Fear and Loathing in Financial Markets: The Determinants of Cross-Asset and Cross-Border Volatilty Spillovers

Joel Thomas

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Supervisor: Pr. Thomas Renault

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Abstract

This paper analyses the determinants of the evolution of volatility spillovers between asset classes and global stock markets. In Part 1, this paper quantifies volatility spillovers between the United States' stock, bond, commodity and foreign exchange markets. Employing a generalised vector autoregressive (VAR) framework using a rolling window, total, directional, pairwise and net volatility spillovers can be computed. The determinants of the evolution of these spillovers are investigated by employing measures of sentiment, uncertainty, liquidity, financial stress and the extensity of macroprudential regulation. Section 2 applies the same VAR methodology to the stock markets of the United States, United Kingdom, Japan, Germany, France, Australia and Mexico. Spillovers received by the partner countries in aggregate and specifically from the United States are explained by employing a panel data set of financial time series and two original indexes. The 'Corndog Index' quantifies the relative incidence of American topics in the sample countries' news and the 'Cooperation Index' measures the net impact of cooperative and uncooperative actions between the United States and the partner country. The results point to uncertainty, financial stress and economic crises are key contributors to heightened volatility spillovers between asset classes. The macroprudential attitude of policymakers is identified as limiting the connectedness of the asset classes. Investor 'fear', measured by the VIX, trade freedom and banking sector resilience is identified as being significant for cross-border spillovers.

JEL Classification Codes: C22, C23, E44, E60, F15, G01

Contents

1 Introduction

Portfolio theory suggests that investors should be able to reduce systematic portfolio risk by diversifying their investments (Markowitz, 1952) and may look to different asset classes or countries to do this (Solnik, 1974). However, particularly with the recent acceleration of financial globalisation, asset classes and global markets have become increasingly interconnected (Gagnon & Karolyi, 2006). Liberalisation of capital flows and growth in international investment has changed the relationship of global capital markets and they are increasingly observed to follow similar patterns in returns and volatility, particularly so during periods of crisis (Chen & Sun, 2024; Longin & Solnik, 1995).

The financial crisis of 2008 illustrated the ease at which financial crises can propagate in the global financial system. Beginning as the burst of a housing bubble, the crisis rapidly spread outside of America's equity markets to commodities, foreign exchange, and bonds within the United States and overseas (Chen & Sun, 2024). The growing interdependence of asset classes and national markets threatens the ability of investors to effectively hedge portfolio risks and creates a growing concern for policy makers' capacity to isolate international and sectoral volatility shocks to protect domestic financial stability. Therefore, understanding of the factors that ease or restrict the transmission mechanisms of spillovers has crucial implications both for the risk management of investors and for financial regulators whose objective is to protect the integrity of the financial system (Bank of England, 2022).

This paper contributes to discussion of these factors in several ways. As far as the author is aware, no paper presents a comparative analysis of factors that affect both cross-country and cross-asset volatility spillovers. This paper employs a diverse panel dataset including factors previously identified as determinants of spillover severity like uncertainty, fear, and financial condition, but supplements the literature by performing estimations for both relationships between asset classes and national stock markets. This paper is able to compare the effects of these variables that were previously examined one-dimensionally with respect to either cross-asset spillovers or cross-border spillovers by examining them in tandem.

Previous spillover literature focuses on the effects of economic fundamentals like trade, real activity and fear, but little insight is offered for policy makers. This paper extends the analysis, using more comprehensive measures of economic uncertainty, liquidity and sentiment while also constructing original variables to give greater resolution to the causes of volatility spillovers and contagion. In both the cross-asset and cross-border parts of this paper, a macroprudential policy variable is constructed from the International Monetary Fund's iMAPP database, capturing the attitudes of policy makers and the effect on spillovers. This allows identification not just of the effect of immutable factors like financial stress on the ease of spillover transmission but also factors modifiable by regulators, like the activation or deactivation of macroprudential instruments. In the second part of this paper, two additional original variables are constructed using Global Database of Events, Language and Tone's Global Knowledge Graph and Events database. The 'Corndog Index' reflects the intensity of American themes in the news sources of the partner countries, while the 'Cooperation Index' measures the diplomatic cooperation of the partner countries with the United States.

Overall, the VIX ('fear gauge'), economic policy uncertainty and a declining financial condition were identified as having positive and significant effects on the transmission of spillovers across asset classes and within an economy. Macroprudential attitude, which is the relative tightening of macroprudential instruments to loosenings, provides a limiting force on these spillovers, with a net tightening of the instruments reducing cross-asset spillovers by up to 3%. For volatility spillovers overseas, trade freedom, the VIX and the z-score were positively associated with the spillovers, while economic policy uncertainty and macroprudential attitude had no noticeable effect. When assessing spillovers with the United States in particular, the Corndog Index did not offer any rewarding results, but the Cooperation Index was positive and significant when estimated in a panel fixed effects model, suggesting volatility spillovers between the United States and the partner countries increase when diplomatic cooperation between the countries increase.

This paper is structured as follows. The first section presents the literature review, discussing the varying methodological and theoretical approaches to measuring spillovers and the factors influencing their transmission. The following section presents the methodology of Diebold and Yilmaz (2012; 2013; 2014) which is employed in this paper. Part 1 then discusses the determinants of the volatility spillovers between the stock, bond, foreign exchange and commodity markets in the United States, building on existing insight into the domestic factors that influence asset market volatility spillovers. Part 2 describes the construction of the Corndog and Cooperation indexes and discusses the factors that influence the propensity of a sample of countries to receive spillovers from the other countries in the sample and the factors that influence the pairwise connectedness of these six countries with the United States. The final section concludes.

2 Literature Review

One of the seminal papers in the study of spillovers is that of Diebold and Yilmaz (2009). The authors were the first to devise a measure of connectedness defined by the forecast error variance decomposition of a vector autoregressive (VAR) model. In their 2009 paper, Diebold and Yilmaz examine the connectedness of 19 global equity markets between January 1992 and November 2007 with respect to their returns and volatility. Their paper is a prelude to the generalised VAR methodology employed in this paper and relies on the Cholesky decomposition for the forecast error variance. The variance decompositions allow them to split the forecast error variances of each variable into parts attributable to the various system shocks, effectively quantifying what fraction of the H step-ahead error variance in forecasting variable i is due to shocks to variable j and what fraction of the H step-ahead error variance in forecasting j is due to shocks to i. The shocks are orthogonal and allow the shocks' contribution to be examined in isolation. Diebold and Yilmaz's definition of spillovers using the familiar notion of variance decompositions facilitates the identification of the highly debated concept of 'contagion' both during periods of crisis and calm. They show return spillovers to be relatively insensitive to crises but with a slowly increasing trend, while volatility spillovers display no trend but exhibit clear bursts associated with crises events or financial instability, motivating the investigation presented in this paper that, among other things, assesses spillover sensitivity to crisis events.

The methodology employed in this paper is one of the more recent innovations of Diebold and Yilmaz. Their 2012 paper addresses several of the limitations of their 2009 framework. Notably, the orthogonalisation using the Cholesky decomposition for the variance decompositions is sensitive to variable ordering. With N variables, the number of possible orderings of the variables is N! making a full sensitivity analysis of the spillover measures to variable orderings intractable for large samples. Secondly, their examination of spillovers in their 2009 paper discussed only spillovers to (from) a variable from (to) all other variables and does not quantify directional spillovers: spillovers to and from particular markets bilaterally. Directional spillovers form the backbone of the spillover discussion presented in this paper and allow a comparative analysis of the determinants of spillovers between assets or countries in isolation.

Diebold and Yilmaz's (2012) paper presents, other than methodological advancements of their framework, an event study discussing evolutions in the directional, net and total volatility spillovers between stocks, bonds, foreign exchange and commodities. They identify several cycles in the spillovers, all associated with turbulent events in the United States' economy at the time, such as the burst of the tech bubble in 2000, unexpected federal funds rate changes in 2006, and the global financial crisis in 2008. The authors present their renewed framework and provide qualitative intuition for shocks to the connectedness of the asset classes, but do not attempt to explain the variation in their connectedness index quantitatively with time series of explanatory variables for the United States, which is a gap in the literature filled by this paper.

Cross-asset spillovers are well documented in general. Nazlioglu et al (2013) examines the transmission of volatility shocks between oil and agricultural commodity markets. Using a sample from 1986 to 2011, they show that interdependency between energy and agricultural markets has increased, and significant risk transmissions are observed after the 2006 commodity crisis.

Aboura and Chevallier (2014), like this paper, examine aggregate indices representing equities, bonds, stocks and foreign exchange allowing more general interpretations than Nazlioglu et al. (2013). They posit that the volatility is caused by the market reacting to new information and the comovements of volatility across asset classes and one class leading the volatility of other classes are most of the time due to the processing and transmission of economic news, notably during periods of crisis. Their results suggest a tangible effect of news coverage on cross-border spillovers, motivating the construction of the Corndog Index used in Part 2 of this paper.

Antonakakis, André and Gupta (2016) formalise some of the drawbacks of Diebold and Yilmaz (DY) framework. Diebold and Yilmaz's reluctance to engage with the spillover series econometrically on a cause-and-effect basis means they do not provide a robust relationship between the economic mechanisms behind the spillovers and the actual spillovers. They do not attempt to estimate a structural relationship by untangling variation in economic fundamentals, uncertainty or macroprudential policy and the effect on the index. Their analysis falls short of a full theoretical explanation of the spillovers but does shed light on the evolution over time.

Su (2020) addresses their omission to some extent. Su decomposes volatility spillovers estimated for the G7 stock markets between July 2004 and December 2015 using the DY framework into short, medium and long-term components with frequency decompositions. They attempt to identify the contributing factors of dynamic volatility spillovers, employing global time series for exchange rates, industrial production, policy uncertainty, oil prices, real activity, VIX and consumer confidence indicators. They find that industrial production, real activity, VIX and consumer confidence all have significant effects on the short-term and long-term net volatility spillovers for most countries. They show that economic policy uncertainty has greater explanatory power for the medium and long-term spillovers, and oil price has a significant effect only for the long-term spillovers only for connectedness between Germany and Canada. Overall, Su demonstrates the tractability of the DY framework econometrically by employing both country-specific and global series that are assumed to be uniform across all G7 countries as explanatory variables, but Su's selection of entity-specific explanatory factors is limited and overlooks factors relating to a country's financial condition, liquidity, macroprudential environment, export dependence and diplomatic cooperation.

