis* | 8/13/1961 | 2.2 | -- | -- |
| Post WW II | Cuban Missile Crisis* | 10/19/1962 | 4.4 | -- | -- |
| Post WW II | Nuclear tests* | 8/23/1963 | 2.2 | -- | -- |
| Post WW II | Vietnam War (further escalation) | 6/1967 | 3.0 | -- | -- |
| Post WW II | Nuclear test* | 9/6/1970 | 2.8 | -- | -- |
| Post WW II | Terrorist attack* | 9/6/1970 | 2.8 | -- | -- |
| Post WW II | Arab Oil Embargo* | 10/19/1973 | 2.2 | -- | -- |
| Post WW II | USSR invades Afghanistan * † | 12/24/1979 | 2.0 | -- | -- |
| Post WW II | Falkland Islands (Malvinas)* | 4/1/1982 | 2.6 | -- | -- |
| Post WW II | US bombs Libya ** | 4/14/1986 | 1.5 | 3.1 | 4.0 |
| Post WW II | Iraq invades Kuwait* ** | 8/2/1990 | 3.2 | 2.5 | 4.7 |
| Post WW II | Gulf War* ** | 1/5-16/1991 | 5.1 | 7.8 | 7.9 |
| Post WW II | Iraq War* ** | 3/19/2003 | 4.9 | 6.3 | 8.3 |
| Post WW II | Russia's annexation of Crimea | 3/18/2014 | -0.9 | 0.9 | 1.9 |
| Post WW II | Russia's invasion of Ukraine* ** † | 2/24/2022 | 2.4 | 7.0 | 7.4 |
| Post WW II | Middle East tensions ** | 10/7/2023 | 1.5 | 2.1 | 4.0 |
| Post WW II – Terrorist Attacks | 9/11 * ** | 9/11/2001 | 6.4 | 10.5 | 15.8 |
| Post WW II – Terrorist Attacks | Madrid ** | 3/11/2004 | 0.5 | 1.3 | 2.6 |
| Post WW II – Terrorist Attacks | London ** | 7/6/2005 | 1.0 | 6.2 | 6.2 |
| Post WW II – Terrorist Attacks | Boston | 4/15/2013 | -0.5 | 0.1 | 1.1 |
| Post WW II – Terrorist Attacks | Paris ** | 11/13/2015 | 0.9 | 3.2 | 4.2 |

Sources: Caldara and Iacoviello (2022), and IMF staff calculations.
Note: The table shows the set of post WWII events for which the monthly global GPR index of Caldara and Iacoviello (2022) is more than two standard deviations above its historical average. Major spikes in the global GPR index during WWII are noted for comparison. Post-1985 events included in Figure 4 are Iraq's invasion of Kuwait (1990), the Gulf War (1991), 9/11 terrorist attacks on the US (2001), the Iraq War (2003), Russia's annexation of Crimea (2014), Russia's invasion of Ukraine (2022), and the Israel-Gaza conflict (2023). Column (1) shows, for each event, the difference between the level of the monthly GPR index in the event month and the historical average of the monthly GPR index, divided by its historical standard deviation. Columns (2) and (3) show the size of the shocks at a daily frequency, at the onset of the event (column (2)) and when the shock attains its highest value during the event (column (3)). * Events for which the monthly global GPR index is above the historical average by more than two standard deviations for the post-WWII period. ** Events for which the daily global GPR index is above the historical average by more than two standard deviations for the post-1984 period. † Monthly global GPR index captures the elevation in geopolitical risks mostly in the subsequent month.

## Online Annex 2.4. How do aggregate stock market indices respond to geopolitical risk shocks?

Geopolitical risks, macroeconomic outcomes and financial asset prices are intertwined. A vector autoregression (VAR) model is, therefore, employed to model the different transmission channels of geopolitical risk shocks to asset prices. This approach helps to separate endogenous, systematic relationships between variables from exogenous shocks transmitted through the system. To account for country heterogeneity, the chapter employs a panel VAR model as the benchmark, controlling for country and pandemic country-time fixed effects. Estimating the VAR coefficients and identifying exogenous geopolitical shocks allows tracing the dynamic causal effect of such shocks on the cross-country average stock market index.

**Empirical methodology and estimation.** The panel VAR model uses Bayesian estimation and a Gibbs sampler to approximate the joint posterior distribution of the unknown coefficients of the system (for technical details, see Mumtaz and Sunder-Plassmann, 2020). The prior distributions are standard, set following the Minnesota procedure implemented as in Banbura, Giannone and Reichlin (2010). To account for abnormal data fluctuations during the COVID-19 pandemic, the chapter adopts the approach of pandemic-priors following Cascaldi-Garcia (2024), which are introduced via the exogenous $V_t$ variables in the following baseline specification:

$$Z_{it} = c_i + \sum_{j=1}^{P} b_{i,j} Z_{it-j} + d_i V_t + u_{it} \qquad (2.4.1)$$

where the vector of monthly endogenous variables $Z_{it}$ for country $i$ out of a total of $M$ considered in the benchmark model, comprises the geopolitical risk indicator (GPR), industrial production index, consumer price index (CPI), policy and long-term interest rates, real equity prices (CPI-deflated stock market indices in USD), the real price of oil (US CPI-deflated WTI) and the VIX. The sample comprises 43 AEs and EMDEs over the period 1986 to 2024, resulting in an unbalanced panel with differing starting points of the sample across countries.[1] Adopting the approach of Fernandez-Villaverde and others (2024), observations above (below) the highest (lowest) 1.25$^{th}$ percentile of their empirical distributions are dropped. The chosen model specification addresses the need to account for key economic variables of the New Keynesian benchmark model (real sector prices and activity, monetary policy), for features specific to small open economies in the cross-section (exchange rate effects accounted for in the stock market index denomination in USD and commodity prices), while also sampling monthly data to analyze financial market responses at relatively higher frequencies when compared to quarterly national accounts. The specification is broadly consistent with the variable selection in Caldara and Iacoviello (2022) and Fernandez-Villaverde and others (2024).

The stock market reaction to GPR shocks may vary depending on factors such as the size of the shock or the level of geopolitical tensions upon the materialization of the shock, the degree of global financial integration, or whether the country is a commodity exporter or importer. The chapter assesses the significance of these factors for the response of asset prices to GPR shocks. To evaluate the presence of non-linearities in the stock market response to larger GPR shocks or shocks occurring when the level of geopolitical tensions is already elevated, the GPR index is replaced with its z-score, whenever it exceeds the two standard deviations threshold and set to zero otherwise. This ensures that shocks identified by the model are either shocks occurring when the level of tensions is already high or very large shocks that increase the GPR index from levels around its historical average. Country groupings considered in the analysis are by the level of economic development, G7 economies, AEs excluding G7 (AEs ex. G7) and emerging market (EMEs), and by commodity dependence, i.e., commodity exporters and non-exporters.

In the baseline specification, variables are sampled at a monthly frequency and enter the model in log levels, except for interest rates that are not logged. Formally, $b_{i,j}$ are reduced-form VAR coefficients, while $c_i$ denote country fixed-effects, allowing for heterogenous country-specific initial conditions. Finally, $V_t$ flexibly accounts for other exogenous regressors or dummy variables for specific periods (the chapter considers only the use of COVID-19 country-time fixed effects as additional controls in $V_t$). The number of lags, $P$, is set to 2, according to the Bayes Information Criterion. Reduced-form errors captured by $u_{it}$ estimate cross-sectionally correlated shocks and, hence, cannot be ascribed unambiguous structural economic interpretations.

**Identification and causal inference**. Identifying structural economic shocks requires additional assumptions. Caldara and Iacoviello (2022) adopt a plausible, recursive (Cholesky) identification scheme, assuming structural shocks to GPR affect all other variables contemporaneously, while remaining shocks do not have a bearing on the presumably exogenous GPR. The chapter follows this recursive ordering as an identification strategy.

**Empirical Results.** Based on the estimated reduced-form parameters of the VAR model and the identification scheme, structural impulse response functions (IRFs) trace the dynamic causal effect of the identified shocks on the target variables. Results in the main text of the chapter show the responses of equity markets, stock market option-implied volatility, risk-aversion and uncertainty to geopolitical shocks. Impulse responses of remaining variables to GPR shocks in the benchmark model are reported below. Although data are sampled at a higher frequency and model specifications are somewhat different, results are broadly consistent with the literature.[2]

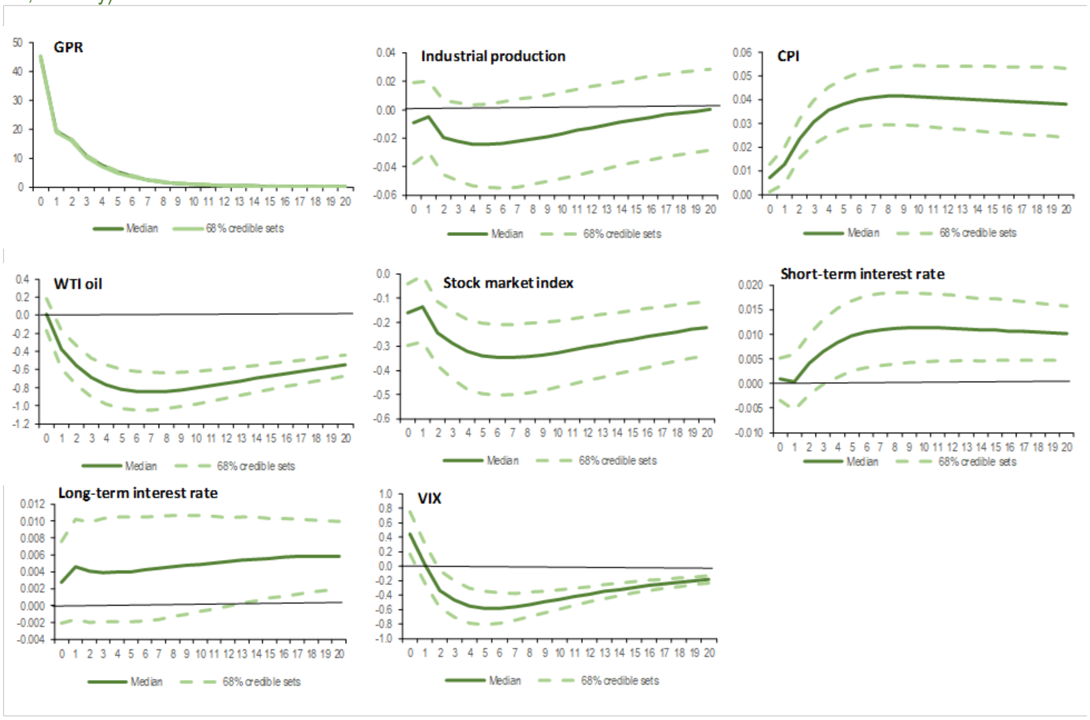
The results are qualitatively robust to various changes in the model specification:

[1] The sample of 43 AEs and EMEs is used for the analysis where global shocks are considered. When country-specific shocks are considered, 6 countries are dropped due to the unavailability of their domestic GPR.

[2] Results documented in this section are benchmarked against the seminal work of Caldara and Iacoviello (2022) that focuses on quarterly US data and Fernandez-Villaverde and others (2024), which focuses on quarterly data of a narrower selection of countries. While model specifications differ, they are similar in spirit. Results are qualitatively consistent with these studies. While the average aggregate stock market response is modest when considering average country-specific GPR shocks (ca. -0.3% at peak), it is significantly larger in the case of large country-specific shocks (ca. -2%), closer to the estimates of Caldara and Iacoviello (2022) or Fernandez-Villaverde and others (2024) who find stock price responses between ca. 0% to ca. -6% across specifications and identification strategies. Separately, Metiu (2025) uses a factor-augmented VAR model to document cross-country effects of geopolitical shocks identified through recursive and narrative restrictions; results are consistent with those reported in the chapter.

- increasing the lag order to 3 as suggested by the less parsimonious AIC criterion,
- replacing the VIX with the risk-aversion and uncertainty measures,
- dropping the long-term interest rate variable,
- switching from the stock market index in US dollar terms to local currency,
- considering the pre-COVID-19 pandemic period only,
- excluding US data from the cross-section.

**Online Annex Figure 2.4.1. Response of Variables in the VAR Model to Country GPR Shocks**
(Percent, monthly)




Source: IMF staff calculations.
Note: The panels report impulse responses from the benchmark VAR model. The shock is identified using a recursive ordering where GPR comes first, consistent with its plausible exogeneity. Solid lines report the median IRFs, while dotted lines are the 68 percent credible sets around the median. The geopolitical risk indicator is the country GPR index by Caldara and Iacoviello (2022).

Online Annex Figure 2.4.1 IRFs to GPR shocks based on recursive identification provide not only average responses across time and countries in the sample, but also across transmission channels. On average, the negative response of equity prices and the spike in option-implied volatility is accompanied by persistent oil price declines[3], modest inflationary pressures and the contraction of industrial production, while the yield curve bear flattens. The wide uncertainty bands around the median IRFs indicate that responses to shocks may substantially differ depending on country characteristics, transmission channels and the specificity of the geopolitical event. As discussed in the chapter, geopolitical shocks are transmitted across financial markets through uncertainty about fundamentals and investors' risk-aversion. As illustrated by the response of oil prices, these shocks are also propagated and possibly amplified by commodity markets.

There are two main channels through which commodity prices could affect financial asset prices, impacting fundamentals, but also causing monetary policy reactions. First, by disrupting oil supply and hence raising the price of oil, which is akin to aggregate supply/cost-push shocks that lower real economic activity and increase consumer prices. Second, by denting global demand through the uncertainty effects, hence lowering the price of oil and of other goods and services. The positive, significant and persistent response of uncertainty to GPR shocks supports the conjecture that shocks are weighing on global demand through uncertainty and ultimately lead to lower oil prices, as activity slows. This is also consistent with results from Bloom (2007) who documents negative effects on aggregate demand through various channels following uncertainty shocks. As the average effect on oil across these channels in Online Annex Figure 2.4.1 is negative, results reported in the chapter suggest that across geopolitical risk episodes, the aggregate demand and

[3] While oil prices fluctuate within the first month after geopolitical shocks, the cumulative effect on oil prices peaks at ca. -1 percent several months after the shock, and is larger in the case of global or large country-specific GPR shocks. The negative effect on oil prices is consistent with evidence from important historical geopolitical stress episodes after which, despite volatile prices in the immediate aftermath of the shock, oil prices contracted in the subsequent months (e.g., Gulf Wars).

uncertainty channels of geopolitical shocks dominate for the commodity market responses. Nevertheless, on aggregate, activity seems to slow, while prices tend to persistently increase, albeit very mildly, with the yield curve reaction consistent with a more proactive monetary policy – suggesting the dominance of protracted aggregate supply channel for the real sector.

Cross-country IRFs in the chapter correspond to the average stock market responses across 43 markets and across a variety of geopolitical shocks in the data. While stock markets in G7 economies react more negatively for longer, other AEs and EMEs stock markets are broadly aligned with the average effect (Online Annex Figure 2.4.2, panel 1).

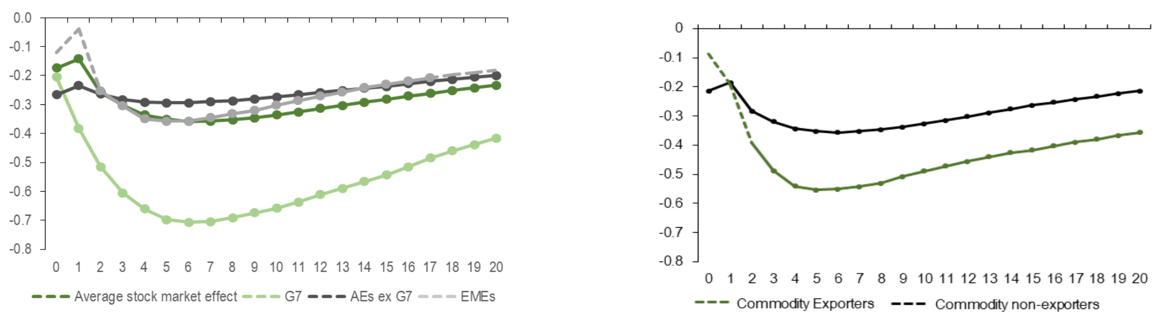
**Online Annex Figure 2.4.2. Response of Aggregate Stock Prices – Country Heterogeneities**

*Average stock market responses mask important cross-country heterogeneities…*

**1. Cumulative change in Real Aggregate Stock Price after Domestic Geopolitical Risk Shocks across Country Groupings**
(Percent, monthly)

*… highlighting the importance of the commodity channel for the transmission of geopolitical shocks*

**2. Cumulative change in Real Aggregate Stock Price after Domestic Geopolitical Risk Shocks by Commodity Dependence Status**
(Percent, monthly)




Source: IMF staff calculations.
Note: Panels 1 and 2 are impulse responses from the benchmark VAR model introduced in this section, while the shock is identified using a recursive ordering where GPR comes first, consistent with the plausible exogeneity of the variable. The reported IRFs are derived from models estimated separately on the designated country groupings. Solid lines and round markers indicate the periods where the effect is statistically significant, that is, where the 68 percent credible set around the IRF is not crossing the x-axis. The geopolitical risk indicator is the country GPR index by Caldara and Iacoviello (2022).