Jiang, Konstantinidi and Skiadopolous (2012) identify United States and European news announcements as one such factor. They distinguish between scheduled and unscheduled news releases and the effect on implied volatility spillovers. They find scheduled news releases resolve uncertainty and cause a decrease in volatility, while unscheduled releases create uncertainty and cause increased volatility. The authors show that uncertainty is a determinant of volatility spillovers and illustrate the importance of controlling for sentimental variables in explaining the evolution of spillovers.

The DY framework has been used extensively for spillover effects beyond stock market returns and volatility. Liu et al. (2023) explore cross-category and cross-country economic policy uncertainty spillovers, finding cross-category spillovers within China greater than that of the United States, suggesting greater policy coordination. They also find that cross-border spillovers from the United States to China are greater than from China to the United States implying that the United States' hegemony status extends beyond its currency, military and economy (Gopinath et al., 2020) and into economic uncertainty as well.

Morano & Beltratti's (2008) paper has an overlap in sample with this paper. They propose a theoretical framework to assess the linkages across moments and markets between 1973 and 2004 for the United States, United Kingdom, Germany and Japan. They realise growing integration of the four markets, with increasing comovements in returns, prices and volatilities, particularly for the United States and Europe. Their findings build on the research of Longin and Solnik (1995) who identify a similar trend of increasing equity market comovements using a broader sample of the United Kingdom, United States, France, Germany and Japan with historical data from January 1959 to December 1996. They also identify asymmetry in the correlation coefficients: the correlation of returns tends to increase for negative returns. The results suggest that negative spillovers are more readily transmitted than positive spillovers. This findings preclude some of the results of this paper which finds spillovers to increase during times of crisis, poorer financial conditions and increased investor 'panic' as measured by the VIX.

Alternatives to the Diebold and Yilmaz framework for spillover methodologies exist. The Diebold and Yilmaz framework relies on the forecast error variance decomposition to estimate the contribution of each variable's innovations to the future variance of other variables, giving the proportion of variance that can be attributed to the shocks. Billio et al. (2012) propose several other measures of connectedness based on principal components analysis (PCA) and Granger-causality networks, applying them to the monthly returns of hedge funds, banks, dealers and insurance companies. PCA yields a diagonal matrix of eigenvalues and the first few usually explain most of the variation. They focus on a subset of the total eigenvalues which capture a larger portion of the total volatility when the returns move together. In other words, when a smaller number of the principal components explains more of the volatility in the system, the monthly returns are more interconnected. This gives a measure of total connectedness, but to determine directionality of the causal relationships. Billio et al. (2012) propose a granger causality framework. Unlike the Diebold and Yilmaz framework that is built on the variance of future innovations in the series, the Granger causality methodology determines directional connectedness by the ability of past values of variable i to predict future values of variable j beyond what information is contained in past values of variable j. Hence, while the Diebold and Yilmaz framework is forward looking, the granger causality method is backwards looking.

The causes of, and barriers to, spillovers are nuanced. Chen and Zhang (1997) find strong evidence that cross-border correlation in stock returns is related to international trade. Focusing on the correlations between emerging and developed markets in four global regions, they find the sum of total imports and exports with a region as a percentage of GDP to explain up to 40% of the variation in the correlation coefficients of the regions' stock market returns. This kind of 'gravity model' for stock market connectedness is continued in Bracker et al.'s (1999) paper who found imports and physical distance between the countries to be significant, but exports and volatility in the exchange rate to not be significant, in explaining interdependence defined by measures of feedback between stock markets (Pretorius, 2002).

Overall, the literature suggests that cross-border and cross-asset interdependence is robust to the methodology chosen and is observed to be increasing. The DY methodology lays the groundwork for much of the literature on connectedness and allows the generation of time series for spillovers against which explanatory factors can be assessed. The most salient factors identified for volatility spillovers throughout the literature include the presence of crises and investor fear (Longin & Solnik, 1995) and economic uncertainty (Jiang et al., 2012) for cross-asset spillovers and additionally bilateral trade (Chen & Zhang, 1997; Bracker et al., 1999) for cross-border spillovers.

3 The Connectedness Index

The methodology employed to calculate the connectedness between the asset classes and countries' equity markets is adopted from Diebold and Yilmaz (2012). Their approach builds upon previous work in Diebold and Yilmaz (2009). Diebold and Yilmaz (2009) focused on total spillovers in a simple VAR model framework with potentially order dependent results required by the Cholesky orthogonalisation (Diebold & Yilmaz, 2012). In their 2012 methodology however, Diebold and Yilmaz extend their existing framework by employing a generalised VAR framework eliminating the sensitivity of the results to the ordering of the variables. In this paper, the same methodological approach is applied to calculate spillovers for both Part 1 and Part 2: cross-asset spillovers and cross-border spillovers

The model follows the standard specifications of a generalised VAR estimation, $x_t = \Sigma_{i=1}^{p} \phi_i x_{t-i} + \epsilon_t$ where ϵ is a vector of independently and identically distributed errors $\epsilon \sim (0, \Sigma)$. The representation of the VAR in moving average form is $x_t = \Sigma_{i=0}^{\infty} A_i \epsilon_{t-i}$ with the $N \times N$ coefficient matrices A_i obeying $A_i = \phi A_{t-1} + \phi_2 A_{t-2} + ... + \phi_p A_{i-p}$ where A_0 takes the value of an $N \times N$ identity matrix and $A_i = 0$ for values of i less than 0. It is the moving average coefficients, ϕ_i, that allow the calculation of the spillovers. Diebold and Yilmaz (2012) use the variance decompositions to parse the forecast error variances of each variable into parts that are attributable to shocks to each of the series employed, be that volatility for asset prices in the United States or volatility of country-specific equity indexes.

The innovations are required to be orthogonal for identification of the relationships between variables through the variance decomposition in a simple VAR (Sims, 1980). Traditionally, and in their 2009 construction of a spillover index, the reliance has been on methods based on Cholesky factorisation for orthogonality. Standard VAR models are sensitive to the ordering because placement of x_i before x_j with $i \neq j$ in the model implies x_i can have a contemporaneous effect on x_j but x_j cannot contemporaneously affect x_i. Hence, variables are ordered by endogeneity. Diebold and Yilmaz (2013) note that it is often found that the total connectedness index is robust to variable ordering, but the directional connectedness is not.

The framework proposed by Diebold and Yilmaz (2012) circumvents the ordering dilemma by exploiting the generalised VAR framework from Koop, Pesaran and Potter (1996). The generalised VAR model allows correlation (non-orthogonal) shocks but accounts for this using the historical observed distribution of the errors. The essential benefit of this for this paper is that the forecast-error variance decompositions are invariant to the ordering of the variables in the VAR. But, as the shocks are not orthogonal, the sum of the contributions to the variance of the forecast error are not equal to one. Hence, the contributions are normalised across the row sum of elements to distinguish varying contributions to the forecast error of a given variable caused by shocks to another variable or itself (Diebold & Yilmaz, 2013).

Own variance shares will be the contribution to the error variances in forecasting x_i H-steps ahead caused by shocks to x_i. Cross variance shares - spillovers or connectedness (used interchangeably) - are the fractions of the H-step ahead error variances in forecasting x_i that are due to shocks to x_j where $j \neq i$. The generalised VAR H-step ahead forecast error variance decompositions are denoted with $\theta^g_{ij}(H)$ for $H = 1, 2, 3....$ This gives $\theta^g_{ij} = \frac{\sigma^{-1}_{jj}\Sigma^{H-1}_{h=0}(e'_i A_h \Sigma e_j)^2}{\Sigma^{H-1}_{h=0}(e'_i A_h \Sigma A'_h e_i)}$ where Σ is the variance matrix of the error vector ϵ for the estimated VAR model, σ_{jj} is the standard deviation of the error term for the jth equation. e_i is the selection vector that has 1 as the ith element and zeros otherwise. The row sum of the variance decomposition will not be equal to one: $\Sigma^N_{j=1}\theta^g_{ij}(H) \neq 1$ so each entry of the variance decomposition matrix in the calculation of the spillovers is normalised by the row sum: $\tilde{\theta}^g_{ij}(H) = \frac{\theta^g_{ij}(H)}{\Sigma^N_{j=1}\theta^g_{ij}(H)}$. Hence, $\Sigma^N_{j=1}\tilde{\theta}^g_{ij}(H) = 1$ and $\Sigma^N_{i,j=1}\tilde{\theta}^g_{ij}(H) = N$ where N is the number of variables under investigation. For Part 1, $N = 4$ with i the volatilities $i = \{Stocks, Bonds, Commodities, ForeignExchange\}$ and for Part 2, $N = 7$ where i is the volatilities of the national stock indexes for $i = \{UnitedStates, UnitedKingdom, Australia, France, Germany, Japan, Mexico\}$.

The total spillovers or total connectedness can now be constructed. The volatility contributions allow the calculations of $S^g = \frac{\Sigma^N_{i,j=1,i\neq j}\tilde{\theta}^g_{ij}(H)}{\Sigma^N_{i,j=1}\tilde{\theta}^g_{ij}}(H) \cdot 100 = \frac{\Sigma^N_{i,j=1,i\neq j}\tilde{\theta}^g_{ij}(H)}{N} \cdot 100$. The total connectedness or total spillover index is therefore defined by the contribution of spillovers of volatility shocks across variables i to the total forecast error variance in percentage terms. The total spillover index is then corrected to restrict the index between 0 and 1 using the method introduced by Chatziantoniou and Gaubauer (2021). Showing through Monte Carlo simulations that the own variance shares are by construction always larger or equal to all cross-variance shares (Gaubauer, 2021), the total connectedness index ranges between $\left[0, \frac{N-1}{N}\right]$ where N is the number of variables. To arrive at an index between 0 and 1, the total connectedness index is multiplied by $\frac{N}{N-1}$ (Gaubauer, 2021; da Costa Filho, 2023). Hence, the total connectedness index becomes $TCI = \frac{\Sigma^N_{i,j=1,i\neq j}\tilde{\theta}^g_{ij}(H)}{\Sigma^N_{i,j=1}\tilde{\theta}^g_{ij}}(H) \cdot 100 \cdot \frac{m}{m-1}$.