Furthermore, commodity markets are an important transmission channel of geopolitical shocks. On average, oil prices decline significantly and persistently in the months after an adverse geopolitical shock. Relative to stock markets in commodity non-exporting economies, equities in commodity exporting economies suffer larger price declines (Online Annex Figure 2.4.2, panel 2). This difference is a reflection of the negative oil price response, weighing more on stock markets in economies with higher exposures to commodity exporting activities.

## Online Annex 2.5. How do firm stock returns react to geopolitical risk events?

This section examines how firm-level stock returns react to domestic and foreign geopolitical risk events, by estimating variants of the following empirical model:

$$y_{i,t} = \alpha + \beta\, I(Event)_{c,t} + \gamma \sum_{c'}^{C} w_{c,c',t-12}(I(Event)_{c',t}) + \theta\, Controls_{i|c,t-1} + \mu_i + \epsilon_{i,t} \quad (2.5.1)$$

where $y_{i,t}$ is the percent return from holding the stock of firm *i* in country $c$ from month *t-1* to *t*, including stock price gains and any dividend yields, in US dollar terms in excess of monthly US Treasury yields over the same horizon. $I(Event)_{c,t}$ is a dummy variable taking the value 1 in the month of a major geopolitical risk event, and 0 otherwise (see Online Annex 2.3 for the definition of major geopolitical risk events). $I(Event)_{c',t}$ is similarly defined, taking a value 1 if country $c'$, a trading partner of country $c$, experiences a geopolitical risk event, and 0 otherwise, and is weighted according to cross-border trade exposures in the previous year ($w_{c,c',t-12}$). $I(Event)_{c,t}$ and $I(Event)_{c',t}$ are then disaggregated into event types, namely international military conflicts and other events (comprising events such as diplomatic tensions, domestic unrest, or terrorist attacks). $Controls_{i|c,t-1}$ include firm- and macro-level controls, namely, firm size (log (total assets)), leverage (equity-to-total assets), and return on assets, and real GDP growth, inflation, (log) real GDP per capita, and (log) financial markets depth, all measured ex-ante.[4] $\mu_i$ denote firm fixed effects, absorbing time-invariant firm, sector, or country characteristics.

The estimated coefficients $\beta$ and $\gamma$ thus reflect the average impact on monthly stock returns following domestic and foreign geopolitical risk events, respectively. While the analysis does not capture the intensity of events (as in, *e.g.*, Berkman and others, 2011; Federle and others, 2024b), military conflicts may have a more severe impact on returns than other types of risk events and home country's involvement in a military conflict could have a greater impact than a trading partner country's involvement.

To improve the identification of the impact of geopolitical risk events on returns, the section then utilizes *firm-level* exposures to foreign geopolitical risk events to exploit within country-sector variation, as follows:

$$y_{i,t} = \alpha + \beta\, I(Event)_{c,t} + \gamma \sum_{c' \in C}^{C} w_{i,c',t-12}(I(Event)_{c',t}) + \theta\, Controls_{i,t-1} + \mu_i + \nu_{c,s,t} + \epsilon_{i,t} \quad (2.5.2)$$

where $w_{i,c',t-12}$ denote (i) firm *i*'s revenue derived from country $c'$ in percent of its total revenues, or (ii) whether firm *i* has a subsidiary in country $c'$, both measured in the previous year. $\nu_{c,s,t}$ are country-(4-digit)sector-month fixed effects, absorbing time-varying country- and sector-specific factors.

*Sample Characteristics*. The first set of analyses is based on a global panel of firms, comprising about 60 thousand firms from 20 AEs and 20 EMEs. Sample size for the analyses based on geographical distribution of firm revenues and subsidiary presence, is up to 39 countries, including about three thousand and twenty thousand firms, respectively. The exact number of firms and countries for each specification are provided in the regression output tables.

Average monthly US dollar excess return in the full sample is about 0.5 percent (0.4 percent for AEs, and 0.7 percent for EMEs). The share of firms in the sample that are situated in countries involved in an international military conflict is about one percent, while the share of those facing major geopolitical risk events other than international military conflicts is 2.6 percent. Firms are also exposed to major geopolitical risk events in foreign countries, including through trade linkages.

**Empirical Results**

Firm stock returns decline by 0.7 percentage points in local-currency terms and one percentage point in excess US dollar terms following a major geopolitical risk event in the home country (the country where a firm's main operations are located). These estimates are broadly in line with Berkman et al. (2011) who, based on a different geopolitical risk measure (number of international crises as defined by International Crisis Behavior Database (ICBD)) and a longer sample (1919-2011), estimate an average 0.4 percentage points decline in global stock returns at the start of international conflicts.[5] Moreover, the estimated decline in stock returns in the event month appears on par with the VAR-based analyses reported earlier. The effect is sizeable, considering the average monthly stock return, in excess US dollar terms, of about 0.6 percent in the sample. Further results, as reported in the chapter, are the following:

*Country trade linkages matter in the transmission of geopolitical risk events*. Firms in countries that are exposed to geopolitical risk events in other countries through trade linkages systematically fare worse (compared to firms in otherwise similar countries). On average, involvement in a military conflict of a major trading partner, e.g., with 10 percent weight in total trade (the sum of exports and imports), is estimated to lead to a decline in firms' stock returns by about 0.4 percentage points in AEs, and by 0.7 percentage points in EMEs.[6] Trade partners' involvement in less severe geopolitical risk events, diplomatic tensions, domestic unrest, etc., seems to also matter, especially in the case of key trading partners as the disruption in revenue stream or supply chain could be more material.

*Home country involvement in an international military conflict has more adverse effect on stock returns for EMEs*. The effect of home country involvement in a military conflict appears to be significantly adverse for firms in EMEs (by more than 4.5 percentage points on average. This reflects an average impact across military conflicts with varying degrees of severity (ranging from armed border disputes and small-scale military operations to wars). The impact for firms in AEs does not appear to be statistically significant, possibly because the military conflicts involving AEs during the sample period

[4] Firm controls are lagged by 1 quarter, and macro controls by 1 year.

[5] Berkman and others (2011) also show that the decline in global equity returns could be significantly stronger in case of more severe conflicts, e.g., wars (-1.3 percentage points) or involvement of major powers (-0.7 percentage points). They also find a milder decline on world stock returns *during* the course of the conflict, and a positive impact when the conflict *ends*.

[6] A 10 percent share in cross-border trade corresponds to a country with a share that is 2½ standard deviations above the mean.

have generally not been on their home soil, and typically exhibited large differences in economic and military power (e.g., US vs. Iraq).

*Firm-level exposures*. Online Annex Table 2.5.1 presents the results pertaining to equation (2.5.2). Among firms within the same country and sector, those that derive a greater share of their revenues from the countries involved in an international military conflict experience a significant decline in their stock returns, with similar effects for AE and EM firms. The estimated average decline is about 0.2 percentage points for firms with a two-standard-deviation higher ex-ante revenue exposure to countries affected by a major geopolitical risk event. Similarly, having a subsidiary in countries experiencing a major geopolitical risk event also matters. The estimated impact is numerically large –with an average decline of 0.5 percentage points on average and appears to be driven mainly by AE firms. Having a parent company in an affected country also matters, particularly for EM firms and following a major non-war conflict in the parent company's country. These results should be interpreted as the additional impact of firms' cross-border exposures to geopolitical risks on their stock returns beyond the country- and sector-wide effects.

**Online Annex Table 2.5.1. Impact of Higher Domestic or Foreign Geopolitical Risk on Firm Stock Returns – The Role of Firm-Level Exposures**

| Country Coverage: | All | Advanced Economies | Emerging Markets | All | Advanced Economies | Emerging Markets | All | Advanced Economies | Emerging Markets |
|---|---|---|---|---|---|---|---|---|---|
| Weight for Foreign GPR (firm level): | Revenue Exposure | | | Subsidiary Presence | | | Shareholders | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| W. Aveg. Foreign GPR (international military conflict) | -9.707** | -9.656** | -10.350* | -2.321* | -3.587* | -0.284 | 1.166 | 1.213 | -1.225 |
| | (4.378) | (4.539) | (5.809) | (1.240) | (1.887) | (0.665) | (1.031) | (1.047) | (1.202) |
| W. Aveg. Foreign GPR (others) | -0.639 | -0.328 | -1.116 | -0.188 | -0.269 | -0.055 | -0.297** | -0.173 | -0.612*** |
| | (0.775) | (0.934) | (1.080) | (0.131) | (0.178) | (0.142) | (0.132) | (0.181) | (0.177) |
| Controls | Included | Included | Included | Included | Included | Included | Included | Included | Included |
| Country x Sector x Month F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Number of Firms | 2,829 | 1,636 | 1,193 | 25,142 | 19,283 | 5,859 | 23,644 | 17,218 | 6,426 |
| Number of Countries | 37 | 20 | 17 | 40 | 20 | 20 | 40 | 20 | 20 |
| Total Obs. (Firm-Month) | 312,897 | 172,895 | 140,002 | 1,764,153 | 1,357,934 | 406,219 | 684,736 | 517,208 | 167,528 |
| R2 | 0.58 | 0.56 | 0.60 | 0.35 | 0.31 | 0.49 | 0.43 | 0.39 | 0.57 |

Sources: IMF staff calculations.
Note: The dependent variable is total return from holding the stock of a firm from month t-1 to t in US dollars in excess of monthly US Treasury yields over the same horizon. Standard errors are double clustered at the firm and month level, and provided in parentheses. ***,**,* indicate statistical significance levels at 1, 5, and 10 percent, respectively.

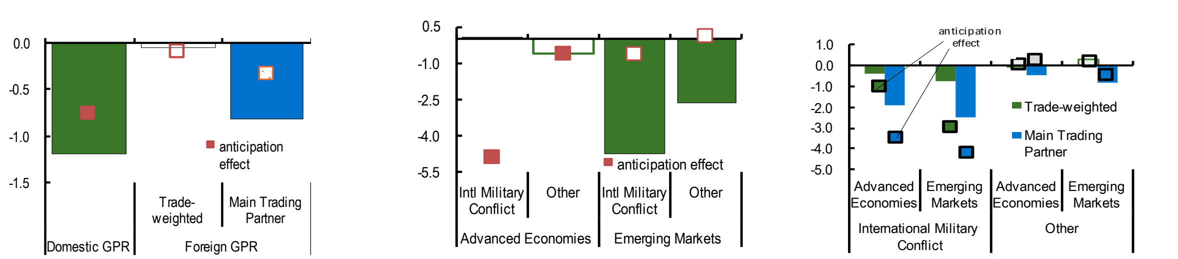
*Anticipatory effects*. Since the analyses are based on news-based indices, they already capture potential anticipation effects. However, to better capture anticipation effects, additional analyses examine the contemporaneous impact on stock returns of geopolitical risk events occurring in the following month (while controlling for those that occurred in the current month). The results, summarized in Online Annex Figure 2.5.1, confirm that anticipation effects could be significant. For example, firms' stock returns in AEs appear to have declined by about 5 percentage points, on average, a month before the country's involvement in an international military conflict (panel 2). Anticipation of a trading partner's involvement in a military conflict also appears to weigh on contemporaneous stock returns, especially if the trading partner is a major export destination or import source, and particularly for EMEs (panel 3).

**Online Annex Figure 2.5.1. Rise in Global Geopolitical Tensions and Firm Stock Returns: The Role of Anticipation Effects**

**1. Monthly Response of Firms' Stock Returns to Geopolitical Risk Events**
*(Percentage points)*

**2. Monthly Response of Firms' Stock Returns to Domestic Geopolitical Risk Events**
*(Percentage points)*

**3. Monthly Response of Firms' Stock Returns to Foreign Geopolitical Risk Events**
*(Percentage points)*

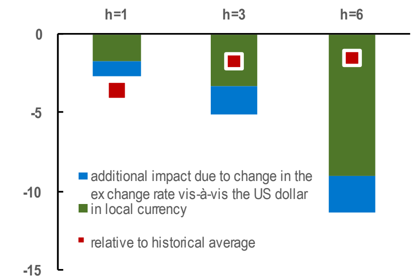



Source: Caldara and Iacoviello (2022); FactSet; IMF, Direction of Trade Statistics and World Economic Outlook databases; LSEG Datastream; Orbis; and IMF staff calculations.
Note: See detailed notes for Figure 2.6. Bars show the estimated impact of geopolitical risks events occuring in the contemporanous month. Markers denote the impact of geopolitical risk events occuring in the following month conditional on geopolitical risk event occurring or not occurring in the current month. Solid bars or markers denote statistical significance at 10 percent level.

*Persistence and foreign exchange rate effects*. Firm-level analyses confirm aggregate evidence documented in Online Annex 2.4, that elevated geopolitical risks could have a persistent impact on stock prices. Expanding the horizon of returns, the dependent variable in eq. (2.5.1), implies that the impact persists for at least 6 months for EMEs (Online Annex Figure 2.5.2). Moreover, about a third of the contemporaneous impact appears to be driven by exchange rate movements, and about one-fifth six months after (Online Annex Figure 2.5.2, blue versus green bars across the horizons).

The results should be caveated as follows: First, the effects identified capture average effects across events with varying degrees of intensity or duration. Second, firms are exposed to conflict zones not only through *first-order* but also *higher-order* exposures (e.g., revenue exposure to a country whose key trading partners are affected by a geopolitical risk shock). Moreover, supply chain exposure is only accounted for based on aggregated bilateral country-level import exposures not global supply chain network data which would allow for sharper inferences. Moreover, the analyses do not formally distinguish between military conflicts on the home soil versus elsewhere, and the difference in economic and military capacity between countries involved in a particular conflict.

**Online Annex Figure 2.5.2. The impact of major domestic geopolitical risk events on firm stock returns in EMEs**
(Percentage point)




Source: Caldara and Iacoviello (2022); IMF, World Economic Outlook database; LSEG Datastream; and IMF staff calculations.
Note: The chart shows the percentage points change in firm stock returns within the month a major domestic geopolitical risk event occurs (h=1), after 3 months (h=3), or after 6 months (h=6), where returns are expressed in local currency (green bars) or in US dollars in excess of US Treasury yields (the total of green and blue bars, for each horizon *h*). Red markers show the total impact relative to sample average of cumulative returns for each horizon.

## Online Annex 2.6. How do firm stock returns react to geopolitical risk events: Case Studies

This section presents the methodology and additional details of the empirical analyses and results pertaining to two events: Russia's invasion of Ukraine and the 2018-19 US-China trade tensions. The case studies aim at analyzing the short-term impact of these geopolitical shocks on firms' stock returns across countries and industrial sectors. Employing standard event study methodologies, the chapter quantifies changes in stock returns in the period after a geopolitical risk event occurs.

First, the following model is estimated to examine aggregate impact across industrial sectors or country groups:

$$y_{f,j,c,e} = \alpha + \beta \cdot Exposure_{j/c,e} + \gamma \cdot Controls_f + \nu_c + \epsilon_{f,j,c,e} \text{, (2.6.1)}$$

where $y_{f,j,c}$ is the cumulative US dollar return of firm f in industry j in country c within a narrow daily window τ that starts from the day before the event date (e.g., τ = {[-1,0], [-1,1], [-1,2], … , [-1,20]}). $Exposure_{j/c}$ is either the 2-digit sector where the firms' major product lines belong to, or the country group the firm is domiciled in (AE or EMDEs, and for the latter, regional groups). $Controls_f$ includes firm-level variables such as the log of total assets, the ratio of debt to total assets (leverage), and the return on assets. The model includes country fixed effects ($\nu_c$). Standard errors are clustered at the sector level.