The usefulness of the DY framework is that the range of information contained in the variance decompositions can be aggregated into a single measure which clearly displays the degree of spillovers between the variables. Essentially, the connectedness index measures the cross-asset spillovers by aggregating the share of cross-asset error variance in the variance decompositions relative to the total error variance of the assets (McMillan & Speight, 2010).

The innovation of the generalised VAR and the invariance to the variable ordering is sufficient to deduce information about the direction of the volatility spillovers. The direction can be identified using the normalised elements of the generalised variance decomposition matrix: $S^g_{i\cdot} = \frac{\Sigma^N_{j=1,i\neq j}\tilde{\theta}^g_{ij}(H)}{\Sigma^N_{i,j=1}\tilde{\theta}^g_{ij}(H)} \cdot 100 = \frac{\Sigma^N_{j=1,i\neq j}\tilde{\theta}^g_{ij}(H)}{N} \cdot 100$. This gives the spillovers *received* by i from all other markets. In the following, spillovers TO a variable are defined by this equation. Hence, the spillover index TO stocks can be interpreted as spillovers *received* by stocks from all other asset classes. Equivalently, *from* all other asset classes *to* stocks.

The converse is spillovers contributed (FROM) asset class or country i to other asset classes or countries. Spillovers FROM is therefore defined as $S^g_{\cdot i} = \frac{\Sigma^N_{j=1,i\neq j}\tilde{\theta}^g_{ji}(H)}{\Sigma^N_{i,j=1}\tilde{\theta}^g_{ji}(H)} \cdot 100 = \frac{\Sigma^N_{j=1,i\neq j}\tilde{\theta}^g_{ji}(H)}{N} \cdot 100$.

Straightforwardly, the net spillovers are spillovers FROM less spillovers TO: $S^g_i(H) = S^g_{\cdot i}(H) - S^g_{i\cdot}(H)$. Hence, a positive net value would indicate that more spillovers have originated from i than have been received by i. For example, in Part 2 it is realised that Japan is a net sender of spillovers rather than a net receiver indicated by the positive net value in the connectedness table.

It is also possible to calculate the pairwise directional spillovers. Much of the investigation in Part 2 relies on the ability to calculate the extensity of the United States' connectedness to other countries. The net pairwise spillovers are calculated as $S^g_{ij}(H) = (\frac{\tilde{\theta}^g_{ji}(H)}{\Sigma^N_{i,k=1}\tilde{\theta}^g_{ik}(H)} - \frac{\tilde{\theta}^g_{ji}(H)}{\Sigma^N_{j,k=1}\tilde{\theta}^g_{jk}(H)}) \cdot 100 = (\frac{\tilde{\theta}^g_{ji}(H) - \tilde{\theta}^g_{ij}(H)}{N}) \cdot 100$. Intuitively, the net pairwise dynamic connectedness (NPDC) between i and j is the spillovers transmitted from i to j less the spillovers transmitted from j to i. Practically, it is the same as net spillovers but considering only two variables in isolation.

The pairwise connectedness index, which is an innovation of Gaubauer (2021) is used extensively in Part 2 of this paper. The pairwise connectedness index measures the bi-directional connectedness between two variables providing a dynamic indication of the propensity of i to transmit volatility shocks to j and also for j to transmit shocks to i. It is calculated as $PCI^g_{ij} = 2(\frac{\tilde{\theta}^g_{ji}(H) + \tilde{\theta}^g_{ij}(H)}{\tilde{\theta}^g_{ii}(H) + \tilde{\theta}^g_{ij}(H) + \tilde{\theta}^g_{jj}(H) + \tilde{\theta}^g_{ji}(H)}) \cdot 100$. Essentially, the pairwise connectedness index is the ratio of contributions of innovations from i on the forecast error variance decomposition of j (from i to j) and the contribution of innovations from j on the forecast error variance decomposition of i (from j to i) to the total spillovers from each of the two variables to itself and the other asset. The numerator quantifies the spillovers from one to the other while the denominator quantifies the total spillovers of the two variables i and j to each other and themselves. This gives a measure of bilateral connectedness between 0 and 1 which is multiplied by 100 for a percentage.

4 Part 1: Cross-Asset Volatility Spillovers

4.1 Asset Sample

In Part 1, the variables i to be employed in the spillover framework of Diebold and Yilmaz (2012) above are the volatilities in prices of the stock, bond, foreign exchange and commodity markets of the United States, still following in the spirit of Diebold and Yilmaz's (2012) paper.

Part 1 is dedicated to investigating the causes of, and limits to, the connectedness of different elements of the United States' financial system. The four asset classes chosen are broad enough to capture contagion across the entire financial system. In other words, we can capture the translation of shocks to one asset class to other asset classes that may be employed in hedging strategies. Therefore, we can identify compromises, or the *ease* of compromise, to the financial system as a whole through the calculation of the connectedness indexes for these four variables.

Daily prices for the S&P 500, the Bloomberg commodity index (Dow Jones-AIG commodity Index prior to July 2014), the Intercontinental Exchange's US Dollar Futures Index and daily yield data for the 10-year Treasury bill are retrieved from Yahoo! Finance (2024) to represent stocks, commodities, the foreign exchange and bonds respectively. With the high and low daily price and yield data, the daily volatility is calculated as $\tilde{\sigma}_{it}^2 = \frac{1}{4ln2}\left[lnP_{it}^{High} - lnP_{it}^{low}\right]^2$ (Brooks, 2019). $\frac{1}{4ln2}$ is a scaling factor identified by Parkinson (1980) that translates the observed deviation in high and low prices to the volatility using the extreme value method for random walk processes. i is asset $i = \{Stocks, Bonds, FOREX, Commodities\}$ and t is day. P_{it}^{High} is the highest recorded price for asset i on day t, and P_{it}^{Low} is the lowest recorded price for asset i on day t.

Where there are missing observations, the last observation is carried forward. The data stretches from the 15th November 2001 to 8th February 2024, yielding more than twenty years of observations and more than 5000 observations for each asset. The plots of the volatility over time are shown below in Figure 1.1.

Table 1.1: Volatility summary statistics

Statistic	N	Mean	St. Dev.	Min	Max	Skewness	Kurtosis
Stocks	5,595	0.0000932118	0.0002297090	0.0000007650	0.0042884150	9.424156	124.7396
Commodities	5,595	0.0000729464	0.0002013035	0.0000009157	0.0130527900	48.83092	3096.35
Bonds	5,595	0.0003434607	0.0010415630	0.0000030365	0.0311868000	19.15337	480.4949
Foreign Exchange	5,595	0.0000250337	0.0000311137	0.0000006689	0.0004862218	5.07484	47.21969

There are a number of notable observations to be made. The bond market is the most volatile on average, followed by the equity market. Both are sensitive to business cycles (King & Watson, 1996). One surprising observation is that the maximum volatility observed is the commodities market. The greatest variation between the high and low price was on November 2nd 2015, where the price of the index reached a high of 104.78, vastly exceeding the average high price at the

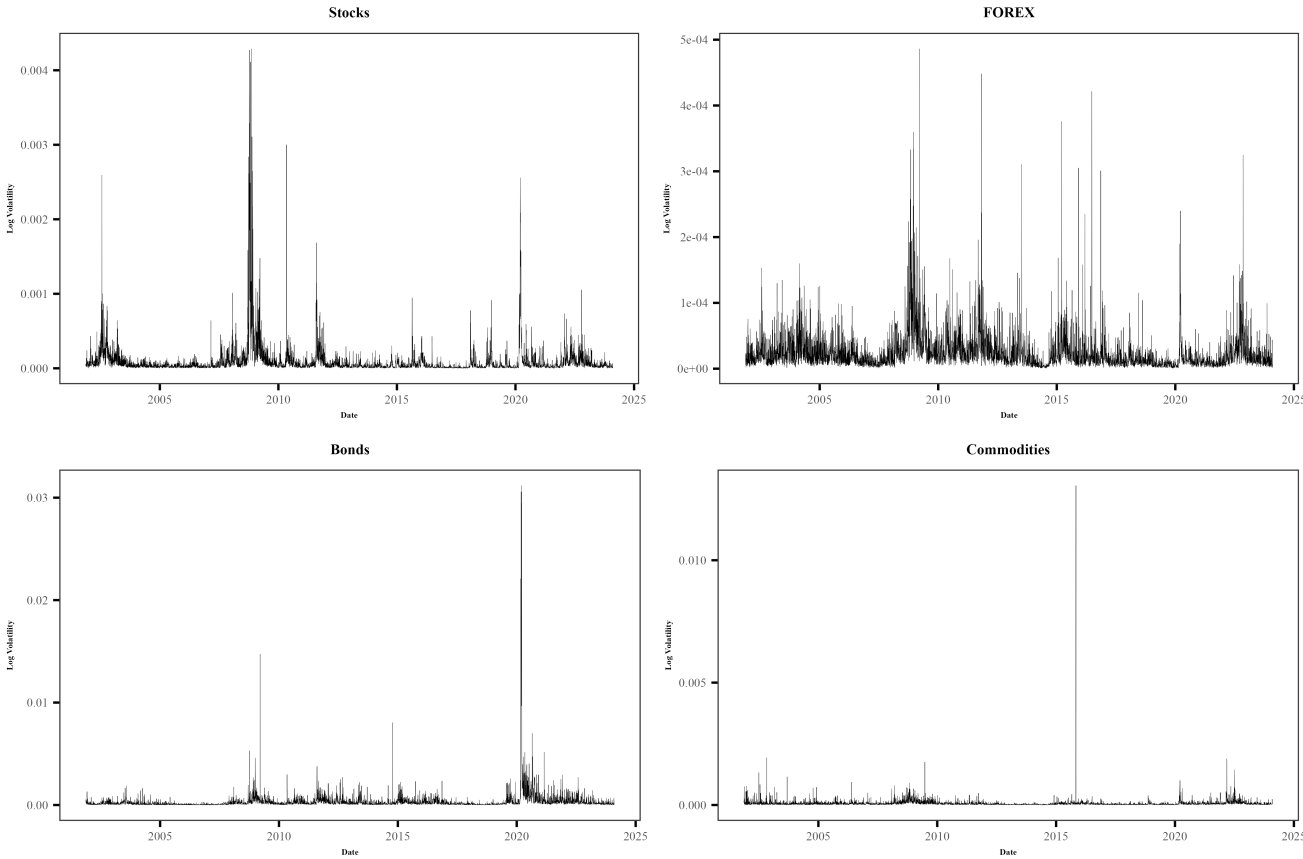

Figure 1.1: Volatility of the Stock, Foreign Exchange, Bond and Commodity Markets

time which was the mid to low 80s. This coincides with TransCanada Corp's request to suspend the review of the Keystone XL pipeline (Davis, 2015), although the high price is still anomalously large and makes the volatility of commodities extremely positively skewed. The global financial crisis and pandemic are visible in all series with sharp increases in volatility, particularly for stocks in 2008 and bonds in 2020. The foreign exchange market is the most stable over time with its volatility being the lowest on average at 0.000025 and the standard deviation in the volatility being 0.00003.

All series are positively skewed and leptokurtic. Naturally, the Jarque-Bera test's null hypothesis of a normal distribution is rejected in all cases. Tests of unit roots indicate stationarity in the series, with the null hypotheses of unit roots in the augmented Dickey-Fuller (ADF) tests with no constant or trend, a constant, and a constant trend being rejected in all cases. Furthermore, the Elliot, Rothenberg and Stock (ERS) is also performed. The ERS test is a modified version of the ADF test (Stata, 2024) and reveals the same with the p-values being 0 for all series.

Table 1.2: Augmented Dickey-Fuller Test Results on Volatility

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
GSPC_vol	−20.8295	0.0000	−22.9791	0.0000	−23.0657	0.0000
BCOM_vol	−40.9662	0.0000	−47.4485	0.0000	−47.4936	0.0000
TNX_vol	−23.5931	0.0000	−25.2594	0.0000	−25.5449	0.0000
USDX_vol	−23.7184	0.0000	−34.2310	0.0000	−34.7361	0.0000

Examination of the bivariate correlation matrix reveals that the volatility of the stock market is the most highly correlated to the other variables. The highest Pearson's correlation coefficient is stocks with the foreign exchange market where the coefficient is 0.33. The least correlated asset with stocks is commodities with a correlation coefficient of 0.15. The lowest bivariate correlation overall is of bonds with commodities, the coefficient being only 0.07. The foreign exchange market's volatility is relatively highly correlated with that of bonds, but the volatility of commodities is weakly correlated with all other asset classes. Judging by the correlation coefficients alone we may expect spillovers of the stock market with the other markets to be the highest, and commodities to be the least connected overall.

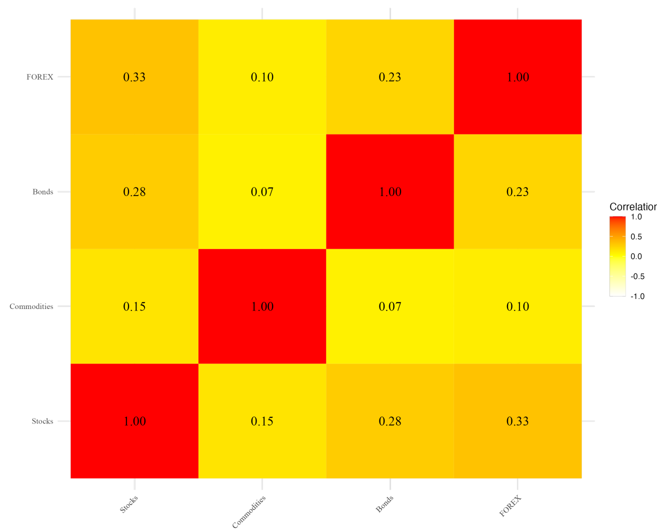

Figure 1.2: Bivariate Correlation Matrix

Generalised variance decompositions require normality, so to correct for the extreme values, high skewness and leptokurtosis, and to induce a more normal distribution, the log transformation is applied to all series before estimation of the VAR model, as in Diebold and Yilmaz (2012). The logged volatility for asset i on day t that is used in the estimation of the VAR models is then calculated as $ln\tilde{\sigma}^2_{it}$.

Following the log transformation, the ADF tests and the ERS tests continue to indicate stationarity with at least 95% confidence (Table A.2). Only the logged volatility of the foreign exchange market results in a failure to reject the null hypothesis of the Jarque-Bera test with a p-value of 0.38, but the kurtosis and skewness are both much more moderated indicating suitability for VAR estimation. Full summary statistics, the ADF tests and the bivariate correlation matrix of the logged series are available in Appendix A.

4.2 Connectedness

4.2.1 Model Specification

The stationarity of the logged volatility in the prices of the four asset classes was confirmed by both the ERS test and the ADF test and are suitable for the generalised VAR framework. However, selection of the order of the lag length, forecast horizon and rolling window size remains.

The lag length of the variables is selected using the Bayesian information criterion (BIC) which is minimised with a lag length of 9. The forecast horizon, H, is simply chosen in line with existing literature at 10-days (see Diebold and Yilmaz (2012) and Su (2020)). Given that the model is to be estimated with data spanning more than two decades, it is unlikely that constant parameter values will apply across the entire sample. The financial market has experienced significant development over the previous twenty years, including the growth of hedge funds, greater national and international market connectivity, increasing information capabilities and developments in technology. For this reason, the generalised VAR is estimated with a 200-day rolling window, also like in Diebold and Yilmaz (2012) and Su (2020). This does not restrict the VAR parameters to the same values across the twenty-year sample and will allow for changes in parameters reflecting changes or trends in the evolution of financial services, as well as allowing for cyclicality.

Following the methodology in the previous section, the following average spillovers result.

Table 1.3: Connectedness

	Stocks	Commodities	Bonds	FOREX	FROM
Stocks	77.88	6.15	8.58	7.39	22.12
Commodities	8.34	79.32	5.93	6.41	20.68
Bonds	7.56	5.80	74.74	11.91	25.26
FOREX	6.38	5.58	12.18	75.87	24.13
TO	22.27	17.53	26.68	25.71	92.20
Inc.Own	100.16	96.85	101.42	101.57	cTCI/TCI
NET	-0.16	3.15	-1.42	-1.57	30.73/23.05

The rows indicate the volatility spillovers coming from the variable in the first column, while the columns indicate the spillovers to the asset in the first row. In other words, the ijth entry is the spillover to asset i coming from innovations to asset j. For example, the average spillovers over the sample period coming from innovations in commodities to stocks is 8.34, and the average spillovers coming from stocks to bonds is 8.58. The FROM column is the row sum and the TO row is the column sum giving the average spillovers from and to, which are displayed dynamically in Figures 1.4 and 1.5. The total spillovers TO, including itself, for each column need not sum to 100, but the total across all columns sum to 400.

All off-diagonal entries are the $N^2 - N$ pieces of the forecast-error variance decompositions, measuring the pairwise directional connectedness. To better explain the methodology, Diebold and Yilmaz relate the spillovers to bilateral trade. The entries on the connectedness table are like the spillover version of bilateral imports and exports for the N countries where the off-diagonal entries show the trade balance. In the same spirit, the TO and FROM columns show the total imports and total exports and the NET row shows the equivalent of net exports. The total connectedness in the bottom right corner shows the system-wide connectedness, equivalent to the total imports (equal to the total exports) per each entity, so divided by N.

The forecast error variance for any of the four variables can be attributed to innovations to any of the four variables, including itself. Innovations to the volatility stocks contributes to the forecast error variance of the volatility of stocks, just as innovations to commodities contributes to the forecast error variance of the volatility of commodities. There is naturally asymmetry in the magnitude of the TO including own and FROM. The TO including own can sum to more than 100 for each asset but will not sum to more than 400 in total. This is because an asset with high spillovers can contribute both to its own forecast error variance and others and may take contribute 'more than its fair share' of overall forecast error variance (more than $\frac{1}{N}$ of $N \cdot 100$). The spillovers in the FROM column details only the spillovers to the other assets, not including the contribution of the spillovers coming FROM an asset to itself. In theory, the FROM column could sum to 400 if each asset contributes only to other assets and no forecast error variance can be attributed to itself. Overall, the TO including own shows how innovations of all assets contribute to the forecast error variance of the asset, but the spillovers FROM only details the effects innovations outside of the asset's own innovations.

Hence, the total spillover index is the sum of the TO or FROM columns (which are themselves equal because what is to all the assets in the sample must come from the assets in the sample) divided by 4. Correcting for the number of variables as in Chatziantoniou and Gaubauer (2021) by multiplying by $\frac{4}{3}$ gives 30.73 as the average corrected total connectedness.

Unsurprisingly, spillovers from commodities are the lowest of all the asset classes. It was noted above how the volatility of commodities was the least correlated with the volatility of the other assets. Due to the international nature of the commodity index, it is to be expected that the volatility of commodities has the lowest spillovers to the volatility of more United States-centric assets like the stocks included in the S&P 500 or the treasury bill. The greatest receiver of commodity spillovers is the stock market suggesting the markets are the most interrelated. Foreign exchange volatility and bonds are also highly interrelated with significant connectedness across the sample which was again suggested by the correlation coefficients. The greatest receiver of foreign exchange volatility spillovers are bonds, and the greatest receiver of bond volatility spillovers is foreign exchange. This makes economic sense given how closely related both the bond market and foreign exchange market is to changes in interest rates, and indeed the purchase of treasury bonds from abroad requires also the purchase of US dollars.

Commodities like gold are traditionally a valuable hedge for investments in the stock market (Baur & Lucey, 2009) and this perhaps explains why the spillovers from stocks is lowest for commodities at 6.15. Commodities are also resilient against spillovers from the bond market and foreign exchange market, which again could be explained by how decentralised the commodity market is. The overall greatest contributor to other assets' 10-step ahead forecast error variance is the bond market. Explanations of this are offered in the results section, but volatility in the bond market tends to be reflective of financial conditions in general. With treasury bills the traditional safe asset, it is likely that increased volatility in treasury bills has an effect on confidence and uncertainty in the financial market which is captured by the 25.26 average spillover FROM.

The corrected (30.73) and uncorrected (23.05) total connectedness index is displayed in the bottom right-hand corner. For the remainder of this paper, total connectedness refers to the corrected total connectedness.