Second, for more granular identification, the following empirical model is estimated:

$$y^{\tau}_{f,j,c} = \alpha + \beta \cdot Exposure_{f,c'} + \gamma \cdot Controls_f + \nu_{c,j} + \epsilon_{f,j,c} \text{, (2.6.2)}$$

where $\boldsymbol{y_{f,j,c}}$ is the cumulative US dollar return of firm *f* in industry *j* in country *c* within a daily window τ that starts from the day before the event date (e.g., τ = {[-1,0], [-1,1], [-1,2], … , [-1,20]}). $Exposure_{f,c'}$ is measured ex ante, and is (i) $Revenue\ Exposure_{f,c'}$ referring to the share of revenue of firm *f* attributed to country *c´* to total revenue, measured as of the year prior to each event, or (ii) $Subsidiary\ Presence_{f,c'}$ is a dummy variable indicating if firm *f*'s had a subsidiary presence in country $c'$ as of the end of the year preceding each event. $Controls_f$ includes the log of total assets, the ratio of debt to total assets (leverage), and the return on assets. The model further includes country-sector fixed effects ($\nu_{c,j}$) to account for country and sector time-invariant characteristics. Standard errors are clustered at the sector level. Moreover, to explore whether subsidiary size matters, the model is extended to include the interaction of subsidiary presence with the asset size of the subsidiary relative to that of the parent firm.

**Russia-Ukraine War**

Russia's invasion of Ukraine had differential impacts across country groups, with firms in EMDEs experiencing a more negative impact (-1.1 percentage points) than those in AEs (Online Annex Figure 2.6.1, Panel 1). Among EMDEs, Emerging Asia and Latin America appear to experience a relatively moderate decline, as some commodity-exporting economies benefited from rising energy and agricultural prices. Emerging Europe, on the other hand, which is geographically and economically close to the conflict zone and has stronger economic ties to Russia and Ukraine, saw the most pronounced stock market decline (-9.0 percentage points), reflecting concerns over supply chain disruptions, energy dependency, and geopolitical uncertainty. The effects on firms in Emerging Africa were insignificant.

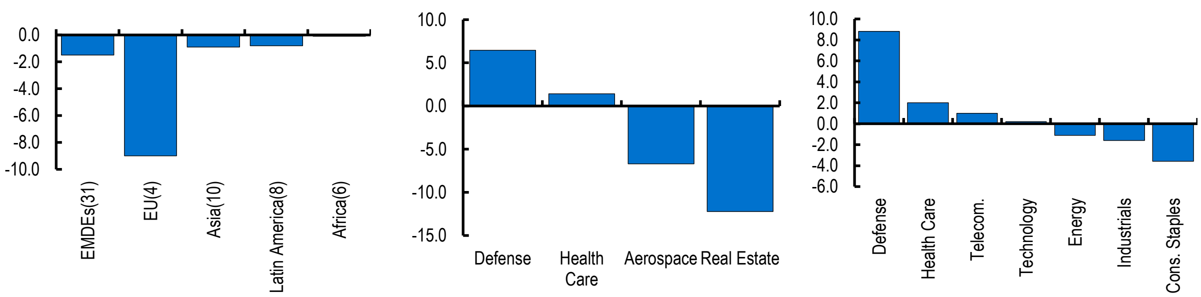
Furthermore, Russia's invasion of Ukraine had a heterogeneous impact on firms with revenue exposure to Russia or Ukraine. For example, firms in the defense sector experienced positive stock returns while others faced declines (Online Annex Figure 2.6.1, Panel 2). Similarly, firms in the defense sector seem to have benefited from having subsidiaries in Russia and Ukraine (Online Annex Figure 2.6.1, Panel 3).

**Online Annex Figure 2.6.1. Effect of Russia's Invasion of Ukraine on Cumulative Stock Returns**

**1. Effects of Russia's Invasion of Ukraine on EMDEs' Cumulative Stock Returns by Region**
(Percentage points)

**2. Effect of Revenue Exposure and Industrial Sectors on Cumulative Stock Returns**
(Percentage points)

**3. Effect of Subsidiary Presence and Industrial Sectors on Cumulative Stock Returns**
(Percentage points)



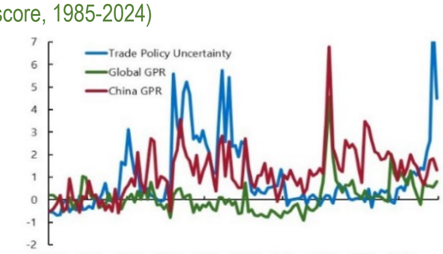

Source: Worldscope, Datastream, Orbis, and IMF staff calculations.
Note: The cumulative returns are measured in US dollar terms for the next 7 days after the even date. Panel 1 illustrates the effects of Russia's invasion of Ukraine on cumulative returns across EMDEs by region, compared to AEs. The regression analysis includes a dummy variable which takes a value of 1 for EMDEs and 0 otherwise, as an explanatory variable. The numbers in parenthesis indicate the number of countries included in each region for analysis. Panels 2 and 3 present the effect of revenue exposure and subsidiary presence in Russia and Ukraine across sectors, reporting the sectors for which there is a statistically significant impact at a 10 percent level or below. The analysis accounts for country-specific fixed effects.

**US-China Trade Tensions.**

The event dates in this analysis were selected based on the earliest publicly available announcements of tariff increases or reductions by the US or Chinese government, as published on official government websites or reported in the media. We focused on announcements that introduced new waves of tariffs (when the tariffed product classes were announced), rather than mere threats or modifications to existing measures. Retaliatory tariff announcements within a few days of an initial government announcement are excluded, as their impact would be confounded by the preceding policy change. This approach ensures that the selected event dates capture the primary market reactions to newly implemented tariff policies. Accordingly, we identified the following event dates: March 22, 2018; June 15, 2018; May 6, 2019; August 1, 2019; August 23, 2019; October 11, 2019; and May 14, 2024 (Online Annex Table 2.6.1). While the increase in the global GPR was modest,

**Online Annex Figure 2.6.2. Trade Policy Uncertainty and Geopolitical Risk Index for China**
*Trade policy uncertainty co-moves with geopolitical risk in China around the time of the US-China trade tensions.*

(Z-score, 1985-2024)




Sources: Caldara and others (2020); Caldara and Iacoviello (2022); IMF staff calculations.
Note: Trade Policy Uncertainty," "Global GPR," and "China GPR" are standardized for the period 1985-2024

both the trade policy uncertainty index, developed by Caldara and others (2020), and the GPR index for China rose from March 2018, suggesting that the trade tensions were a source of geopolitical risk.

Tariff increases by the US and China impacted the majority of sectors. Out of 479 sectors defined by the 4-digit Standard Industrial Classification (SIC), US tariff announcements impacted an average of 234 sectors over the five announcements considered in the analysis, while the Chinese tariff announcement impacted 254 sectors. In sectors impacted by tariff announcements, on average, 37.9 percent of products in a given sector appear in the tariff product list across US announcements, while 22.8 percent of products appear in Chinese retaliation tariff lists.

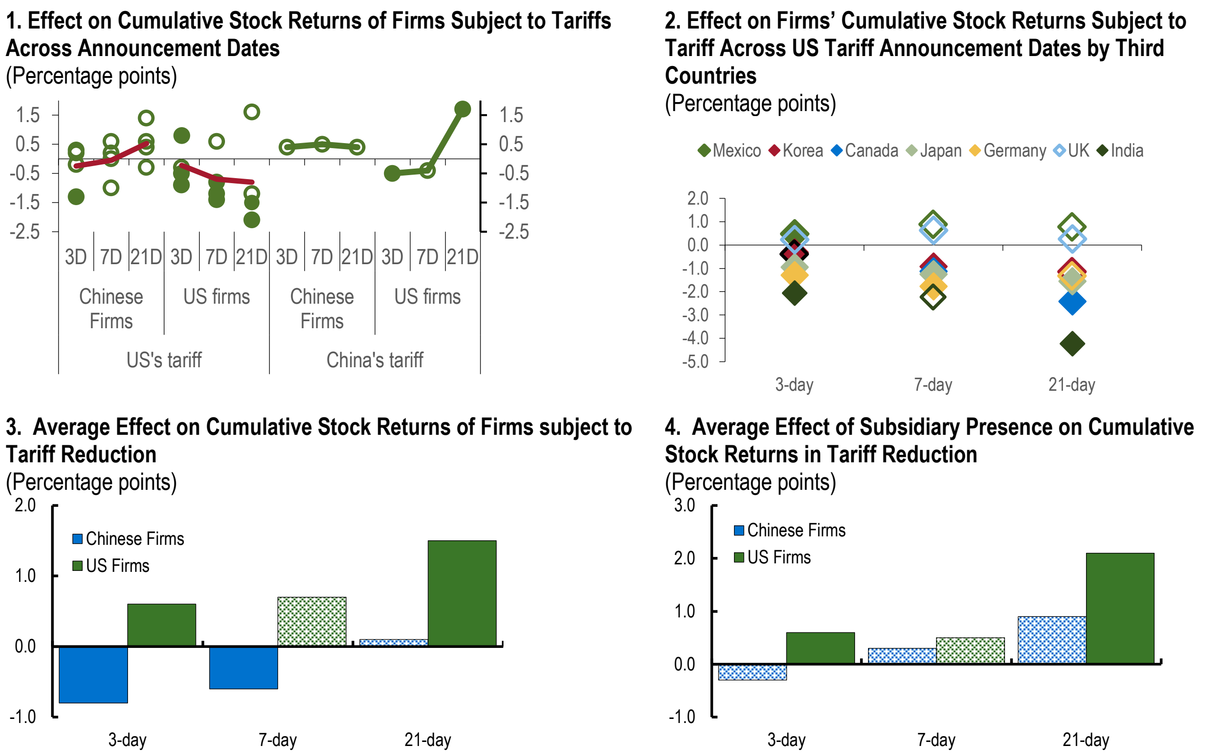
Online Annex Figure 2.6.3, Panel 1, shows the impact of tariff announcements on the cumulative stock returns of firms subject to tariffs, distinguishing between US and Chinese tariffs. The US tariff announcements had significant but mixed effects on Chinese firms over the 3-day event window, while their impact on US firms was consistently negative across different time windows. In response to China's tariff announcements, US firms initially experienced a decline in cumulative returns over the 3-day event window but showed an upward trend over the 21-day event window. Meanwhile, the effects on Chinese firms remained statistically significant.

Panel 2 in Online Annex Figure 2.6.3 illustrates the average effect of US tariff announcements on the cumulative stock returns of firms in third-party countries whose products fall within the same product classification as those subject to US tariffs on China. Firms in Mexico display a significant positive effect in the short event window while firms in Korea, Canada, Japan, Germany, the UK, and India generally experienced negative stock market reactions, possibly reflecting heightened trade policy uncertainty.

**Online Annex Table 2.6.1. US-China Trade Disputes Tariff Description**

| Date | Country | Direction of Tariff Adjustments | Main Content of Announcement |
|---|---|---|---|
| March 22, 2018 | US | Increase | US imposed tariffs on $50-60 billion worth of Chinese goods, including aircraft and weapon parts, batteries, televisions, medical devices, and satellites. |
| June 15, 2018 | US and China | Increase | US imposed an additional 10% tariffs on $200 billion worth of Chinese goods. As retaliation, China imposes tariffs on $50 billion worth of US goods. |
| May 6, 2019 | US | Increase | The previous tariff of 10% on $200 billion worth of Chinese goods was raised to 25%. |
| August 1, 2019 | US | Increase | US imposed tariffs of 15% on $300 billion worth of Chinese goods. |
| August 23, 2019 | China | Increase | China announced a new round of retaliative tariffs on $75 billion worth of US goods, including soy and auto parts. |
| October 11, 2019 | US and China | Reduction | United States and China reached a tentative agreement for the "first phase" of a trade deal. US reduced tariffs announced on 2nd August 2019, whereas China reduced tariffs announced on 23rd August 2019. |
| May 14, 2024 | US | Increase | US imposed tariffs on various Chinese products, including steel, aluminum, medical equipment, solar cells, electric vehicles, and batteries. |

**Online Annex Figure 2.6.3. Effect of US and China Trade Tension on Cumulative Stock Returns**




Source: FactSet, LSEG Datastream, Orbis, and IMF staff calculations.
Note: In Panel 1, The US tariff increases correspond to the following announcement dates: March 22, 2018; May 6, 2019; August 1, 2019; and May 14, 2024. China's tariff increase on the US was announced on August 23, 2019. Solid circles indicate statistical significance at the 10 percent level or below, and solid lines represent the average effect across events. Panel 2 shows the effects on firms with products subject to US tariffs. Standard errors are clustered at the country-level. Solid diamonds indicate that the effects are statistically significant at the 10 percent level or below in at least half of the announcements. In Panels 3 and 4, firms' cumulative stock returns are measured over 3, 7, and 21 days after the event. The tariff reduction event date is October 11, 2019. Panel 4 shows the effects on firms subject to tariffs and with subsidiaries in the US or China. The regression analysis accounts for industry-specific fixed effects.

The average direct effect of the tariff reduction announcement on October 11, 2019, on the cumulative stock returns of Chinese and US firms reveals a divergent impact between the two countries. Following the announcement, US firms whose products were subject to tariff reductions (blue bars) initially experienced negative stock returns compared to those whose products were not affected. However, this negative effect diminished over time. In contrast, Chinese firms (green bars) exhibited positive returns from the outset, suggesting a favorable market response (Online Annex Figure 2.6.3, Panel 3).

The impact of subsidiary presence on cumulative stock returns also differed between Chinese and US firms in response to the tariff reduction announcement. Chinese firms (green bars) consistently experienced positive stock returns, with the 7-day window effects being statistically insignificant, whereas US firms (blue bars) exhibited an insignificant and more varied response, as indicated by the blue dotted bars. (Online Annex Figure 2.6.3, Panel 4) While Chinese firms with subsidiaries benefited significantly from the tariff reductions, the impact on US firms was more uncertain and less pronounced.

## Online Annex 2.7. The Response of Sovereign Risk Premia and Yields to Major Geopolitical Risk Events

*Sovereign risk premia.* Major geopolitical risk events could widen sovereign CDS premia—particularly of countries directly involved in the conflict, or those with greater trade or financial exposures to the conflict zone—as uncertainty about the risks and disruption to cross-border trade and investment may weigh on the domestic economy, elevate macroeconomic uncertainty, prompt greater fiscal spending on defense, and in turn, raise debt sustainability concerns. The nature and intensity of the geopolitical risk also matters. Extreme geopolitical risk events such as military interventions and actual wars are likely to have a more severe impact than less severe events such as diplomatic tensions.[7] To evaluate these channels, variants of the following empirical model are estimated:

$$y_{c,t} = \alpha + \beta\, I(Event)_{c,t} + \gamma \sum_{c' \in C}^{C} w_{c,c',t-12} I(Event)_{c',t} + \theta\, Controls_{c,t-12} + \mu_c + \nu_t + \epsilon_{c,t} \quad (2.7.1)$$

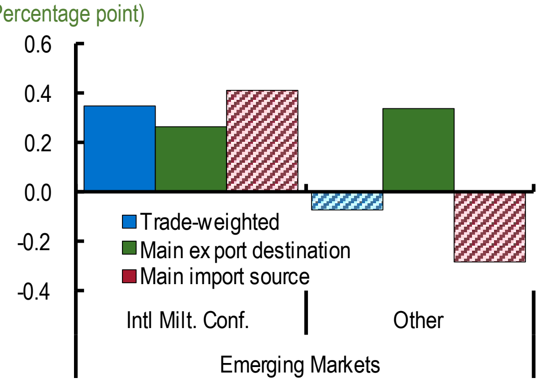
where $y_{c,t}$ denote (log of) 5-year sovereign CDS spreads of country *c* at the end of the month *t* (the analyses will later focus also on long-term sovereign bond yields). $I(Event)_{c,t}$ and $I(Event)_{c',t}$ , indicate major geopolitical risk events for country $c$ and $c'$ in month *t*, as defined above, with the latter weighted by trade exposures, $w_{c,c',t-12}$. Control variables include public debt-to-GDP ratio, (log) real GDP per capita, inflation (year-on-year percent change in CPI), financial markets depth,[8] (log) institutional quality,[9] all measured ex-ante, following related literature (see, *e.g.,* Huang and others, 2015; Afonso and others, 2024). $\mu_c$ and $\nu_t$ are country and month fixed effects.

The key hypothesis is that sovereign CDS premia rise following domestic or foreign geopolitical risk events, *i.e.,* $\beta>0$ and $\gamma>0$ , respectively. The chapter further assesses whether the risk premia of sovereigns with weaker fiscal and external buffers, or lower institutional quality reacts more to foreign GPR events by interacting $\sum_{c' \in C}^{C} w_{c,c',t-12} I(Event)_{c',t}$ with lagged public debt-to-GDP ratio, international reserves adequacy ratio (as defined by IMF, 2016), or institutional quality, averaging the scores by International Country Risk Guide (ICRG) on bureaucracy quality, corruption, democratic accountability, investment profile, and law and order of a country.[10]

The analysis in this section is based on a sample of 20 AEs and 21 EMEs for the period January 2002 to December 2023. The average sovereign CDS premium is 176 basis points for the full sample, 55 basis points for AEs, and 279 basis points for EMEs.[11]

The results suggest that sovereign CDS premiums rise following a major domestic geopolitical risk event in both advanced and EMEs. The impacts are economically sizeable, a 16 to 27 percent increase in sovereign CDS premia. Evaluated at respective means for the country groups, this translates into about 44 basis points increase for AEs and 182 basis points for EMEs.

**Online Annex Figure 2.7.1. The impact of major foreign geopolitical risk events on long-term yields in EMEs**
(Percentage point)




Source: Bloomberg Finance L.P.; Caldara and Iacoviello (2022); International Country Risk Guide (ICRG); IMF, World Economic Outlook and Direction of Trade Statistics database; and IMF staff calculations.
Notes: Solid bars indicate statistical significance at 10 percent. Intl Milt. Conf.=International Military Conflict.

Moreover, trade linkages matter for the transmission of foreign geopolitical risk events. On average, for the full sample, involvement of a trading partner with 10 percent higher trade share (corresponding to a 2 ½-standard-deviation higher trade share) in an international military conflict appears to induce about 40 basis increase in sovereign CDS premia for AEs. Moreover, the impact is much larger in the case of a military conflict of major trading partners (main export destination or main import

[7] For recent examples on the impact of geopolitical risk shocks on sovereign bond spreads, see, e.g., Huang and others (2015) and Afonso and others (2024). Huang and others (2015) show that an increase in "international political crisis", defined as the total number of political crises globally, where political crises are defined as by International Crisis Behavior (ICB) database, leads to an increase in sovereign yields globally, with stronger impacts on sovereigns with weaker institutions. Afonso and others (2024) show that geopolitical tensions in neighboring countries, measured by the GPR indices of Caldara and Iacoviello (2022), raise sovereign yields and CDS spreads for the home country due to spillover effects.
[8] The index reflects various measures of financial market depth, including stock market capitalization-to-GDP, stocks traded-to-GDP, international debt securities of government-to-GDP, and total debt securities of financial and non-financial corporations-to-GDP ratios.
[9] This reflects the average score for bureaucracy quality, corruption, democratic accountability, government stability and law and order by the International Country Risk Guide (ICRG), which excludes scores for internal or external conflicts, and ethnic tensions.
[10] While weaker fundamentals should also matter for how sovereign CDS premia react to domestic geopolitical risk events, these events are typically less exogenous to macroeconomic fundamentals, e.g., domestic unrest due to macroeconomic mismanagement or starting a war to distract from political or economic issues (see, e.g., Biglaiser and others, 2024; or Federle and others, 2024b). Hence, the interaction of domestic events with macroeconomic fundamentals is not studied.
[11] On the first trading day after Russia's invasion of Ukraine, Russia's 5-year sovereign CDS premia reached over 900 basis points, and soon after, over ten thousand basis points, a ten-fold increase from the levels before news reports about the Russian military build-up on the Ukrainian border

source), and particularly for EMEs. The impact on sovereign CDS premia for AEs in the case of involvement of major trading partners cannot be identified, due to the lack of such cases.

Next, foreign major geopolitical risk event indicator variables are interacted with (ex-ante) public debt-to-GDP ratios, international reserves adequacy ratios, or institutional quality, for the EME sample (see, e.g., IMF, 2016, for a related discussion, and the methodology for constructing the metric for reserves adequacy).[12] The results suggest that EMEs with public-debt-to-GDP ratios above the median EME, or international reserves adequacy or institutional quality below the median EME experience a larger and significant increase in sovereign CDS premia following a major foreign geopolitical risk event.

*Sovereign yields.* Equation (2.7.1) is re-estimated with the dependent variable replaced with 10-year local-currency government bond yields. The results suggest a decline in long-term government bond yields in AEs (Figure 2.10, panel 4), following major domestic geopolitical risk events, particularly after involvement in an international military conflict. This effect, as documented in the chapter, appears to be driven mainly by safe haven effects.[13] In contrast, EMEs experience an increase in their long-term government bond yields. Following major foreign conflicts, EMEs also experience a rise in their long-term yields (Online Annex Figure 2.7.1)).

## Online Annex 2.8. The Pricing of Geopolitical Risk

This section first analyzes whether geopolitical risk is a relevant pricing factor for the cross-section of expected excess stock returns, reflecting central forecasts. Second, since geopolitical risk events are likely to have a low probability but large downside risk, the chapter explores whether geopolitical risks are reflected in the cost of protecting against downside risk, by using stock options data around the realization of recent major geopolitical risk events.

**Risk Premiums in Cross-Sectional Stock Returns.**

**Methodology and Data**

**First step: Estimating GPR beta.** Shocks to the global GPR index of Caldara and Iacoviello (2022) are estimated using an AR(1) model, similar to Hirshleifer and others (2023), to eliminate possible trends in the GPR index over the sample period and better capture unexpected changes in geopolitical risk. Specifically, the following model is estimated:

$$\log(GPR_t) = a_0 + a_1 \log(GPR_{t-1}) + \varepsilon_t^{GPR} \qquad \textbf{(2.8.1)}$$

where $GPR_t$ denotes the global GPR index in month *t*, and $\varepsilon_t^{GPR}$ denotes the "geopolitical risk shocks", referred to as the "GPR factor" in this Annex. Next, the GPR beta, the sensitivity of individual stock returns to the GPR factor, is estimated controlling for excess market returns to isolate the information contained in the GPR factor that is relevant for market returns. Specifically, for each stock, we estimate the following time-series OLS regressions, using a 48-month rolling window:

$$r_{i,t} = \alpha + \beta_{i,GPR}\varepsilon_t^{GPR} + \beta_{i,MKT} r_{m,t} + \varepsilon_{i,t}, \quad i = 1, 2, 3, \ldots, N \qquad \textbf{(2.8.2)}$$

where $r_{i,t}$ and $r_{m,t}$ represent returns of stock *i* and the market returns from month *t-1* to *t*, respectively, in excess of US dollar based monthly risk-free returns proxied by the one-month US T-bill rate. $\beta_{i,MKT}$ captures the market beta, and $\beta_{i,GPR}$ is the GPR-beta measuring the sensitivity of stock returns to the GPR factor, after controlling for the market factor. Figure 11 in the chapter shows the distribution of the GPR betas by industry. The unconditional correlations of excess returns and excess market returns with the GPR factor are modestly negative, -0.02 and -0.06, respectively, theoretically implying negative premiums for stocks with higher GPR betas. Online Annex Figure 2.8.1 shows the evolution of the number of sample firms and the distribution of the firm sample across various countries

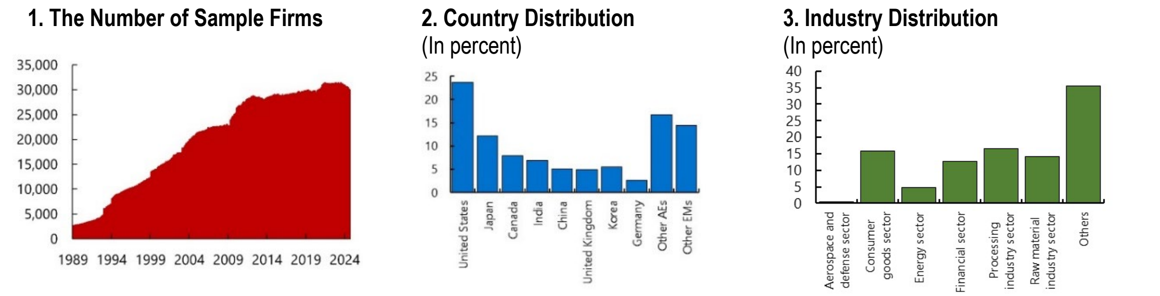
(October 2021). Ukrainian 5-year sovereign CDS premia also jumped after the invasion, to over 3000 basis points, quadrupling from the levels in October 2021. The Ukrainian sovereign CDS premium also spiked in the run up to and at the onset of the annexation of Crimea, nearly doubling from a year earlier. To avoid these extreme values to bias the estimates, the sovereign CDS premia is assumed to be at most 1000 basis points.

[12] The results for AEs for the public debt-to-GDP ratio is mixed, with the impact of higher public debt-to-GDP ratios on the sensitivity of sovereign CDS premium to major foreign geopolitical risk events not statistically significant at conventional levels when international military conflicts and other types of events are combined. However, AEs with above median public-debt-to-GDP ratios appear to have lower CDS premiums following their trading partners' involvement in international military conflicts, potentially indicating safe haven effects.

[13] To analyze safe haven effects on yields, the regression model further includes an interaction of domestic and foreign geopolitical risk indicators with an indicator variable for safe haven countries (assumed to be those that are traditionally considered as safe haven, including Germany, Japan, Switzerland, the United Kingdom, and the United States).

and industries. The GPR beta for each stock is generally stable, as the first-order autocorrelation of all samples is estimated as 0.97.

**Online Annex Figure 2.8.1. Samples: GPR betas**




Source: Caldara and Iacoviello (2022); LSEG Datastream and Worldscope Fundamentals database; and IMF staff calculations.
Note: Panels 2 and 3 respectively represent the share of each country and industry in the sample for the period of January 1989-September 2024.

**Second step:** To estimate the premiums for the GPR beta, the chapter employs Fama-MacBeth (1973) regressions. Specifically, it estimates the following equation using cross-sectional regressions across all stocks for each month *t*, applying robust regressions to address outliers:

$$r_{i,c,t+1} = \gamma_c + \gamma_t^{GPR}\hat{\beta}_{i,c,t,GPR} + \gamma_{m,t}\hat{\beta}_{i,c,t,MKT} + \gamma_t^X \boldsymbol{X_{i,c,t}} + \varepsilon_{i,c,t+1} \quad \textbf{(2.8.3)}$$

where $r_{i,c,t+1}$ and $\gamma_c$ denote excess return of stock *i* in country *c* from month *t* to *t+1* and country fixed effects, respectively, and $\hat{\beta}_{i,c,t,GPR}$ and $\hat{\beta}_{i,c,t,MKT}$ denote the estimated GPR beta and market beta of stock *i* in month *t*, respectively, from equation (2.8.2). $\boldsymbol{X_{i,c,t}}$ represents a set of control variables for cross-sectional stock returns (Fama and French 1993, Carhart 1997, Adrian, Etula, and Muir 2014, and Zaremba and other 2022), including proxies for the betas of (i) size, measured as the natural logarithm of the previous month's market capitalization (ii) book-to-market ratios, and (iii) momentum factors, measured by stock *i*'s cumulative return for month *t–12* to month *t–1*. The time-series average of $\hat{\gamma}_t^{GPR}$, $\hat{\gamma}^{GPR}$indicate the premiums of the GPR beta for excess stock returns. A non-zero $\hat{\gamma}^{GPR}$ implies that investors require a non-zero premium for exposure to the GPR factor. Figure 11 presents the estimated $\hat{\gamma}^{GPR}$, where standard errors are Newey West (1987) estimators.

To complement the Fama-Macbeth regression, the chapter also employs decile portfolio analysis. Following standard methods used in the literature, all stocks in each country are sorted based on their GPR beta values from the previous month and divided into deciles (equal-weighted portfolios). The first decile contains stocks with the lowest GPR beta, while the tenth decile contains stocks with the highest. A long-short portfolio is generated that takes a long position in the stocks in the tenth decile and a short position in stocks in the first decile. Then, the average excess returns of the portfolio ($r_{d,c,t}$) in each country are calculated.[14] To control for the influence of other factors, as shown below in equation (2.8.4), the excess return of each portfolio ($r_{d,c,t}$) in all sample countries is regressed on the standard factors (market factor, size factor, book-to-market factor, and momentum factor) in each country ($\boldsymbol{X_{i,c,t}}$)[15] and $\alpha_d$ (the 'risk-adjusted average return') is estimated by ordinary-least squares as[16]

$$r_{d,c,t} = \alpha_d + \boldsymbol{\gamma_d^X}\boldsymbol{X_{i,c,t}} + \varepsilon_{d,c,t}. \quad \textbf{(2.8.4)}$$

Specifically, if $\hat{\alpha}_d$ is statistically different from zero, this would imply that investors demand a premium for exposure to geopolitical risk. The standard errors are clustered at the country-level. Figure 11 presents the estimated $\hat{\alpha}_d$.

**Additional Results**

**Comparison of the GPR factor with standard factors.** To understand to which extent the GPR factor-mimicking portfolio is close to the efficient frontier the Sharpe ratios of the GPR factor-mimicking portfolio and of the efficient frontier based on standard factors are calculated and compared. The mimicking portfolio intends to project the non-traded GPR factor ($\varepsilon_t^{GPR}$ in equation (2.8.1)) on the return space in a country, consisting of standard factors for excess

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[14] The advantage of this approach compared to Fama-Macbeth regression is that it does not suffer from errors-in-variables problems associated with volatile individual stock returns, as the analysis is conducted at the portfolio level. However, the disadvantage is that it loses information from individual stock returns. Given these advantages and disadvantages, both approaches are employed in the analysis.

[15] All of these factors are sourced from https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html. Because the country-level factors are available only for US and Japan, and only regional/country group level factors are available for Europe, Developed Markets, Asia Pacific excluding Japan, North America, and EMEs, the most related market is assigned to each sample country.

[16] To mitigate the impact from outliers, both dependent and explanatory variables are winsorized at the 5th and 95th percentiles.

returns, following Adrian, Etula, and Muir (2014) and Hirshleifer and others (2023). The equation for this projection is given as follows.

$$\varepsilon_t^{GPR} = \alpha + \boldsymbol{\gamma}[SL_t, SM_t, SH_t, BL_t, BM_t, BH_t, Mom_t] + \varepsilon_{i,t} \qquad \textbf{(2.8.5)}$$

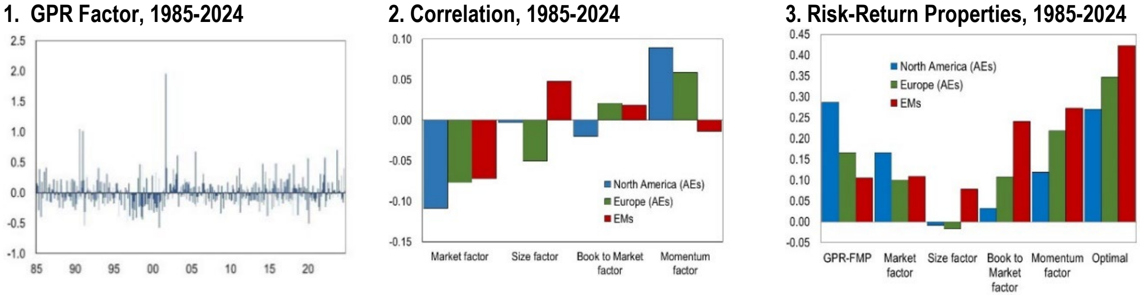
where $[SL_t, SM_t, SH_t, BL_t, BM_t, BH_t, Mom_t]$ represent the vector of excess returns of the six Fama-French benchmark portfolios on size (Small [S] and Big [B]) and book-to-market (Low [L], Medium [M], and High [H]) over the risk-free rate and the momentum factor (Mom)[17] and $\boldsymbol{\gamma}$ indicates the estimates of the coefficients for these factors. $\alpha$ and $\varepsilon_{i,t}$ represents constant and an error term, respectively, and estimation is done by ordinary least squares. Then, the GPR factor-mimicking portfolio (GPRMP) is given as follows:

$$GPRMP_t = \hat{\boldsymbol{\gamma}}[SL_t, SM_t, SH_t, BL_t, BM_t, BH_t, Mom_t] \qquad \textbf{(2.8.6)}$$

The Sharpe ratios (historical return over historical standard deviation) are then calculated for the Fama-French (1993) three factors (market factor, size factor, book-to-market factor), momentum factors, GPRMP and of the optimized portfolios with four factors (market factor (Mkt), size factor (Size), book-to-market factor (BM), and momentum factor (Mom)). The weights for each factor, $W_t(x) = \frac{w_t(x)}{\sum w_t(x')}$ for $x, x' \in \{Mkt, Size, BM, Mom\}$, are optimized based on a grid search with intervals of 0.05 within the range $w_t(x) \in$ [-0.5 0.5]. Online Annex Figure 2.8.2 presents the results of the exercise as well as the time-series of the GPR factor. It indicates that the GPR factor is negatively correlated with the market factor, while the Sharpe ratio of GPR-FMP is close to the efficient frontier based on standard factors in AEs.