Given that the data on the assets is obtained with a daily frequency, the total, to, from, net and total pairwise connectedness index is also daily. Through the use of the 200-day rolling window, the connectedness indexes range from 20th August 2002 to 8th February 2024. In order to use the indexes as dependent variables in the following regression models, the frequency must be matched with the frequency of the explanatory variables, the majority of which are obtained monthly. Hence, the indexes are converted into a monthly frequency by averaging the daily spillovers over the month.

While the table above shows the static average spillovers, the dynamic spillovers can be plotted for total, TO and FROM connectedness as well as the net pairwise connectedness and the overall pairwise connectedness.

4.2.2 Total Connectedness

Figure 1.3 shows the evolution of the total connectedness index over time. The values on the vertical axis indicate the average percentage of forecast error variance in the assets' volatility that is caused by innovations to the other assets.

The index appears to exhibit some cyclicality with peaks and troughs bi-yearly, coinciding with the American election cycle where presidential and midterm elections are held every four years but are staggered by two.

The index begins at the 18% mark increasing steeply to 31% by 2003 reflecting the heightened uncertainty resulting from the war in Iraq (Altig, 2019). The index sharply decreases towards the initial value in 2005 before rising and falling again. There is an increase between 2006 and 2007, perhaps reflecting the surprise in unemployment recorded in December 2007 and the resulting stimulus debate (Stone & Cox, 2008). The total connectedness increases to around 35% in 2008 with the collapse of Lehman brothers and the onset of the global financial crisis but falls towards the mean value of 23% in 2010. The spillover increase to 36% in the early 2010s is in line with the eurozone crisis and the midterm elections which ended Democratic control of Congress (Taylor, 2010). The increase to 42% shortly after is in line with the debt ceiling debate accelerated by the Republican control of Congress which led to the passage of the Budget Control Act of 2011 (The New York Times, 2011). They increase again after 2015 and the election of Trump in 2016 which fuelled trade policy tensions between the United States and China, undergoing three small cycles of higher mean before collapsing to the low 20s in late 2018. The sharpest and most significant increase is the COVID-19 crisis in 2020 which sees the connectedness index increase to almost 63% in April 2020, but by the end of the year the spillovers have mostly reverted to their initial value. The reaction to the Russian invasion of Ukraine in February of 2022 is slight, but

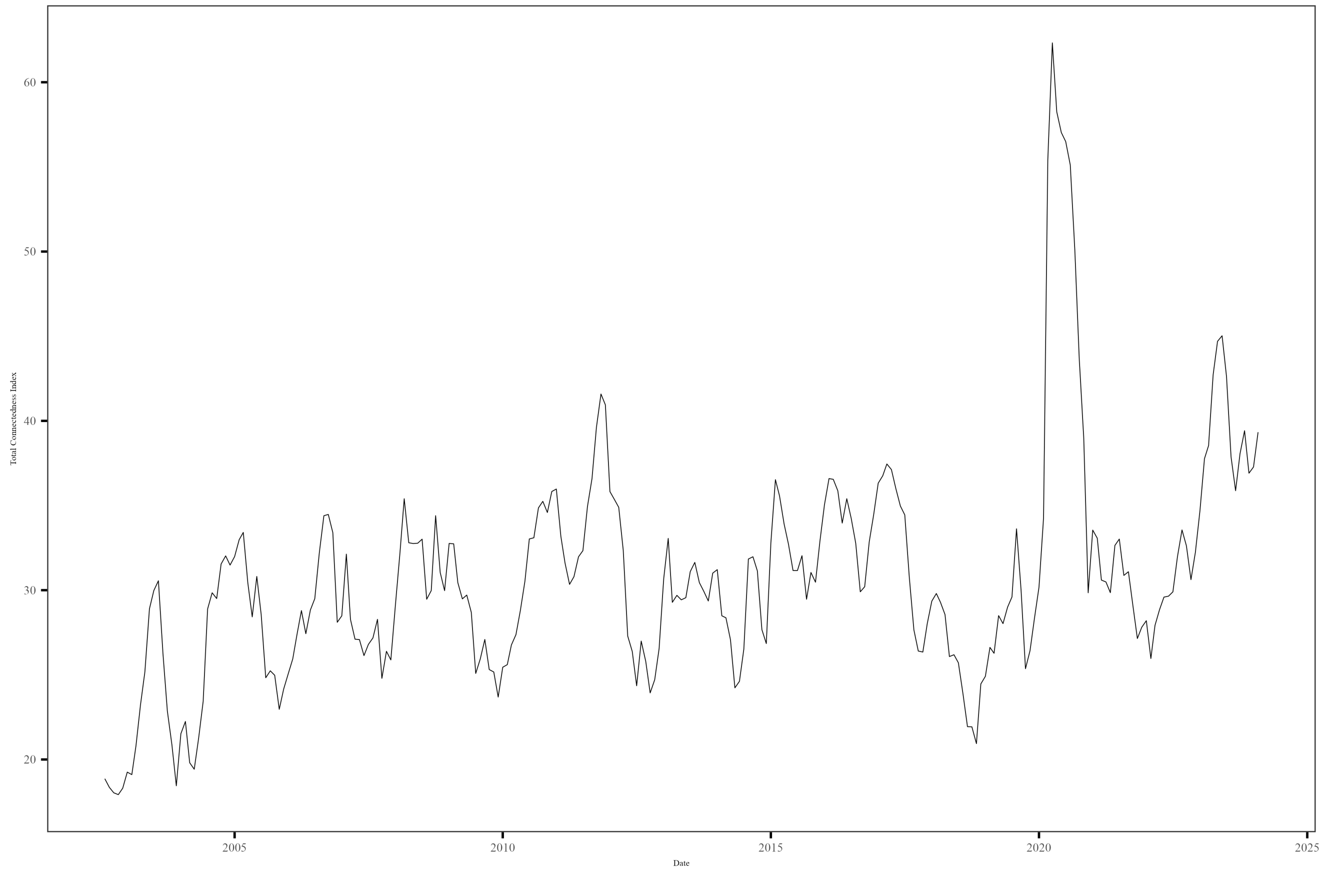

Figure 1.3: Total Connectedness Index

there is a significant increase in April of 2023 to 45% which is correlated with the brent crude oil surge after OPEC announced an unexpected reduction in the output of oil exports (The Guardian, 2023). Overall, much of the variation in the total connectedness index appears to be correlated with significant developments in the economic and political sphere concerning uncertainty, fear and financial condition which inspires the choice of explanatory variables.

4.2.3 Spillovers Received

Commodities are the most resilient to innovations in the volatility of the other assets. The spillovers from others to commodities vary between 4% and 34%, reaching a maximum in early 2011. Despite the large shock to the volatility of commodities in November 2015 which was observable in the raw volatility time series, it appears little of this shock was transmitted to the other assets.

Spillovers received by stocks is generally higher than commodities, but they are less volatile. Furthermore, the effect of the pandemic is clearly visible in the spillovers received by the stock market. True also for foreign exchange and bonds, there is a clear spike at the beginning of 2020, suggesting that the contributions to the total connectedness index during this period were these three assets. Both foreign exchange and bonds spillovers received are fairly stable. Foreign exchange peaks at a value lower than that of stocks in 2020, and bonds peak lower still at 57% in September of 2020. So far, commodities appear to be the most resistant to spillovers from the other asset classes and did not absorb much of the volatility from the others during the pandemic.

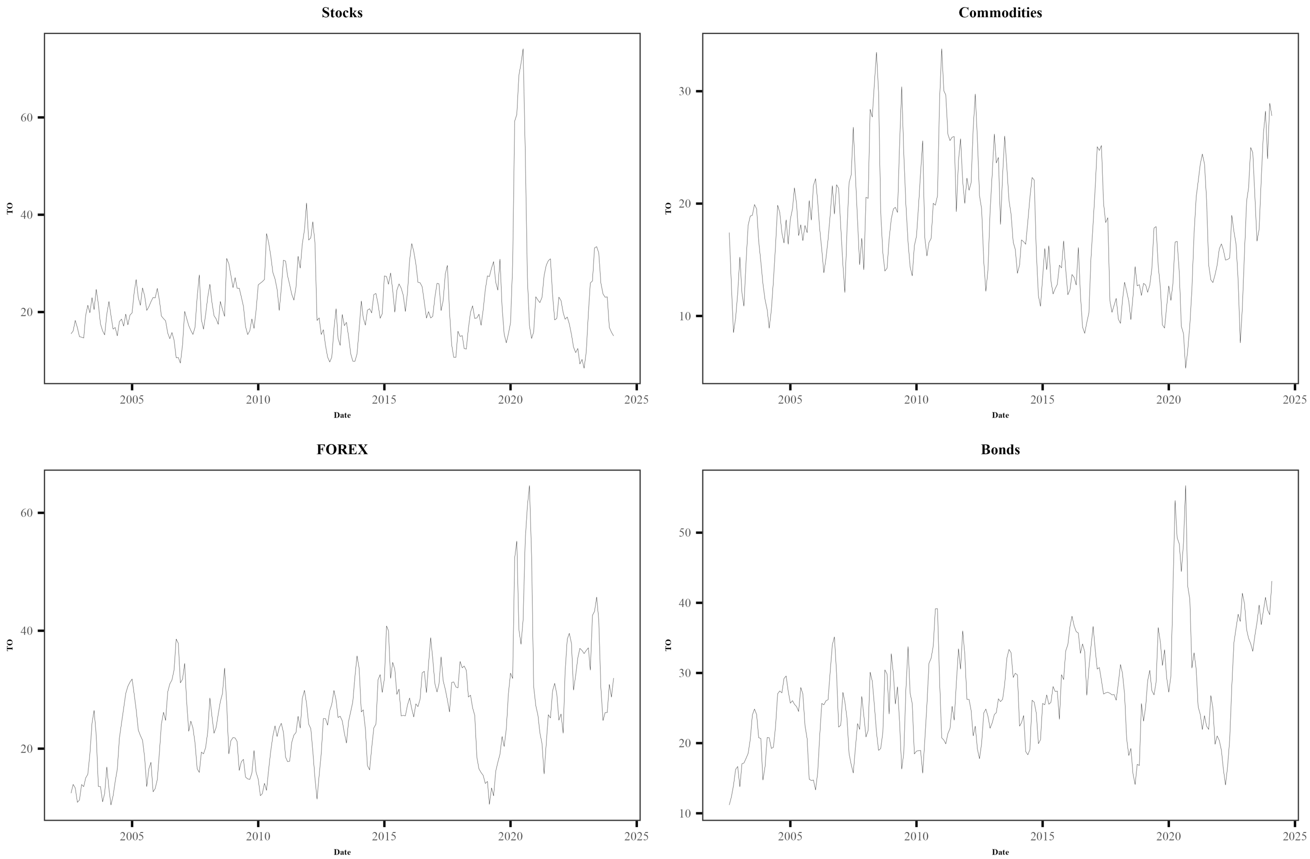

Figure 1.4: Spillovers TO

4.2.4 Spillovers Contributed

Considering now spillovers from each asset to others, we observe a different pattern. It is necessary that overall spillovers to (not including own) are equal to spillovers from in aggregate, so the interest lies in the changing contribution of each asset class to the overall spillovers. We see a similar pattern with the means being more or less the same. However, a spike in the spillovers for the pandemic is now visible for all four asset classes. Not only is the spike observable for stocks, foreign exchange and bonds, but unlike spillovers received, commodities now reflect the same pattern. This means that commodities were resilient to the volatility of the other markets, but the other markets were not resilient to the changing volatility of commodities. The commodity market does not spike during the global financial crisis and volatility spillovers peak at 51% in April of 2020, reflecting heightened uncertainty surrounding construction, manufacturing, travel and fuel use with the pandemic (Ahmed & Sarkodie, 2021). The spillovers from stocks are less than the spillovers received by stocks during the COVID crisis, which is coherent with the cause of the crisis not originating in the stock market. However, the same can be said for the financial crisis. The height of spillovers from stocks during the financial crisis was 27% in August of 2008, but the height over spillovers received by stocks during the crisis reached a maximum of 31% in

October of 2008.

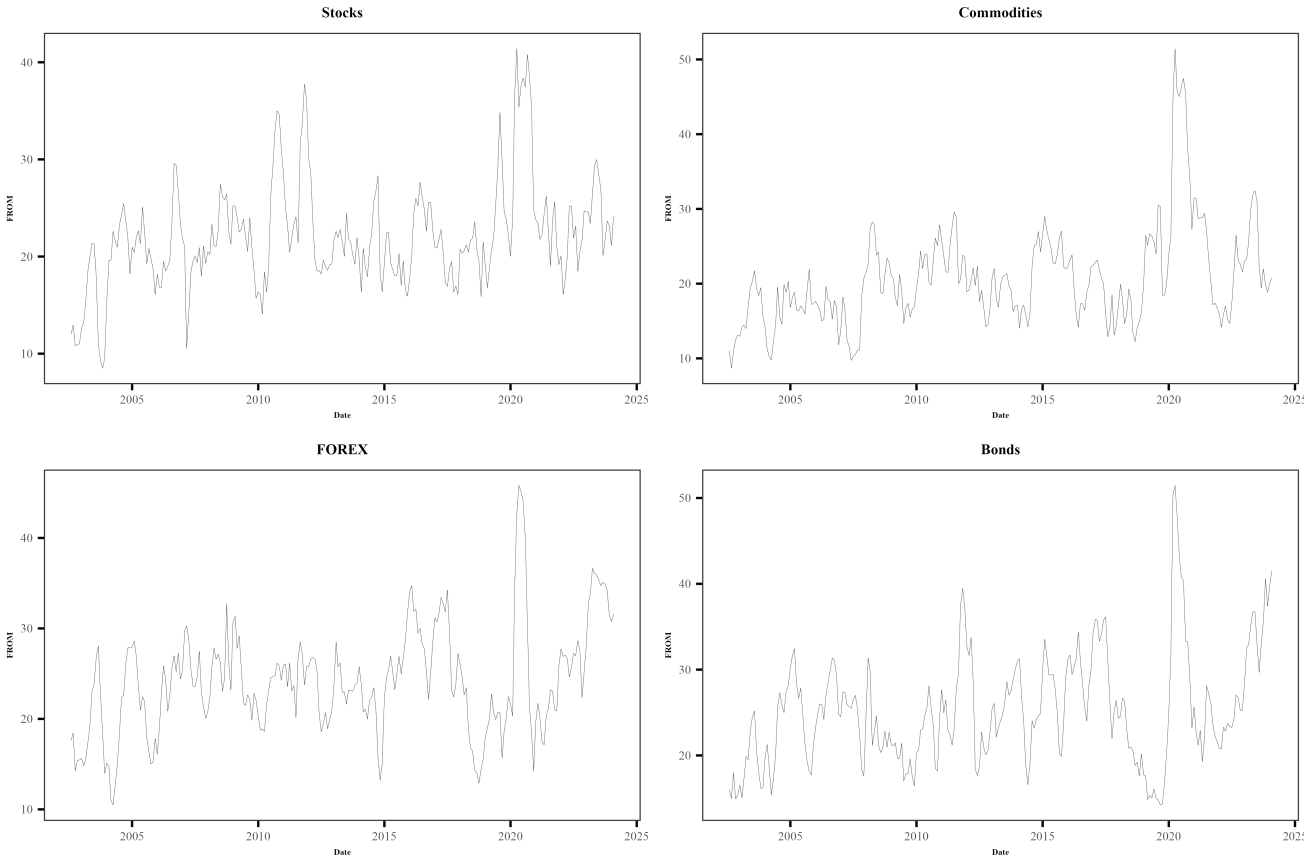

Figure 1.5: Spillovers FROM

4.2.5 Net Pairwise Connectedness

The net pairwise dynamic connectedness plots in Figure 1.6 indicate for which periods each asset in a pair was a net contributor of spillovers with another asset. A plot for $i - j$ is calculated as spillovers from i to j less spillovers from j to i. In this way, the positive value for Commodities-FOREX in 2020 means the spillovers from commodities to foreign exchange is greater than the spillovers from foreign exchange to commodities. This allows us to discern periods where some assets' spillovers contributed to other assets exceeds the spillovers received from the other assets, but does not allow us to identify the magnitude of connectedness per se. The net spillovers can be 0 if both assets are contributing large but equal spillovers to each other. Hence, it can illustrate net spillovers on the pairwise level and the source of some of the volatility observed in the time series but does not necessarily make it easily interpretable which assets are most closely connected bilaterally.

There are some reflections to be made from the net pairwise dynamic spillovers. The net spillovers for stocks and bonds are consistently negative, suggesting that the volatility spillovers of the bond market to the stock market exceeds the reverse. There are two exceptions: one in late

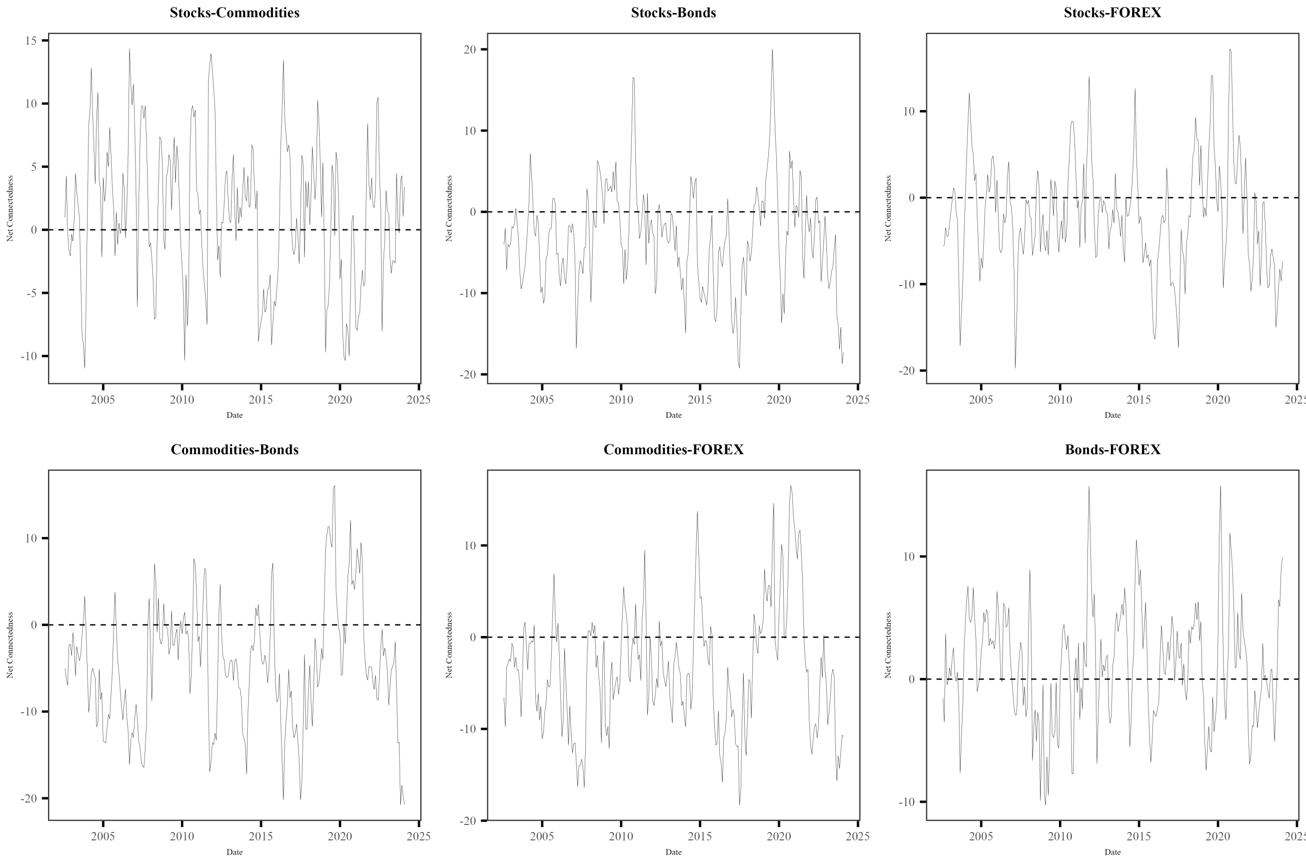

Figure 1.6: Net Dynamic Pairwise Connectedness

2010 and one in late 2019. The first may be attributed to concerns over the European sovereign debt crisis which led to equity market volatility globally (García & Rambaud, 2023). The second could potentially be attributed to the US-China trade war. In August 2019, President Trump announced that the US would be imposing 10% tariffs on Chinese imports (Li, 2019) which caused uncertainty regarding Chinese retaliation and the effect this would have on the stock market (Altig, 2019).