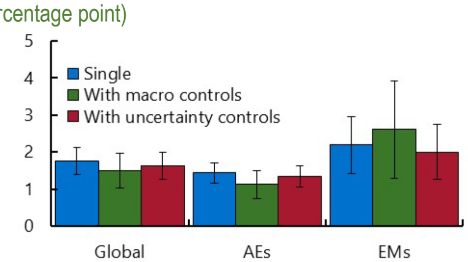
**Online Annex Figure 2.8.2. Characteristics of the GPR Factor**

**1. GPR Factor, 1985-2024** **2. Correlation, 1985-2024** **3. Risk-Return Properties, 1985-2024**




Source: Caldara and Iacoviello (2022); Kenneth French's database; and IMF staff calculations.
Note: Panel 2 shows correlation between GPR factor and standard factors in each group of countries. Panel 3 shows the sharpe ratios in each countries, where "GPR-FMP" and "Optional" represent, respectively, GPR mimicking portfolios and the optiomal portfolios based on market, size, book to market, and momentum factors from the viewpoint of sharpe ratio. The sample periods for Panels 2 and 3 span from February 1985 to September 2024.

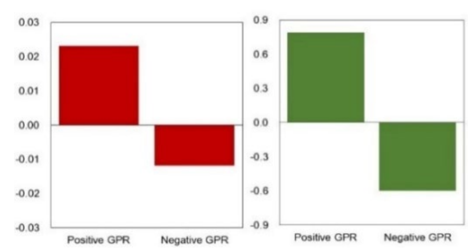
**Online Annex Figure 2.8.3. Market Return Predictability of GPR Factor, 1989-2024**
(Percentage point)




Source: Caldara and Iacoviello (2022 LSEG Datastream and Worldscope Fundamentals database; Economic policy Uncertainty database; Sydney Ludvigson's website; and IMF staff calculations.
Note: Bars and whiskers, respectively, indicate point estimates and 90 percent confidence intervals. The standard errors are country-level cluster robust standard errors. The sample period is from January 1989 to September 2024.

**Online Annex Figure 2.8.4. GPR Premiums under Positive and Negative GPR factor, 1990-2024**
(Percentage point)

**i) Fama-Macbeth Regression** **ii) Decile Portfolio**




Source: Caldara and Iacoviello (2022); LSEG Datastream and Worldscope Fundamentals database; and IMF staff calculations.
Note: The panel shows the estimated average coefficients for GPR betas during the period when the GPR factor is positive or negative, as well as the alphas of the returns for simple average portfolios constructed by buying stocks in the top 10 percent of GPR betas and selling those in the bottom 10 percent, controlling for Fama-French three factors and the momentum factor. The sample period is May 1990 to July 2024. Bars indicate statistical significance at the 10 percent level or below.

**The GPR factors' predictability of aggregate returns.** While this chapter focuses on whether the geopolitical risk

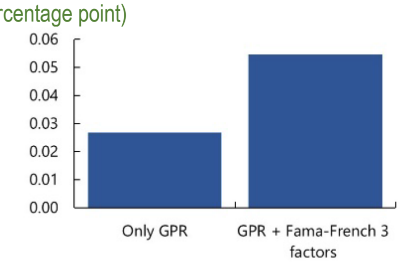
[17] These portfolios are sourced from https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

factor is relevant for the pricing of cross-sectional stock returns, this annex also examines whether the factor can predict future market stock returns. To this end, following Hirshleifer and others (2023), the following monthly panel regression model is estimated.

$$r_{c,t+1} = \delta_c + \delta^{GPR}\varepsilon_t^{GPR} + \boldsymbol{\gamma}^X \boldsymbol{X}_{c,t} + \varepsilon_{c,t+1} \quad \textbf{(2.8.7)}$$

where $\varepsilon_t^{GPR}$ and $r_{c,t+1}$ represent the GPR factor in period *t* and excess market return over the next month (*t+1*), respectively. $\delta_c$ are country-fixed effects and $\varepsilon_{c,t+1}$ is an error term. $\boldsymbol{X}_{c,t}$ represents control variables that are typically used in the literature (e.g., Hirshleifer and others 2023) and are available for our sample of countries. These include country-level controls (realized daily stock return volatility over the past three months, price-to-earning ratios, dividend yields, three-month and 10-year government bond yields, industrial production (yoy changes), and inflation (yoy changes)), global factors (such as global economic policy uncertainty by Baker and others (2016), US macroeconomic uncertainty by Jurado and others (2015), real economic uncertainty and financial uncertainty by Ludvigson and others (2021)). Online Annex Figure 2.8.3 presents the estimates of $\delta^{GPR}$ for the full sample (covering the time period of 1989-2024) and those for AEs and EMEs under three types of specifications in equation (2.8.7): (i) only the GPR factor ("Single"), (ii) the GPR factor and macro controls, and (iii) the GPR factor and uncertainty controls. The results indicate that the GPR factor generally predicts one-month ahead excess market returns.

**Online Annex Figure 2.8.5. GPR Beta-Based Sorted Portfolios, 1991-2024**
(Percentage point)




Source: Caldara and Iacoviello (2022); LSEG Datastream and Worldscope Fundamentals database; and IMF staff calculations.
Note: The panel presents the estimated coefficient for GPR beta-based sorted portfolios, with and without controlling for Fama-French three factors. The sample period is April 1990 to June 2024. Bars indicate statistical significance at the 10 percent level or below. Standard errors are clustered at the country-level.

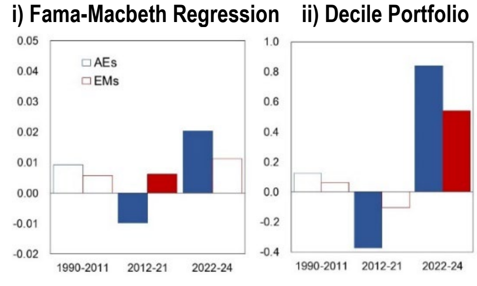
**GPR premiums under positive and negative GPR factors.** Figure 11 shows GPR premiums over different horizons. Theoretically, GPR premiums should be negative in normal times and positive when geopolitical risk materializes, as stocks with higher GPR betas exhibit higher returns at that time. Online Annex Figure 2.8.4 presents the estimates of GPR premiums when the GPR factor is positive and negative, representing high and low risk environments. The Figure confirms the theoretical predictions.

**Hedging geopolitical risk.** This annex examines if GPR beta-based sorted portfolios serve as a hedge against geopolitical risk. To this end, following Engle and others (2020), factor mimicking portfolio analysis is conducted. Specifically, the following panel data model is estimated by Ordinary Least Squares:

$$\varepsilon_t^{GPR} = \eta_c + \eta^{GPR} Z_{t-1}^{GPR} r_{i,c,t} + \eta^{Mkt} Z_{t-1}^{MKT} r_{i,c,t}$$
$$+\eta^{Size} Z_{t-1}^{Size} r_{i,c,t} + \eta^{BM} Z_{t-1}^{BM} r_{i,c,t} + \varepsilon_{c,t} \quad \textbf{(2.8.8)}$$

where $\varepsilon_t^{GPR}$ and $r_{i,c,t}$ represent the GPR factor (from equation (2.8.1)) and excess stock returns of firm *i* in country c, respectively. We transform the continuous values of $\varepsilon_t^{GPR}$ into a dummy variable that takes a value of one if the GPR factor is higher than one historical standard deviations and zero otherwise, to focus on major geopolitical events. $Z_{t-1}^{GPR}$ is a weight constructed by ranking the firms cross-sectionally based on their GPR betas, and then standardizing these rankings to range between -0.5 and +0.5. $Z_{t-1}^{GPR} r_{i,c,t}$ represents the return of the GPR beta sorted portfolio. Our interest is on the sign and statistical significance of the estimated coefficient $\eta^{GPR}$, controlling for Fama-French three factors sorted. To mitigate the impact of noisy observations in countries with limited availability of stock returns, only countries with more than 100 stocks are included in estimation.

**Online Annex Figure 2.8.6. GPR Premiums in AEs and EMEs, 1990-2024**
(Percentage point)




Source: Caldara and Iacoviello (2022); LSEG Datastream and Worldscope Fundamentals database; and IMF staff calculations.
Note: The panel indicates the estimated averages coefficients of GPR betas for respective time-windows in Fama-Macbeth regression (left chart) and the alphas of the returns of the simple average portfolios constructed by buying stocks with top 10 percent GPR betas and selling those with bottom 10 percent GPR betas, controlling for Fama-French three factors and the momentum factor (right chart). The sample period is May 1990 to July 2024. Bars indicate statistical significance at the 10 percent level or below. Estimation with stocks in "EMs" exclude the book-to-market factor. AEs=Advanced Economies. EMEs=Emerging Market Economies.

Online Annex Figure 2.8.5 shows the estimates of $\eta^{GPR}$ with and without controlling for Fama-French 3 factors. GPR beta sorted portfolios have positive and statistically significant coefficients.

**Advanced Economies vs Emerging Market Economies.** The pricing of geopolitical risk could depend on the liquidity of stock markets. A sub-sample analysis with stocks listed in AEs and EMEs shows that geopolitical risk has been significantly priced mainly in AEs, likely reflecting higher market liquidity, or better availability of data (Online Annex Figure 2.8.6).

**Heterogeneity across sub-components of the GPR index.** Geopolitical risk events are complex and multidimensional. Caldara and Iacoviello (2022) also publish sub-indexes and eight components of the global GPR index. This annex considers such components, beginning with the broad categories of "threat" and "act" as well as their respective sub-components: threats (war threats, peace threats, military buildups, nuclear threats, terror threats) and acts (the beginning of war, escalation of war, and terror acts), where each sub component represents the percentages of articles that include the relevant words. The correlations between "threat" and "acts" GPR factors and overall GPR factor are 0.90 and 0.82, respectively. The correlations between the factors from sub-components and general GPR factor are as follows: war threats (0.55), peace threats (0.11), military buildups (0.61), nuclear threats (0.33), terror threats (0.52), the beginning of war (0.54), escalation of war (0.38), and terror acts (0.61), with sub-components for equation (2.8.1) normalized to a mean of 100. Online Annex Table 2.8.1 shows the GPR beta premiums across different sub-components. In both the threats and acts indices, as well as their underlying sub-components, patterns about GPR premiums are similar, except for terror threats and acts for which the estimates for GPR premiums for 2012-21 are positive, not negative, suggesting that wars and terrorism may be priced differently by investors.

**Robustness**

The main results of this analysis—(i) industry-level heterogeneity in GPR betas and (ii) negative premiums for stocks with higher GPR betas since the global financial crisis till the Russia's invasion of Ukraine—are robust to the following tests:

**Online Annex Table 2.8.1. GPR Beta Premiums of Sub-Components, 1990-2024**
(Percentage point)

**i) Fama-Macbeth Regression**

| | 1990-2011 | 2012-21 | 2022-24 |
|---|---|---|---|
| Threats index | 0.007 | **-0.020** | 0.012 |
| War threats (percent) | 0.004 | -0.003 | 0.001 |
| Peace threats (percent) | 0.001 | **-0.002** | **0.009** |
| Military buildups (percent) | 0.000 | **-0.024** | **-0.006** |
| Nuclear threats (percent) | 0.000 | -0.006 | 0.006 |
| Terror threats (percent) | **0.007** | 0.003 | -0.003 |
| Acts index | **0.015** | 0.003 | **0.045** |
| The beginning of war (percent) | **0.017** | -0.009 | **0.023** |
| Escalation of war (percent) | 0.013 | **-0.013** | 0.018 |
| Terror Acts (percent) | **0.008** | **0.011** | 0.001 |

**ii) Decile Portfolio**

| | 1990-2011 | 2012-21 | 2022-24 |
|---|---|---|---|
| Threats index | 0.139 | -0.362 | 0.471 |
| War threats (percent) | -0.022 | -0.292 | **0.844** |
| Peace threats (percent) | 0.017 | 0.044 | **0.741** |
| Military buildups (percent) | 0.244 | **-0.498** | 0.401 |
| Nuclear threats (percent) | 0.236 | -0.149 | 0.213 |
| Terror threats (percent) | 0.168 | -0.180 | **-0.591** |
| Acts index | -0.053 | -0.205 | **1.239** |
| The beginning of war (percent) | -0.039 | **-0.388** | **0.984** |
| Escalation of war (percent) | -0.002 | -0.181 | **0.675** |
| Terror Acts (percent) | -0.135 | -0.085 | **-0.514** |

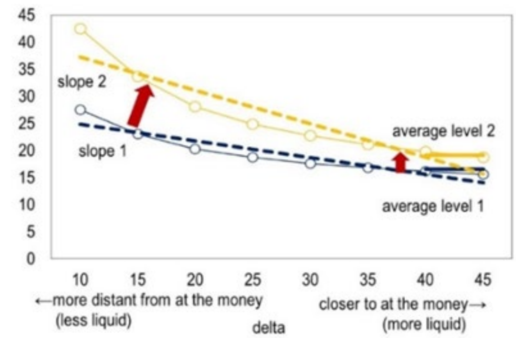
Source: Caldara and Iacoviello (2022); Kenneth French's database; LSEG Datastream and Worldscope Fundamentals database; and IMF staff calculations.
Note: Panels present the estimated averages coefficients for GPR betas for respective time-windows in Fama-Macbeth regression and the alphas of the returns of the simple average portfolios constructed by buying stocks with bottom 10 percent GPR betas and selling those with top 10 percent GPR betas, controlling Fama-French three factors and momentum factor, where the sample period is from May 1990 to July 2024. The estimates that are statistically significant at the 10 percent level or below are in bold.

- Longer sample windows for equation (2.8.2) (48 months to 120 months).
- Robust regressions for equations (2.8.1) and (2.8.2).
- Shocks to the GPR index estimated using a GARCH model, given potential volatility clustering in the GPR index.
- Only positive shocks to the GPR index used for the estimation of GPR betas.
- As an alternative to shocks to global GPR, using shocks to country-level GPR indices (in this case, equation (2.8.1) is estimated on a country-by-country basis). On average, the correlation between the home country GPR factor and the global GPR factor is about 0.42, with a maximum of 0.98 and a minimum of 0.13.
- Excluding countries with limited number of stocks (less than 100) from Fama-Macbeth regression and decile portfolio analysis.
- Excluding the country effect from the Fama-Macbeth regression and forming groups among all samples (not within each country) in the decile portfolio analysis.
- Allowing for the coefficients of the Fama-French three factors and momentum factors to be heterogeneous across sample countries in Fama-Macbeth regression and decile portfolio analysis ($\gamma_{m,t}$ and $\gamma_t^X$ in equation (2.8.3) and $\gamma_d^X$ in equation (2.8.4))
- Following Zhang and others (2023) by estimating premiums for absolute values of GPR betas. While positive premiums for stocks with lower absolute GPR betas are robustly observed, the stocks with high absolute GPR betas tend to have higher excess return volatility which could reflect the "low volatility anomaly" (see, e.g., Glenn and others, 1995).

**<u>Pricing of Protection for Downside Risks in Stock Options Market</u>**

**Methodology and Data**

**Online Annex Figure 2.8.7. Conceptual Framework: Put Option Delta and Implied Volatility**




Sources: IMF staff.

**Methodology.** This analysis quantifies the prices for protection against downside risk in option markets. Specifically, premiums for protecting against overall downside risk (the left-hand side of the probability distribution) and additional premiums for protecting against downside tail risk (the extreme leftmost portion of the probability distribution) are estimated based on one-month-ahead put options on individual stocks, evaluated on each day. Downside risk is proxied by the average implied volatility across out-of-the-money deltas close to being in-the-money, while downside tail risk is proxied by the slope of the implied volatility curve across all out-of-the-money deltas. The empirical methodology follows the framework of Ilhan and others (2021) and Kelly and others (2016). Specifically, the average level of implied volatility is estimated by regressing the implied volatility of out-of-the-money options that are close to being in-the-money (40, 45) on a constant. When the average level increases (as shown from average level 1 to 2 in Online Annex Figure 3.7.7), it implies that investors require higher premiums to protect against overall downside risk. The advantage of using data from higher deltas only, compared to the intercept that uses data from all deltas, is that the impact of noise from less liquid low deltas is expected to be mitigated (Kelly and others, 2016). The slope is estimated by regressing the implied volatility of out-of-the-money options against deltas, including those far from in the money (15, 20, 25, 30, 35, 40, 45). The implied volatility is derived from option prices using the Black-Scholes formula, assuming log-normal distributions of underlying asset returns. However, the tails of asset returns are considered fatter than those predicted by log-normal distributions, meaning the market prices for options in the tail of the asset return distribution are higher than those implied by the Black-Scholes model. This difference between log-normal and fat-tailed distributions is thus reflected in the difference in implied volatility calculated from option prices at different deltas. Specifically, a more distant strike price from the current price in general leads to higher implied volatility, reflecting higher option prices. Therefore, the estimated slope is typically negative. When the slope becomes steeper (as shown from slope 1 to 2 in Online Annex Figure 2.8.7), it implies that investors demand additional premiums for protecting against downside tail risks. Specifically, we estimate the following equations with firm-level option data.

$$IV_{d,i,c,t} = \alpha + \varepsilon_{d,i,c,t}. \quad \text{for delta} \in \{40,45\} \quad \textbf{(2.8.9)}$$

$$IV_{d,i,c,t} = \alpha_c + \varepsilon_{d,i,c,t}. \quad \text{for delta} \in \{40,45\} \quad \textbf{(2.8.10)}$$

$$IV_{d,i,c,t} = \alpha_s + \varepsilon_{d,i,c,t}. \quad \text{for delta} \in \{40,45\} \quad \textbf{(2.8.11)}$$

$$IV_{d,i,c,t} = \alpha + \alpha^{EXP} Exp_{i,c,t} + \varepsilon_{d,i,c,t}. \quad \text{for delta} \in \{40,45\} \quad \textbf{(2.8.12)}$$

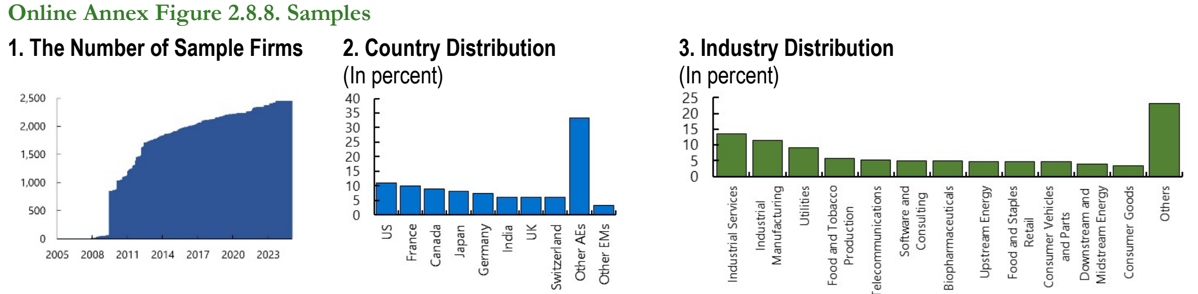
$$IV_{d,i,c,t} = \alpha + \beta delta + \varepsilon_{d,i,c,t}. \quad \text{for delta} \in \{15,20,25,30,35,40,45\} \quad \textbf{(2.8.13)}$$

$$IV_{d,i,c,t} = \alpha_c + \beta_c delta + \varepsilon_{d,i,c,t}. \quad \text{for delta} \in \{15,20,25,30,35,40,45\} \quad \textbf{(2.8.14)}$$

$$IV_{d,i,c,t} = \alpha_s + \beta_s delta + \varepsilon_{d,i,c,t}. \quad \text{for delta} \in \{15,20,25,30,35,40,45\} \quad \textbf{(2.8.15)}$$

$$IV_{d,i,c,t} = \alpha + \alpha^{EXP} Exp_{i,c,t} + \beta delta + \beta^{EXP} Exp_{i,t} delta + \varepsilon_{d,i,c,t}. \quad \text{for delta} \in \{15,20,25,30,35,40,45\} \quad \textbf{(2.8.16)}$$

**Online Annex Figure 2.8.8. Samples**




Source: LSEG Datastream and Worldscope Fundamentals database; and IMF staff calculations.
Note: Panel 1 indicates the number of sample firms in each month. Panels 2 and 3, respectively, represent the share of each country and industry in the sample for the period from January 2005 through January 2025.

where $IV_{d,i,t}$ represents the implied volatility of the options for stock of firm *i* in country *c* at respective deltas (*d*) in period *t*, while $\alpha_t$ and $\beta_t$ indicate the period effects. In this specification, both the intercept and slope of the implied volatility curve are estimated using equations (2.8.9)-(2.8.16), respectively, with daily data over a one-week (five-business-day) window. Specifically, $\alpha$, $\alpha_c$, $\alpha_s$ and $\alpha^{EXP}$ in equations (2.8.9)- (2.8.12) represent the average levels for all firms, firms in each country and industry (sector), and the impact on the average level of firm *i*'s exposure to Russia and Ukraine, respectively. The exposure is measured by (i) the revenue shares from Russia and Ukraine, (ii) asset size of subsidiaries in Russia and Ukraine, relative to parent company's total assets, and (iii) the number of subsidiaries in Russia and Ukraine. Similarly, $\beta$ $\beta_c$, $\beta_s$, and $\beta^{EXP}$ in equations (2.8.13)-(2.8.16), respectively, represent the slope of the implied volatility curve for all firms, firms in each country and industry, and the impact of firm *i*'s exposures to Russia and Ukraine. $\varepsilon_{d,i,c,t}$ is an error term. Figures 12 and 13 display the estimates of the coefficient for the average levels ($\alpha, \alpha_c, \alpha_s, \alpha^{EXP}$) from equations (2.8.9)-(2.8.12) and for cross terms with delta ($\beta, \beta_c, \beta_s, \beta^{EXP}$) in equations (2.8.13)-(2.8.16). Equations (2.8.9)-(2.8.12) are estimated by Ordinary Least Squares with implied volatility for higher deltas (40, 45), where standard errors are clustered at the firm-level, and the equations (2.8.13)-(2.8.16) are estimated by robust regression with implied volatility for various deltas (15, 20, 25, 30, 35, 40, 45). Each firm's implied volatility is normalized to a range of 0 to 1, within each delta for equations (2.8.9)-(2.8.12) and across all deltas for equations (2.8.13)-(2.8.16), based on historical values, to control for differing levels of risk across firms and to mitigate the impact of volatile implied volatilities, though the estimation results remain broadly the same also without normalization.

**Data.** The data is sourced from Refinitiv (available daily from January 2005 through January 2025), and the sample consists of about 2,450 firms as of 2024, all of which are included in the MSCI indexes. Of these, about 800 firms have country and industry information. Online Annex Figure 2.8.8 presents the developments in the number of sample firms, average premiums for downside and downside tail risks across all sample firms, the distribution of the firm sample across various countries and industries, indicating that sample firms are predominantly concentrated in AEs.

**Geopolitical event dates.** For Figure 12 (Russia's Invasion of Ukraine), the event date is set to February 24, 2022. Figure 13 (US-China Trade Tensions) considers nine tariff announcement events: by the US (March 22, 2018; June 15, 2018; May 6, 2019; August 1, 2019), and by China (March 23, 2018; June 15, 2018; August 3, 2018; May 13, 2019; August 23, 2019), following Online Annex Table 2.6.1. Retaliatory tariff announcements are included, based on Amiti and others (2024), where the dates are double-checked against official announcements and media sources. We exclude non-bilateral tariff hikes against all countries.

**Additional Results**

**GPR betas and option premiums.** If higher GPR betas result in additional volatility, they should also be reflected in option markets, as the distribution of future stock returns widens. To estimate the long-run relationship between GPR betas and the slope, the following firm-level cross-sectional regressions are estimated.

$$IV_{d,i,c,t} = \alpha_t + \alpha_c + \alpha^{GPR}\hat{\beta}_{i,c,t,GPR} + \alpha^{MKT}\hat{\beta}_{i,c,t,MKT} + \varepsilon_{d,i,c,t}\text{ . for delta } \in \{40,45\} \quad \textbf{(2.8.17)}$$

$$IV_{d,i,c,t} = \alpha_t + \alpha_c + \alpha^{GPR}\hat{\beta}_{i,c,t,GPR} + \alpha^{MKT}\hat{\beta}_{i,c,t,MKT} + \beta_t delta + \beta_c delta + \beta^{GPR}\hat{\beta}_{i,c,t,GPR} delta + \beta^{MKT}\hat{\beta}_{i,c,t,MKT} delta + \varepsilon_{d,i,c,t}\text{ . for delta } \in \{15,20,25,30,35,40,45\} \quad \textbf{(2.8.18)}$$

where $\alpha_t$ and $\alpha_c$ in equation (2.8.17) represent the period and country dummies, and $\alpha^{GPR}$ and $\alpha^{MKT}$ in equation (2.8.17) indicate the impact of firm *i*'s GPR betas ($\hat{\beta}_{i,c,t,GPR}$) and market betas ($\hat{\beta}_{i,c,t,MKT}$) on the average level. Similarly, $\beta_t$ and $\beta_c$ in equation (2.8.18) represent the period and country dummies for the slope of the implied volatility curve, and $\beta^{GPR}$ and $\beta^{MKT}$ in equation (2.8.18) indicate the impact of firm *i*'s GPR betas and market betas on the slope. $\varepsilon_{d,i,t}$ is an error term. Online Annex Figure 2.8.9 presents the estimates of the coefficient for GPR beta ($\alpha^{GPR}$) in equation (2.8.17) and the cross term between the GPR beta and deltas ($\beta^{GPR}$) in equation (2.8.18). For comparison, the coefficients for market betas ($\alpha^{MKT}$, $\beta^{MKT}$) are also shown, and the coefficients for the GPR betas are normalized to a scale comparable to that of market betas by multiplying the estimates by the ratio of the standard deviation of the GPR betas to that of market betas. Equations (2.8.17) and (2.8.18) are estimated using Ordinary Least Squares with standard errors that are firm-level cluster-robust. Because these equations explore the factors affecting firm's riskiness, implied volatility is not normalized. Since the GPR beta is at a monthly frequency, this equation is estimated using the monthly average of implied volatility. The estimation results indicate that, similar to market betas, the absolute value of GPR betas lead to an increase in premiums for both overall downside risk (panel 1) and tail risk (panel 2), with the magnitude being comparable to that of market betas. This confirms the hypothesis that the additional volatility in stock returns generated by geopolitical risk is priced in stock option markets.

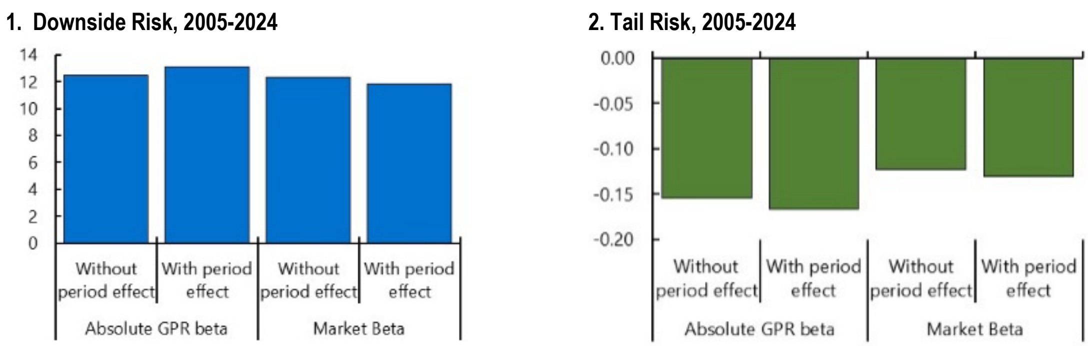
**GPR factor and option premiums.** Figures 12 and 13 examines the premiums for overall downside risk and downside tail risk around Russia's invasion of Ukraine and the US-China trade conflict and shows that the premiums increased for the firms that have higher exposures to these geopolitical events. This Annex explores if, on average, a rising geopolitical factor increased the premiums. To this end, the following equation is estimated.

$$IV_{d,i,c,t} = \alpha + \alpha^{GPR}\varepsilon_t^{GPR} + \varepsilon_{d,i,c,t}\text{ . for delta } \in \{40,45\} \quad \textbf{(2.8.19)}$$

$$IV_{d,i,c,t} = \alpha + \alpha^{GPR}\varepsilon_t^{GPR} + \beta delta + \beta^{GPR}\varepsilon_t^{GPR} delta$$
$$+\varepsilon_{d,i,c,t}\text{ . for delta } \in \{15,20,25,30,35,40,45\} \quad \textbf{(2.8.20)}$$

where $\varepsilon_t^{GPR}$ represents the GPR factor, extracted from equation (2.8.1) and $\varepsilon_{d,i,c,t}$ indicates the error term. Therefore, $\alpha^{GPR}$ in equation (2.8.19) represents the impact of an increase in the GPR factor on premiums for overall downside risk, proxied by average levels of the implied volatility, and $\beta^{GPR}$ in equation (2.8.20) indicates the impact of an increase in the GPR factor on premiums for downside tail risk, proxied by the slope of implied volatility curves. To focus on the impact of major geopolitical events, the GPR factor is transformed into a dummy variable that takes the value of one if the GPR factor is higher than two historical standard deviation and zero otherwise. The frequency is monthly, from January 2005 through January 2025.[18] Online Annex Figure 2.8.10 shows the estimation results. Specifically, the Figure presents the percent changes in option premiums when the GPR factor exceeds two historical standard deviations—calculated as $\frac{\hat{\alpha}^{GPR}}{\hat{\alpha}}$*100 and $\frac{\hat{\beta}^{GPR}}{\hat{\beta}}$*100. The Figure indicates that under major geopolitical events premiums for both downside and downside tail risks tend to increase, respectively, by approximately 4 and 6 percents.

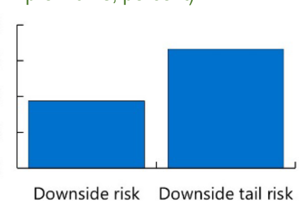
**Online Annex Figure 2.8.9. GPR Beta and Option Premiums**




Source: Caldara and Iacoviello (2022); LSEG Datastream and Worldscope Fundamentals database; and IMF staff calculations.
Note: Panel 1 indicates the estimated coefficients for absolute values of GPR betas and market betas, where the coefficients for absolute GPR betas are multiplied by the ratio of standard deviation of GPR betas to that of market betas, to make them comparable. Panel 2 shows the estimated coefficients for cross-terms between deltas and absolute values of GPR betas and market betas, where the manipulation for panel 1 is employed. Bars indicate statistical significance at the 10 percent level or greater.

**Exposures to Israel-Gaza conflict and option premiums.** This analysis examines the implications of firms' exposures to the Israel-Gaza conflict. Specifically, the left panel of Online Annex Figure 2.8.11 shows the estimates of the premiums for downside and downside tail risks, from equation (2.8.9) and (2.8.13), respectively, and the right panel displays the estimates of the premiums from equations (2.8.12) and (2.8.16). The left panel indicates that, after the onset of the conflict, the premiums for both downside and downside tail risks moderately increased, while the right panel shows that firms with higher revenue exposure to Israel experienced a sharp increase in premiums.

**Online Annex Figure 2.8.10. Geopolitical Risk and Option Premiums, 2005-2025**
(Increase in premiums, percent)

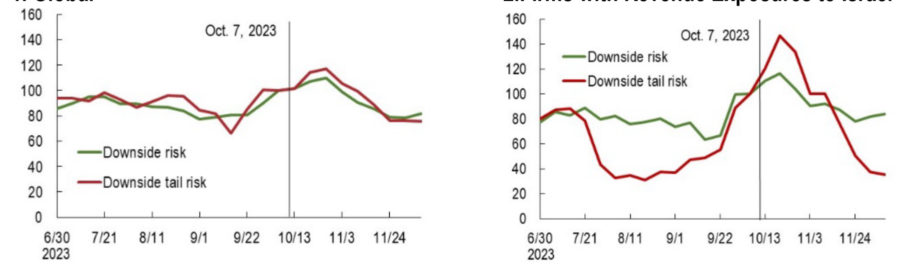



Sources: Caldara and Iacoviello (2022); LSEG Datastream and Worldscope Fundamentals database; and IMF staff calculations.
Note: The panel shows the percent changes in premiums when the GPR factor exceeds two historical standard deviations. These changes are calculated by dividing the estimated coefficients for the GPR factor dummy and the interaction term between the dummy and deltas by the estimated firm-average values of implied volatility and slopes. Bars indicate statistical significance at the 10 percent level or greater.