For commodities, there is a clear positive net spillover effect to bonds, foreign exchange and indeed stocks during the pandemic. As mentioned above, this is likely due to volatility caused by uncertainty surrounding manufacturing, construction and transport, all of which affect the prices of commodities. These spikes with the pandemic are abnormal given that commodities tend to be on the net receiving end of spillovers with bonds and foreign exchange in general. Both foreign exchange and bonds are affected by interest rate changes and changes or volatility in currency value has an effect on import costs and the export revenue of commodities which explains the direction of the net spillovers.

The net spillover relationship of stocks with commodities is the most stable, where the dominant spillover is switching multiple times a year for most of the sample. The relationship of stocks with bonds is also negative in general and there are noticeable negative spikes around the time of the stimulus debate in 2007, the government shutdown in 2013 and again with the pandemic in 2020. Towards the end of the sample, the stocks again become a net receiver of spillovers from bonds, reflecting the high levels of inflation and economic policy uncertainty surrounding changes in federal funds rate which causes volatility in the yield of bonds.

4.2.6 Net Connectedness

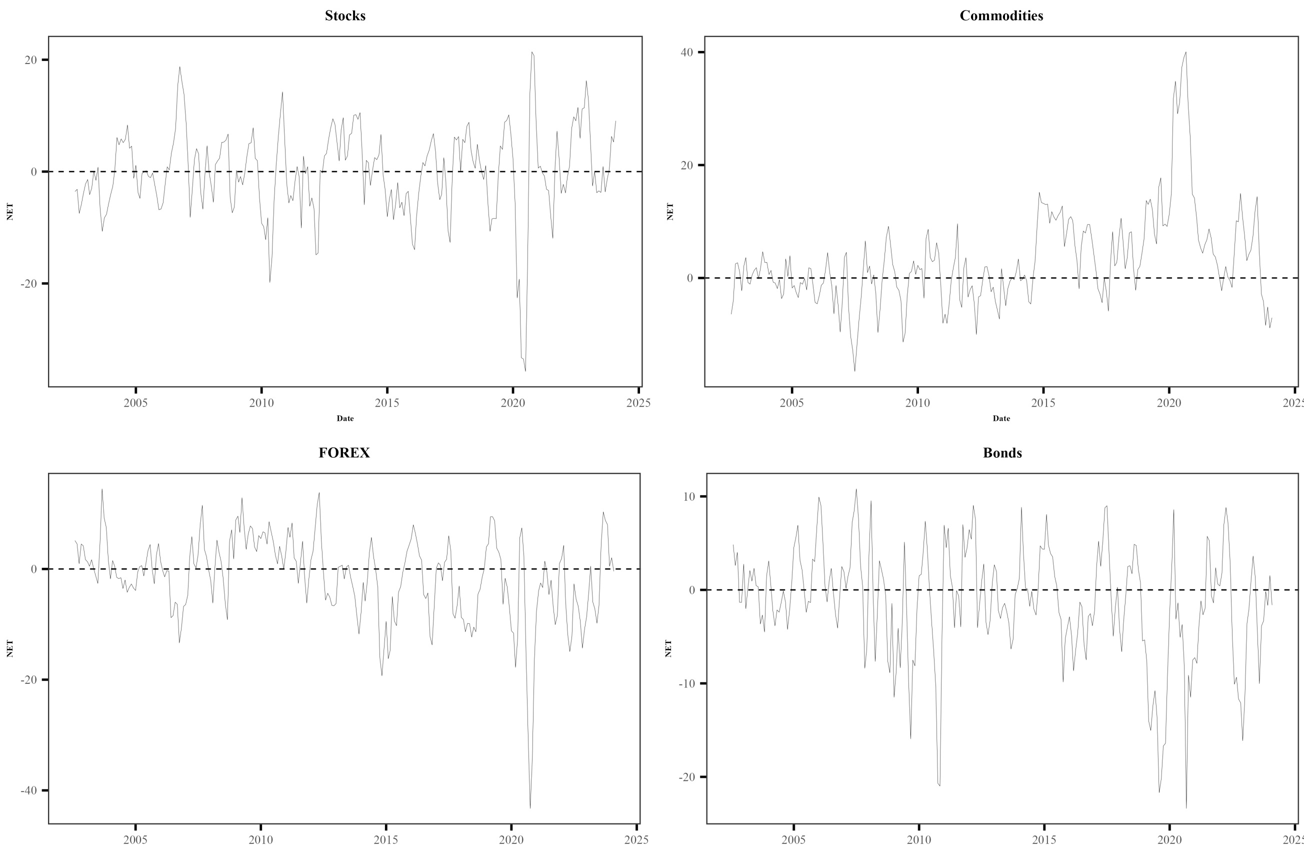

Figure 1.7: Net Connectedness

Figure 1.7 shows net spillovers ‘exported’. It is simply spillovers FROM less spillovers TO. Hence, the large positive value for net commodity spillovers in 2020 indicates that commodities are net contributors of spillovers to others. A majority of the sharp decrease then increase in net spillovers for the stock market is charged by the relationship with the bond market. The net spillover for stocks bottoms out at -36% in July of 2020, but peaks at 21% in October of 2020. In Figure 1.6, before the pandemic stocks initially contributed more spillovers to the bond market than the other way around. Throughout the 2010s, interest rates and inflation had remained low and stable, so it makes sense that much of the volatility in the bond market pre-pandemic was the result of spillovers from other asset classes rather than originating with bonds from interest rate changes. Indeed, the net spillovers for bonds hovers around the zero line with few large variations above or below. However, in early 2020 with the use of unconventional monetary policy by the federal reserve, such as quantitative easing (Liesman, 2020), uncertainty surrounding the yields of bonds grew and bonds became a net contributor of spillovers for a very short while.

The net spillovers of both the foreign exchange market and commodity market follow a similar process until 2020. Both remain close to the 0 line with little variation but displaying shocks with the pandemic. Foreign exchange is on the receiving end of the shocks and commodities contributing. A large proportion of the negative net spillover shock to the foreign exchange market's volatility can be attributed to the positive spillover shock of the commodities market. Uncertainty surrounding commodity will have impacted imports and exports and had a spillover effect on foreign exchange volatility.

4.2.7 Pairwise Connectedness

While the net connectedness shows the dominating spillover effect of pairs of assets, the pairwise connectedness index can be more informative in assessment of the actual connectedness between assets. The net connectedness can be 0 both when each variable is exerting equally powerful spillovers on the other and when each variable is exerting no spillovers on the other. Hence, for the purpose of this investigation, the models in the following section use pairwise connectedness as the dependent variable.

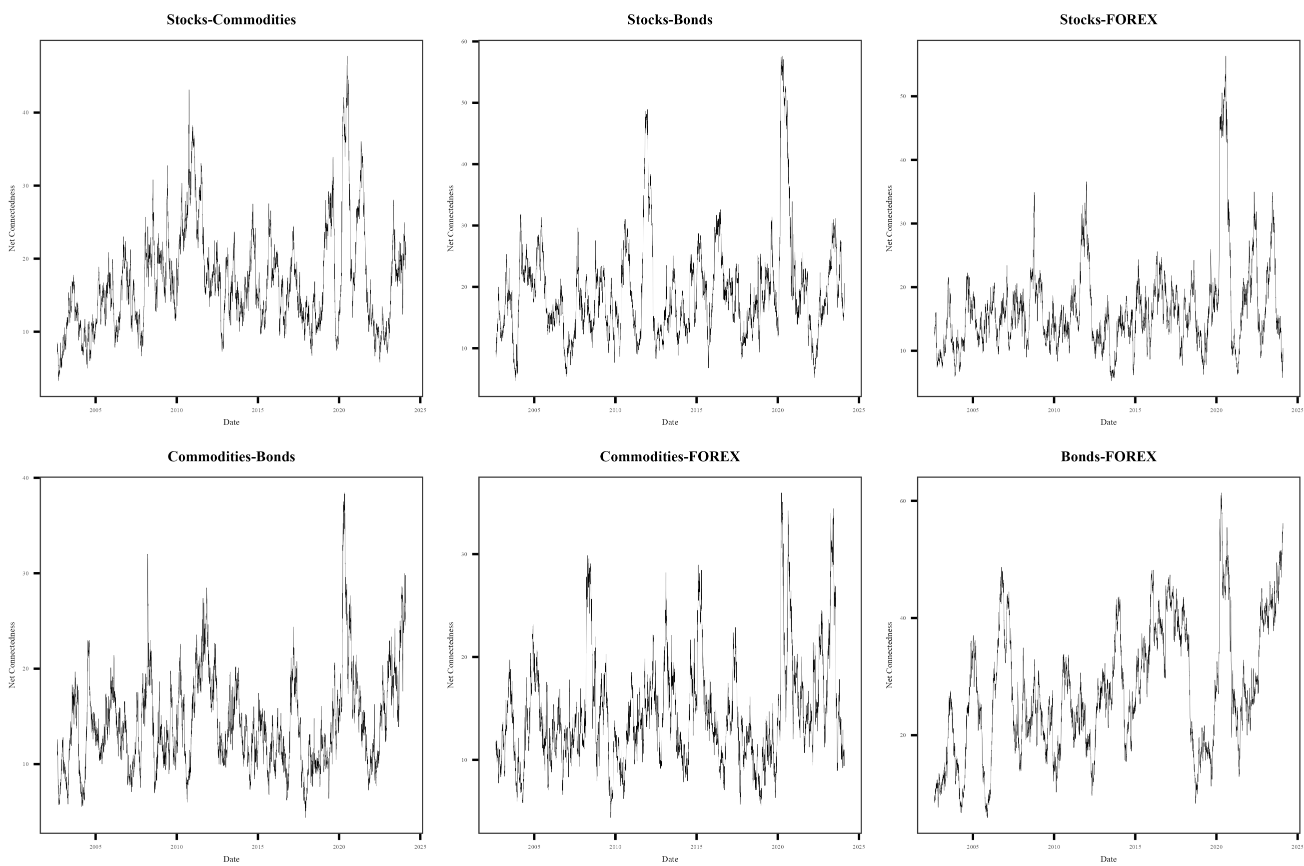

Figure 1.8: Pairwise Connected Index

All asset classes had strong connectedness with each other during the pandemic, but there are some spikes unique to certain pairs. For example, in December 2010 the Stocks-Commodities connectedness peaked at 36%. One explanation is that the start of the Arab spring generated volatility and uncertainty in the commodity market (Altig, 2019) which could have contributed spillovers to the other asset classes. A significant ongoing event in American equity markets at that time concerns the automobile crisis but this was more of a continuous event beginning with the financial crisis and does not explain the sharp jump.