[18] Each firm's implied volatility is normalized to a range from 0 to 1 within each delta for equation (2.8.19) and across all deltas for equation (2.8.20), based on historical values, to control for differing levels of risk across firms and mitigate the impact of extremely volatile implied volatilities, with the implied volatilities winsorized at the 5th and 95th percentiles.

**Stock option markets and stock markets.** This analysis examines the link between stock option premiums and stock returns for each individual stock. Specifically, it evaluates whether an increase in option premiums ($IV_{d,i,c,t}$) is negatively correlated with simultaneous stock (excess) returns ($r_{i,c,t}$). A negative correlation would imply "anticipation effects" in the sense that the stock returns decline when option premiums for future downside risk increases.

**Online Annex Figure 2.8.11. Pricing of Geopolitical Risk: Israel-Gaza Conflict**
(Indices, 1 week before the event=100)



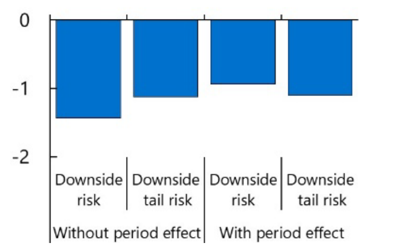

Source: Factset; LSEG Datastream and Worldscope Fundamentals database; and IMF staff calculations.
Note: "Downside risk" and "Downside tail risk" represent the estimates of the average levels and the slopes of implied volatility curves for firm-level stock put options for one-month ahead prices, estimated over a one-week window (the respective date and past four business days). Event week represents the week of October 7, 2023, and the next four business days. The right panel shows the increase in downside risk and tail risk, measured by the average levels and slopes of implied volatility curves, by an increase in exposures to Israel, relative to all firm averages.

$$IV_{d,i,c,t} = \alpha_t + \alpha_c + \alpha^{return} r_{i,c,t} + \varepsilon_{d,i,c,t}\ . \quad \text{for delta} \in \{40,45\} \quad \textbf{(2.8.21)}$$

$$IV_{d,i,c,t} = \alpha_t + \alpha_c + \alpha^{return} r_{i,c,t} + \beta_t delta + \beta_c delta$$
$$+\beta^{return}\, r_{i,c,t} delta + \varepsilon_{d,i,c,t}. \text{for delta} \in \{15,20,25,30,35,40,45\} \quad \textbf{(2.8.22)}$$

where $\alpha_t$ and $\alpha_c$ in equation (2.8.21) represent the period and country dummies, and $\alpha^{return}$ indicates the correlation between stock returns in period *t* ($r_{i,c,t}$) and option premiums in the same period ($IV_{d,i,c,t}$). Similarly, $\beta_t$ and $\beta_c$ in equation (2.8.22) represent the period and country dummies for the slope of the implied volatility curve, and $\beta^{return}$ indicates the correlation between stock returns and the slope. $\varepsilon_{d,i,t}$ is an error term. The frequency of the sample is monthly, from January 2005 through January 2025.[19] Online Annex Figure 2.8.12 presents the estimated values of $\hat{\alpha}^{return}$ in equation (2.8.21) and $\hat{\beta}^{return}$ in equation (2.8.22), with and without period effects. Specifically, the Figure presents the percent changes in downside and downside tail risks when simultaneous stock excess returns increase by one percent—calculated as $\frac{\hat{\alpha}^{return}}{\hat{\alpha}}$*100 and $\frac{\hat{\beta}^{return}}{\hat{\beta}}$*100, where $(\hat{\alpha}, \hat{\beta})$ are obtained by estimating equations (2.8.9) and (2.8.13) with this dataset. The Figure indicates that option premiums for both downside risk and downside tail risk decrease (increase) by approximately one percent for the stocks with excess returns that increase (decrease) by one percent, implying some anticipation effects.

**Online Annex Figure 2.8.12. Stock Returns and Option Premiums, 2005-2025**
(Increase in premiums, percent)




Sources: Caldara and Iacoviello (2022); LSEG Datastream and Worldscope Fundamentals database; and IMF staff calculations.
Note: The panel shows the percent changes in premiums when the simultanoues stock excess returns increase by one percent. These changes are calculated by dividing the estimated coefficients for the stock excess returns and the interaction term between the returns and deltas by the estimated firm-average values of implied volatility and slopes. Bars indicate statistical significance at the 10 percent level or greater.

## Online Annex 2.9. What are the potential implications for banks?

To assess the impact of major geopolitical risk events on banking sector stability, variants of the following empirical model are estimated:

$$y_{b,t} = \alpha + \beta\, I(Event)_{c,t} + \xi\ Bank\ Controls_{b,t-1} + \varphi\ Macro\ Controls_{c,t-1} + \mu_b + \nu_t + \epsilon_{b,t} \quad \textbf{(2.9.1)}$$

where $y_{b,t}$ denotes (i) change in bank equity, normalized by lagged total assets, or (ii) the log change in outstanding gross loans, of bank *b* in country *c* from year *t-1* to *t*. To shed light on the underlying mechanisms, change in the cost of funding (proxied by the change in total interest expenses-to-average interest-bearing liabilities, and the non-performing loans ratio are also studied. $I(Event)_{c,t}$ is defined as an indicator variable equal to 1 if country *c*

[19] Each firm's implied volatility is normalized to a range of 0 to 1 within each delta for equation (2.8.21) and across all deltas for equation (2.8.22), based on historical values, with the implied volatilities winsorized at the 5th and 95th percentiles.

experiences a major geopolitical risk event at time *t* and 0 otherwise (differentiating between international military conflicts and others).

The model includes several bank- and country-level control variables. $Bank\ Controls_{b,t-1}$ are banks' total assets (in US dollars, logs), capital ratio (equity-to-total assets), liquidity ratio (liquid assets-to-total assets), asset quality (non-performing loans-to-gross loans ratio), and profitability (operating profits-to-total assets), all lagged by 1 year. $Macro\ Controls_{c,t-1}$ include real GDP growth, log nominal GDP (in US dollars), CPI-based annual inflation, net capital flows-to-GDP, short-term deposit rates, long-term government bond yields, and the institutional quality index (average of bureaucracy quality, corruption, democratic accountability, government stability and law and order from the ICRG database). The model further includes bank fixed effects ($\mu_b$) to account for time-invariant bank characteristics, and time fixed effects ($\nu_t$), absorbing common time-varying factors. Standard errors are clustered at the bank level.

The key hypothesis is that banks could be adversely affected following a major domestic geopolitical risk event, in the form of higher costs of funding, lower bank capital and capacity to lend, and higher non-performing loans.

The model is then expanded to examine the impact of foreign geopolitical risk shocks on the domestic banking sector by utilizing cross-border banking claims from the BIS Locational Banking Statistics database:[20]

$$y_{b,t} = \alpha + \delta \sum_{c' \in C}^{C} w_{c,c',t-1} I(Event)_{c',t} + \xi\ Bank\ Controls_{b,t-1} + \varphi\ Macro\ Controls_{c,t-1} + \mu_b + \nu_t + \epsilon_{b,t} \quad \textbf{(2.9.2)}$$

where weights ($w_{c,c',t-1}$) are the share of banking sector claims on country *c'* (including both sovereign and private sector assets) in the total cross-border banking claims of country *c's* banking sector in year *t-1*. Alternative specifications include weighting foreign major geopolitical risk events ($w_{c,c',t-1}$) by the share of cross-border liabilities—calculated based on cross-border claims data. $\mu_b$ and $\nu_t$ denote bank and year fixed effects, respectively. Standard errors are clustered at the bank level.

The key hypothesis is that banks with exposure to countries afflicted by major geopolitical risk events are adversely affected, in the form of higher cost of funding, lower bank capital and capacity to lend, and higher non-performing loans. Potential channels include (i) valuation losses through claims exposure (e.g., higher foreign country sovereign CDS spreads would weigh on sovereign bond holders, including non-resident banks), and (ii) tighter funding conditions.

The analyses are based on annual unconsolidated bank-level financial statements for over 6,000 banks from 21 AEs and 15 EMEs. The exact coverage of banks/countries depends on the specification.

The results suggest that banks' cost of funding increases after a major geopolitical risk event, driven by non-military conflict events for AEs, and by military conflicts for EMEs. Moreover, the impact on bank capital has on average been negative, particularly for EMEs, contributing to lower lending. NPL ratios also rise, especially for EMEs following involvement in an international military conflict. Banks are also exposed to major foreign geopolitical risk events through their cross-border claims and liabilities with impacts appearing stronger for EMEs. Banks in EMEs, on average, experience higher funding costs and a decline in their capital relative to lagged assets, especially if their funding sources are involved in an international military conflict. In part due to deteriorated risk-taking capacity, bank lending declines.[21]

[20] Conditional on the home country not experiencing a major geopolitical risk event in that year, i.e., $I(Event)_{c,t}$ is equal to 0. This assumption is due to the low frequency of the underlying data (annual)—which makes it challenging to identify the impact of domestic and foreign events occurring in the same year jointly.

[21] Full set of results are available upon request.

## Online Annex 2.10. What are the potential implications for the non-bank financial sector?

The analysis encompasses ca. 35,000 to 40,000 exchange-traded funds, mutual funds, insurance funds, pension funds, and hedge funds from 62 countries, covering the period 2013Q1 to 2024Q2. By fund type, the sample includes bond, equity, mixed asset, and other funds.

**Exposure to Geopolitical Risk Events.**

This section analyzes the impact of geopolitical risk events on investment funds' returns and flows using the following model:

$$Y_{i,c,t} = \alpha + \beta\, Exposure_{i,c',T-1} + \gamma\, Controls_{i,t} + \upsilon_{c,f,t} + \epsilon_{i,t} \qquad \mathbf{(2.10.1)}$$

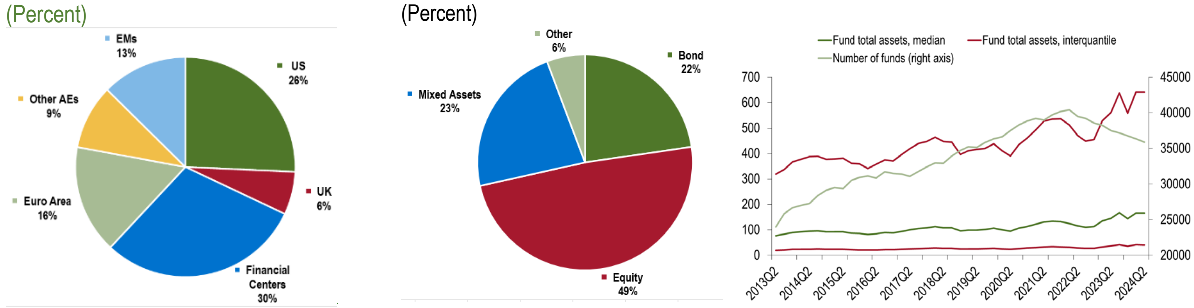
where $Y_{i,c,t}$ is the monthly return of or monthly flows (normalized by assets under management at *t-1*) into investment fund *i* domiciled in country *c* in month *t,* and *T* denotes the event month. $Exposure_{i,c',T-1}$ represents the weighted average of holdings where the issuer is domiciled in countries *c'* that experience geopolitical risk events in quarter *T-1*.

For the return regressions, controls include fund size and cash holdings. For the flow regressions, controls include fund size, cash holdings, and one-month lagged fund returns (as investor flows may depend on past returns). $\upsilon_{c,f,t}$ are country-fund-type-month fixed effects, absorbing time-varying domicile-fund-type-month-specific factors. Fund fixed effects are also added for robustness. Standard errors are two-way clustered by fund and domicile-month.

Overall, investment funds with significant exposure to geopolitical risks, especially international military conflicts, experience lower returns and outflows. Across all types of funds, a 10-percentage point increase in exposure to international military conflicts reduces the monthly return by 0.2 percent and leads to a 0.5 percent monthly outflow. While exposures to other types of GPR events do not have a significant impact on fund returns, they have a modest impact on fund flows, as a 10-percentage point increase leads to a 0.05 percent outflow.

**Online Annex Figure 2.10.1. Sample Coverage**

1.Domicile Distribution of Investment Funds (Percent) | 2.Distribution of Investment Funds by Assets (Percent) | 3.Fund Total Assets and Fund Numbers (Mil USD, Unit)




Sources: FactSet, Lipper, and IMF staff calculations.
Note: Financial centers include Bermuda, British Virgin Islands, Cayman Islands, Guernsey, Hong Kong SAR, Ireland, Liechtenstein, Luxembourg, the Netherlands, Philippines, and Singapore.

**Online Annex Table 2.10.1. The Effects of Exposure to Destination GPR on Investment Fund Monthly Returns**

Dependent Variable: Monthly Fund Return

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| Exposure to Intl Military Conflicts | -0.037*** | -0.105*** | -0.020* | | | | -0.037*** | -0.106*** | -0.020* |
| | (0.013) | (0.040) | (0.011) | | | | (0.013) | (0.040) | (0.011) |
| Exposure to Other GPR Events | | | | 0.006* | 0.006* | -0.002 | 0.006* | 0.006* | -0.002 |
| | | | | (0.003) | (0.004) | (0.002) | (0.003) | (0.004) | (0.002) |
| Fund Return | | 0.049*** | 0.032*** | | 0.049*** | 0.032*** | | 0.049*** | 0.032*** |
| | | (0.018) | (0.003) | | (0.018) | (0.003) | | (0.018) | (0.003) |
| Fund Total Assets | | -0.001 | -0.001 | | -0.001 | -0.001 | | -0.001 | -0.001 |
| | | (0.001) | (0.000) | | (0.001) | (0.000) | | (0.001) | (0.000) |
| Domicile * Fund-Type * Month F.E.s | No | No | Yes | No | No | Yes | No | No | Yes |
| Observations | 4,421,131 | 2,926,915 | 2,925,743 | 4,421,131 | 2,926,915 | 2,925,743 | 4,421,131 | 2,926,915 | 2,925,743 |
| R-squared | 0.000 | 0.001 | 0.640 | 0.000 | 0.001 | 0.640 | 0.000 | 0.001 | 0.640 |

Sources: Caldara and Iacoviello (2022), FactSet, Lipper, and IMF staff calculations.
Note: "Yes" indicates that corresponding fixed effects are included. Standard errors are clustered by fund and month-domicile. ***, **, and * represents 99% significance level, 95% significance level, and 90% significance level, respectively.

**Online Annex Table 2.10.2. The Effects of Exposure to Destination GPR on Investment Fund Monthly Flows**

| Dependent Variable: Monthly Fund Flow | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| Exposure to Intl Military Conflicts | -0.029* | -0.080*** | -0.051*** | | | | -0.029*** | -0.079*** | -0.051*** |
| | (0.014) | (0.019) | (0.015) | | | | (0.007) | (0.019) | (0.015) |
| Exposure to Other GPR Events | | | | -0.007*** | -0.008*** | -0.005*** | -0.007*** | -0.008*** | -0.005*** |
| | | | | (0.002) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Fund Return | | 0.056*** | 0.102*** | | 0.056*** | 0.102*** | | 0.056*** | 0.102*** |
| | | (0.006) | (0.008) | | (0.006) | (0.008) | | (0.006) | (0.008) |
| Fund Total Assets | | 0.138*** | 0.159*** | | 0.137*** | 0.159*** | | 0.137*** | 0.159*** |
| | | (0.010) | (0.012) | | (0.011) | (0.012) | | (0.011) | (0.012) |
| Cash Holding Percentage | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| | | (0.000) | (0.000) | | (0.000) | (0.000) | | (0.000) | (0.000) |
| Domicile * Fund-Type * Month F.E.s | No | No | Yes | No | No | Yes | No | No | Yes |
| Observations | 4,228,192 | 2,848,899 | 2,848,045 | 4,228,192 | 2,848,899 | 2,848,045 | 4,228,192 | 2,848,899 | 2,848,045 |
| R-squared | 0.000 | 0.002 | 0.018 | 0.000 | 0.002 | 0.018 | 0.000 | 0.002 | 0.018 |

Sources: Caldara and Iacoviello (2022), FactSet, Lipper, and IMF staff calculations.
Note: "Yes" indicates that corresponding fixed effects are included. Standard errors are clustered by fund and month-domicile. ***, **, and * represents 99% significance level, 95% significance level, and 90% significance level, respectively.

**Case Studies.**

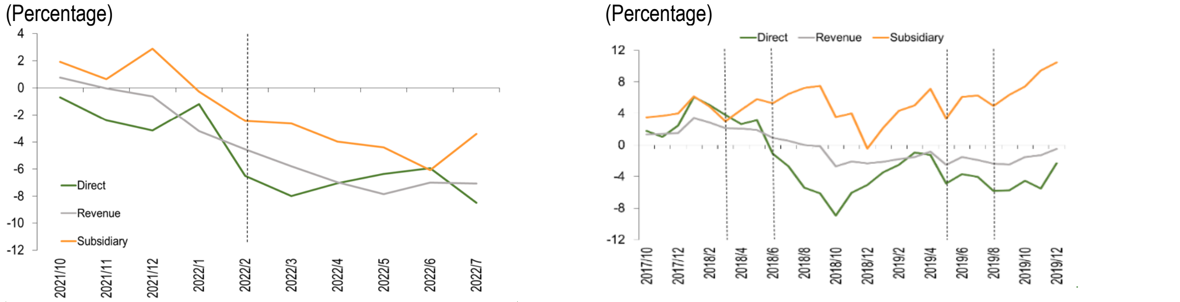
On average and as of 2021Q4, 0.30% of funds' assets under management were domiciled in Russia and Ukraine, 22.25% of assets were issued by non-Russian and non-Ukrainian firms with at least one subsidiary in Russia or Ukraine, 45.15% of assets had at least some revenues from Russia or Ukraine. Similarly, as of 2017Q4, on average, investment funds held 2.87% of assets that were domiciled in China, 33.60% of assets had a subsidiary in China, and 42.80% had revenues from China.

**Online Annex Figure 2.10.2. Change in Investment Fund Cumulative Returns Around Geopolitical Events**

*Following the geopolitical events, investment funds that are more exposed to event countries face lower returns…*

**1.Change in Cumulative Returns Around Russia-Ukraine war for high vs. low exposure funds**
(Percentage)

**2.Change in Cumulative Returns Around US-China trade disputes for high vs. low exposure funds**
(Percentage)




Sources: FactSet, Lipper, Orbis, and IMF staff calculations.
Note: The y-axis represents the relative cumulative returns of investment funds in a global sample, calculated as the percentage difference between the 75th percentile of investment funds and the 25th percentile of investment funds for each measure. For panel 1, cumulative returns are relative to 2020M9. For panel 2, cumulative returns are relative to 2017M9. Exposure measures are derived by calculating the weighted average of an indicator variable indicating if the security issuer (i) is domiciled in, (ii) have at least one subsidiary in, or (iii) derive revenues from Russia and Ukraine, and the revenue percentage is higher than the country-sectoral median. The weights reflect the holding percentage of each security one quarter prior to the event. For the Russia-Ukraine War, event countries are Russia and Ukraine; for the US-China Trade Tension, the event country is China.

**Russia-Ukraine War.**

**Data and Methodology**

The section analyzes the returns of or flows into investment funds following Russia's invasion of Ukraine using the following model:

$$Y_{i,c,t} = \alpha + \beta\ Exposure_{i,c',T-1} + \gamma\ Controls_{i,t} + \upsilon_{c,f,t} + \epsilon_{i,t} \qquad \textbf{(2.10.2)}$$

where $Y_{i,c,t}$ is the cumulative return of or the cumulative flows into investment fund *i* domiciled in country *c* in month *t*, and $T$ denotes event month. The cumulative fund returns and flows start at the month of the invasion, and the cumulative flows are normalized by fund size (total assets under management) one month prior to the event. $Exposure_{i,c',T-1}$ is one of $Direct\ Exposure_{i,c',T-1}$, $Revenue\ Exposure_{i,c',T-1}$ , and $Affiliate_{i,c',T-1}$ measured one quarter prior to the event and defined as follows: $Direct\ Exposure_{i,c',T-1}$ is the value-weighted average holding of assets with issuers domiciled in event countries; $Revenue\ Exposure\ _{i,c',T-1}$ is the value-weighted average of a variable indicating if an asset's issuer derives revenues from country $c'$, does not domicile in country $c'$, *and* the issuer's revenue percentage is higher than the country-sectoral median revenue percentage derived from country $c'$; $Affiliate_{i,c',T-1}$ is the weighted average of a variable indicating if an asset's issuer has at least one subsidiary in country $c'$ and is not domiciled in country $c'$. For regressions with cumulative returns, controls include fund size and cash holdings. For regressions with cumulative flows, controls include fund size, cash holdings, and one-month lagged fund returns. $\upsilon_{c,f,t}$ are country-fund-type fixed effects. Standard errors are clustered by fund and domicile country.

**Empirical Results**

The estimation results indicate that ex-ante more exposed funds experience lower returns and outflows after Russia's invasion of Ukraine (Online Annex Figure 2.10.3). Direct exposure has the largest negative impact on both returns and flows (Chapter 2, Figure 16, panel 3 and 4), while indirect exposures through revenues and subsidiaries are less important (Online Annex Figure 2.10.3).

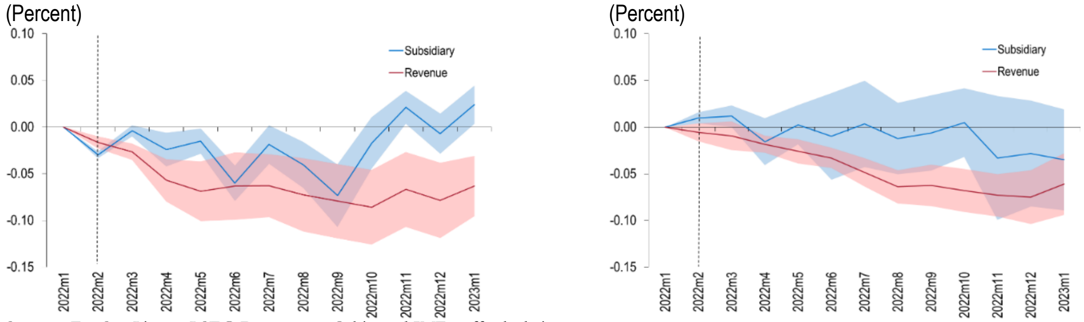
**US-China Trade Tensions.**

**Data and Methodology**

**Online Annex Figure 2.10.3. Indirect Effect of Russia-Ukraine Conflict on Investment Funds' Cumulative Returns**

**1.Average effects of indirect exposure to Russia and Ukraine on cumulative returns**
(Percent)

**2.Average effects of indirect exposure to Russia and Ukraine on cumulative flows**
(Percent)




Sources: FactSet, Lipper, LSEG Datastream, Orbis, and IMF staff calculations.
Note: Cumulative flows and returns are relative to 2022M2. Exposure measures are derived by calculating the weighted average of an indicator variable indicating if the security issuer (i) is domiciled in, (ii) have at least one subsidiary in, or (iii) derive revenues from Russia and Ukraine, and the revenue percentage is higher than the country-sectoral median. The model controls for investment fund size, fund liquidity, one-month lagged fund return (for flow regressions only), and fund type-domicile fixed effects. The weights reflect the holding percentage of each security one quarter prior to the event. Shaded area represents 90% confidence interval.

The section analyzes the returns of or flows into investment funds following tariff announcements using the following model:[22]

$$Y_{i,c,t} = \alpha + \beta_1\ Exposure\ to\ impacted\ Chinese\ firms_{i,T-1} + \beta_2\ Exposure\ to\ impacted\ US\ firms_{i,T-1} + \beta_3\ Exposure\ to\ impacted\ RoW\ firms_{i,c',T-1} + \gamma\ Controls_{i,t} + \upsilon_{c,f,t} + \epsilon_{i,t} \qquad (2.10.3)$$

where $Y_{i,c,t}$ is the cumulative return of or cumulative flows into investment fund *i* domiciled in country *c* in month *t*. Cumulative flows are normalized by the fund size one month prior to the event. For all fund exposure measures, the weights are portfolio holding percentages one quarter prior to the event at *(T-1)*. Since firms in a given sector may produce multiple products within the sector, impacted firms are defined as those operating within sectors that produce at least one product subject to the tariff product list. $Exposure\ to\ impacted\ Chinese\ firms_{i,T-1}$ is the weighted average of a variable indicating if an asset's issuer is a Chinese firm and is impacted by a given tariff announcement; $Exposure\ to\ impacted\ US\ firms_{i,T-1}$ is the weighted average of a variable indicating if an asset's issuer is a US firm and is impacted by a given tariff announcement; $Exposure\ to\ impacted\ RoW\ firms_{i,c',T-1}$ is the weighted average of a variable indicating if an asset's issuer is a non-Chinese non-US (RoW) firm that operates in a sector impacted by a given tariff announcement, and has revenues derived from the tariff-imposing country *c'*. For cumulative return regressions, controls include fund size, cash holdings, exposure to impacted RoW firms that do not derive revenue from tariff-imposing country *c'*, and overall exposure to the country subject to tariffs (calculated as holding percentage of corporate and sovereign assets domiciled in the country subject to tariffs). For cumulative flow regressions, controls include fund size, cash holdings, one-month lagged fund returns, exposure to impacted RoW

[22] See Online Annex 2.6 for a list of tariff announcements.

firms that do not derive revenue from tariff-imposing country *c'*, and overall exposure to the country subject to tariffs. $\upsilon_{c,f,t}$ are country-fund-type fixed effects. Standard errors are clustered by fund and domicile country *c*.

**Empirical Results**

On average, funds with a one-standard deviation (about 2.3 percent) higher exposure to Chinese firms operating in sectors subject to US tariffs experienced a 0.01 standard deviation (equivalent to 0.03 percent) lower cumulative returns in the month following the US tariff announcement. The effect on flows is generally not significant (Online Annex Figure 2.10.5, panels 3 and 4).

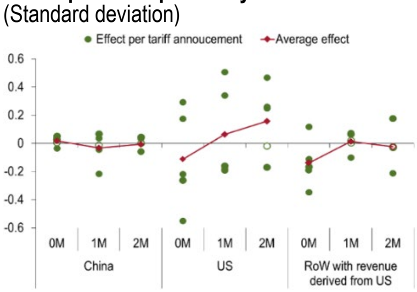
*Robustness.* The results are robust to using alternative mappings from the tariffed product lists to firm sectors, e.g., defining companies as subject to tariffs when they are operating in sectors where at least x percent of product classes in a sector are tariffed.

*Trade agreement.* On January 15th, 2020, US and China signed a trade deal that lifted certain tariffs that were previously imposed during the US-China trade disputes. Investment funds holding Chinese firms that benefited from lower US tariffs on China experienced mild gains, but funds holding US firms experienced lower returns.

**Online Annex Figure 2.10.4. Effect of US-China Trade Disputes on Investment Fund Returns and Flows**

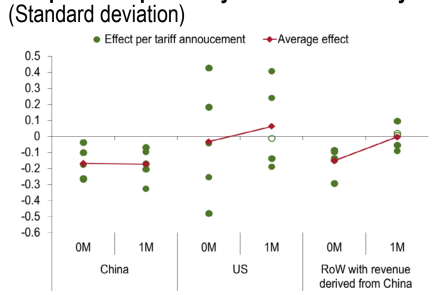
*Holding Chinese firms impacted by US tariffs had negative effect on investment fund returns, and those holding US firms or firms in third countries operating in these sectors seem to gain over time.*

**1.Average effect on fund cumulative returns of the exposure to companies impacted by US tariffs on China**
(Standard deviation)



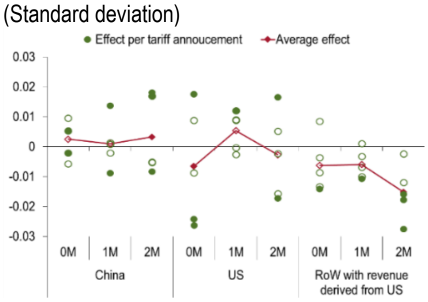

*… while holding securities issued by US firms impacted by Chinese retaliation tariffs does not necessarily lower fund returns.*

**2.Average effect on fund cumulative returns of exposure to companies impacted by China's retaliatory tariffs on US**
(Standard deviation)

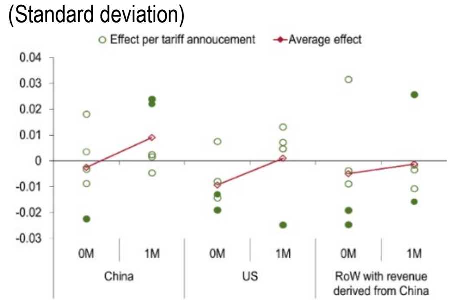



*Nevertheless, funds with assets issued by Chinese firms impacted by US tariffs on China, or with assets issued by US firms impacted by Chinese retaliation tariffs, does not necessarily experience outflows…*

**Average effects of exposure to companies impacted by US tariffs on China on cumulative flows**
(Standard deviation)




**Average effects of exposure to companies impacted by China retaliation tariffs on US on cumulative flows**
(Standard deviation)

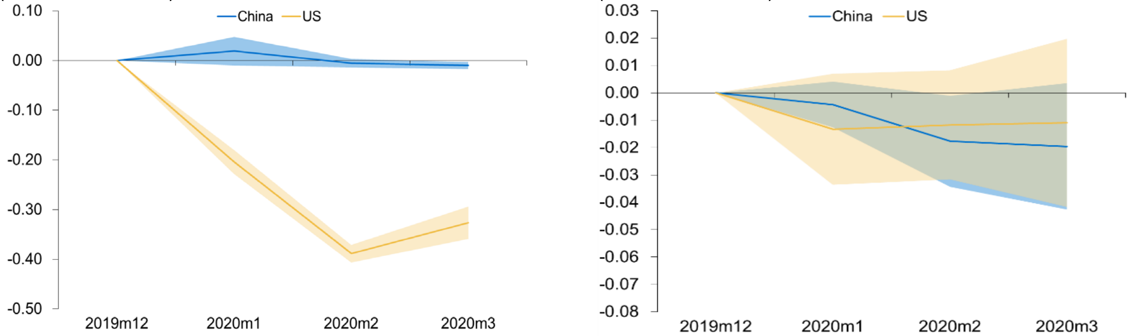



Sources: FactSet, Lipper, LSEG Datastream, Orbis, and IMF staff calculations.
Note: The y-axis represents the range of standardized coefficients, which are calculated per tariff announcement. Cumulative flows and returns are relative to the month of tariff announcement. Exposure measures are derived by calculating the weighted averages of an indicator variable, indicating if the security issuer is i) impacted by a certain tariff announcement, and ii) domiciled in a given country. The model controls for investment fund size, fund liquidity, one-month lagged fund return (for flow regressions only), fund overall exposure to China, fund exposure to RoW impacted companies without revenues deriving from the tariff-imposing country, and fund type-domicile fixed effects. Standard errors are clustered by fund and domicile. The weights reflect the holding percentage of each security one quarter prior to the event. Solid dots represent the results are significant at 90% confidence level, and solid diamonds represent that at least half of regression coefficients are statistically significant at 90% confidence level. RoW = Rest of the World.

**Online Annex Figure 2.10.5. Effect of US-China Trade Agreement on Investment Fund Returns and Flows**

**Average effect on fund cumulative returns of the exposure to companies impacted by US-China Trade Agreement**
(Standard deviation)

**Average effect on fund cumulative flows of exposure to companies impacted by US-China Trade Agreement**
(Standard deviation)




Sources: FactSet, Lipper, LSEG Datastream, and IMF staff calculations.
Note: The y-axis represents standardized coefficients. Cumulative flows and returns are relative to 2020M1. Exposure measures are derived by calculating the weighted averages of an indicator variable, indicating if the security issuer is i) benefited from the tariff agreement as the counterparty country agrees to reduce tariffs, and ii) domiciled in a given country. Benefitted companies are defined as those operating within sectors that produce products subject to the tariff agreement. The model controls for investment fund size, fund liquidity, one-month lagged fund return (for flow regressions only), fund overall exposure to China, fund overall exposure to the US, fund exposure to RoW impacted companies that i) have revenues derived from China, ii) have revenues derived from the US, and iii) do not have revenues derived from the US or China, and fund type-domicile fixed effects. Standard errors are clustered by fund and domicile. The weights reflect the holding percentage of each security one quarter prior to the event. Shaded area represents 90% confidence intervals.

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