Another significant jump is the 47% connectedness observed between the Stock and Bond market in November 2011. This was the centre of the Eurozone debt crisis. It was in this month that Greece held a referendum on the European Union's rescue plan which increased the visibility of the turmoil in the European economy which could have had a residual effect on the American stock and bond market. As mentioned above, it was also the time of debt ceiling debate which caused volatility in bond yields that spread to the stock market. Other than the shock of the pandemic, the commodities market has noticeable shocks in connectedness with other assets towards the beginning of the sample likely caused by the Iraq war in 2003.

4.3 Explanatory Variables

4.3.1 Variable Description

Sentiment and Uncertainty

The first explanatory variables for the cross-asset connectedness are designed to capture sentiment in the United States. A number of series are employed, a majority of which are sourced from Baker et al. (2024). Their measure of economic policy uncertainty (EPU) is constructed using three sources: newspaper coverage, nearing expiry federal tax code provisions (dollar weighted) and disagreement among individual forecaster's opinions about future values of inflation, federal expenditure, and state and local expenditures. Economic policy is associated with greater stock price volatility and reduced investment and employment in policy-sensitive areas like defence, finance and infrastructure construction (Baker et al., 2016). The more specific measures of monetary policy uncertainty, fiscal policy uncertainty, tax uncertainty, government spending uncertainty, national security uncertainty, entitlement program uncertainty regulatory uncertainty, financial regulation uncertainty, trade policy uncertainty, sovereign debt concern, debt ceiling concern and government shutdown concern are also sourced from Baker et al. (2024). All of the their series are available monthly beginning in January 1985 and all but government shutdown uncertainty and debt ceiling uncertainty are available up February 2024. The government shutdown and debt ceiling uncertainty series terminate in April 2023.

To reflect 'fear' in the market, the Chicago Board Options Exchange's volatility index (VIX) is used. The daily series is available from the Federal Reserve of St. Louis' economic database (FRED) beginning January 2nd 1990 and is averaged for a monthly series. Also used is Baker et al.'s (2024) newspaper-based equity market volatility tracker that moves with the VIX and focuses on articles that are categorised as relating to business investment and sentiment. Their measure is available monthly from FRED and spans the period from January 1985 to February 2024. The University of Michigan's consumer sentiment index is also utilised. This is a monthly series available from November 1952 to February 2024.

Financial Conditions and Crisis Indicators

It is well documented in the literature that stock market volatility financial contagion increase in times of crisis (Diebold Yilmaz, 2009; Schwert, 1989; Jiang et al., 2012). It is therefore important to employ suitable measures of the financial environment through financial stress, recession and condition indicators. Two recession indicators are used. The first is the National Bureau of Economic Research's monthly binary recession indicator variable which has data stretching as far back as the 19th century. The continuous smoothed United States recession probability indicator from Chauvet (1998) is also used. Retrieved also from FRED, the data goes as far back as June 1967 and is also of monthly frequency. This variable is an estimate of the probability of recession based on a Markov switching model applied to employment, industrial production, real personal income, and real manufacturing and trade sales.

For financial stress, two related variables are used. The first is the St. Louis Federal Reserve's financial stress index, a weekly indicator constructed using 18 weekly data series including interest rates, yield spreads and other indicators. This variable is averaged over the month to match the frequency of the rest of the series. The index begins in December 1993 and is designed to be zero in mean with positive values indicating above average financial stress and negative values below average.

The second financial stress measure is developed by Püttmann (2018) is available with the uncertainty datasets. This indicator is constructed from the titles of articles in five American newspapers, filtered by their relation to financial markets, and identifies the sentiment of the title based on the net positive words. The raw index is then standardised to a mean of 100 for a monthly index covering 1889 to December 2016.

The spread between the 10-year constant maturity treasury bill and the 2-year constant maturity treasury bill is retrieved from FRED also. A 10-2 Spread approaching 0 indicates a flattening of the yield curve and a declining financial condition. Historically a flattening and inversion of the yield curve precedes a recession (Fonseca et al., 2023). Available daily from June 1976, the data is again averaged over the month for the monthly series employed in the following section.

The final indicator for the financial condition of the United States economy is the Chicago Federal Reserve's financial conditions index, a weekly series beginning august 1971 imported from the FRED database. The series is also averaged over the month to coincide with the frequency of the majority of the explanatory variables.

Monetary Indicators

Liquidity is important to control for when assessing the determinants of the effects of spillovers and pertains to the quantity of liquid assets in an economy (ECB, 2007). The broad money ratio of M2 money supply to reserves reflects the relative amount of cash circulating in the economy. The M2 money supply includes all cash and deposits that can be readily converted into cash while reserves are the total balances maintained by depository institutions including vault cash used to satisfy required reserves. Both series are from FRED, with M2 money supply being a weekly series averaged over the month. The broad money ratio is from November 1980 to January 2024. A higher M2-Reserves ratio indicates an economy that is more highly leveraged, with more lending and the creation of a larger amount of money relative to reserve holdings.

The spread between the 3-month treasury bill and the Federal Funds rate is also an indicator of liquidity and credit risk. This is a monthly series beginning July 1954. A negative spread, with the Federal Funds exceeding the 3-month treasury bill yield suggests a tightening of the liquidity conditions in an economy and increased risk aversion. A lower or increasingly negative spread will be caused by either an increase in the federal funds rate or a decrease in the yield of the 3-month treasury bill but it is the sign of the spread that makes the indicator. If the spread is negative, which is the case on average because the series has a mean of -0.256 (see Table A.3 in Appendix A), it suggests that banks are only willing to lend to each other at a rate above the rate of return for the risk-free government asset indicating lessened willingness to lend. If the spread is positive or increasingly, it suggests that the federal funds rate is less than the return for the risk-free asset indicating loosened liquidity conditions and a willingness to lend at a rate less than the return for the risk-free asset. Hence, the series is a positive indicator of liquidity: an increase indicates greater liquidity, lower credit risk, and willingness to lend.

Macroprudential Policy

One of the main focuses of this paper is the influence of macroprudential policy on volatility spillovers. The extent to which governments can prevent contagion and limit spillovers indicates greater resilience to crises and financial stability. To measure the extensity of macroeconomic policy in the economy, an original measure of 'macroprudential attitude' is constructed from the International Monetary Fund's Integrated Macroprudential Policy (iMAPP) database (Alam et al., 2019). The iMAPP database is available monthly from January 1990 to December 2021 and provides dummy indicators of tightenings and loosenings of macroprudential instruments for more than 130 countries. Among others, it includes changes of loan restrictions, loan-to-value ratios, leverage, foreign exchange positions, reserve requirements and risk mitigation measures. The attitude variable is constructed to reflect the attitude of financial policy regulators in the United States for a given month and is calculated as the number of number of macroprudential tightenings less the number of loosenings as a proportion of the total number of changes, the variable is limited between +1 and -1. A value of +1 means that all macroprudential changes in the US for that month were tightenings, while a value of -1 indicates that all changes in macroprudential policy were liberalising for financial institutions and reduced the level of regulation for the financial sector. The variable can take a 0 value if policy makers made the same number of macroprudential tightenings as loosenings. The iMAPP database cannot provide information on the total level of macroprudential policy, only the changes, but the number and direction of changes in policy captures the macroprudential regulatory environment at a given time.

World Oil Price

The final variable employed is the producer price index adjusted West Texas Intermediate (WTI) world oil price. The monthly series is available from FRED from January 1946. Oil prices are widely used to proxy for economic fundamentals and to explain correlated movements of stock prices (Bodart & Redding, 1999; Su, 2020) and makes the series relevant as a control variable for the models in the following section.

4.3.2 Bivariate Correlation

In total, 26 explanatory variables are used for the US covering the categories of sentiment and uncertainty, the financial condition, liquidity, the macroprudential environment, and economic fundamentals. Many of the variables within each category are different measures of similar concepts, exhibiting high levels of correlation and raising concerns of collinearity which was confirmed with high variance inflation factors in preliminary regressions on all variables. For example, the variance inflation factor on fiscal policy uncertainty when TCI is regressed on all variables is 598 and tax uncertainty is 331 indicating high collinearity. Fiscal policy uncertainty necessarily incorporates tax policy uncertainty, hence the Pearson's correlation coefficient of 0.99. There are also concerns of collinearity between other variables, such as those for financial stress, the recession indicators, and the liquidity indicators. For this reason, principal component analysis is used in Model 4 to extract principal components that are orthogonal to each other for three broad categories: uncertainty, financial stress and equity market volatility.

The first category is defined by financial stress. The Baker et al. financial stress variable, FRED financial stress variable, Chicago Fed's financial conditions indicator, 10-2 spread, binary recession indicator and continuous recession probability indicator all have high correlation. Hence, the first principal component which explains 68% of the variance is used in the PC-OLS model in Model 4 (see Figure A.3). The second principal component explains only 17% and so is neglected.

The same process is applied to the thirteen uncertainty variables. Visible in the bottom left of the bivariate correlation matrix, the correlation coefficients are as high as 0.99 for fiscal and tax, 0.9 for EPU and fiscal, and 0.79 for regulation and financial regulation. The first principal component is 48% of the explained variances and is also employed in Model 4 (see Figure A.4).

The final principal component is for the two related equity market volatility trackers: VIX and the EMV for business investment and sentiment. While the correlation coefficient is only 0.36, the construction of the EMV tracker indicates it moves with the VIX. For these variables, the first principal component is 56% of the explained variance and the second 44% so both are used in Model 4 (see Figure A.2).

There are concerns of spurious regressions with non-stationary explanatory variables. ADF tests on all variables are displayed in Appendix A. The non-stationary explanatory variables are consumer sentiment, the M2-reserves ratio, 10-2 spread and PPI adjusted Oil price which are all first differenced prior to estimation of the models. Most of the spillover series used as dependent variables lead to a rejection of the null hypothesis of the ADF test which reduces concern for spurious regression.

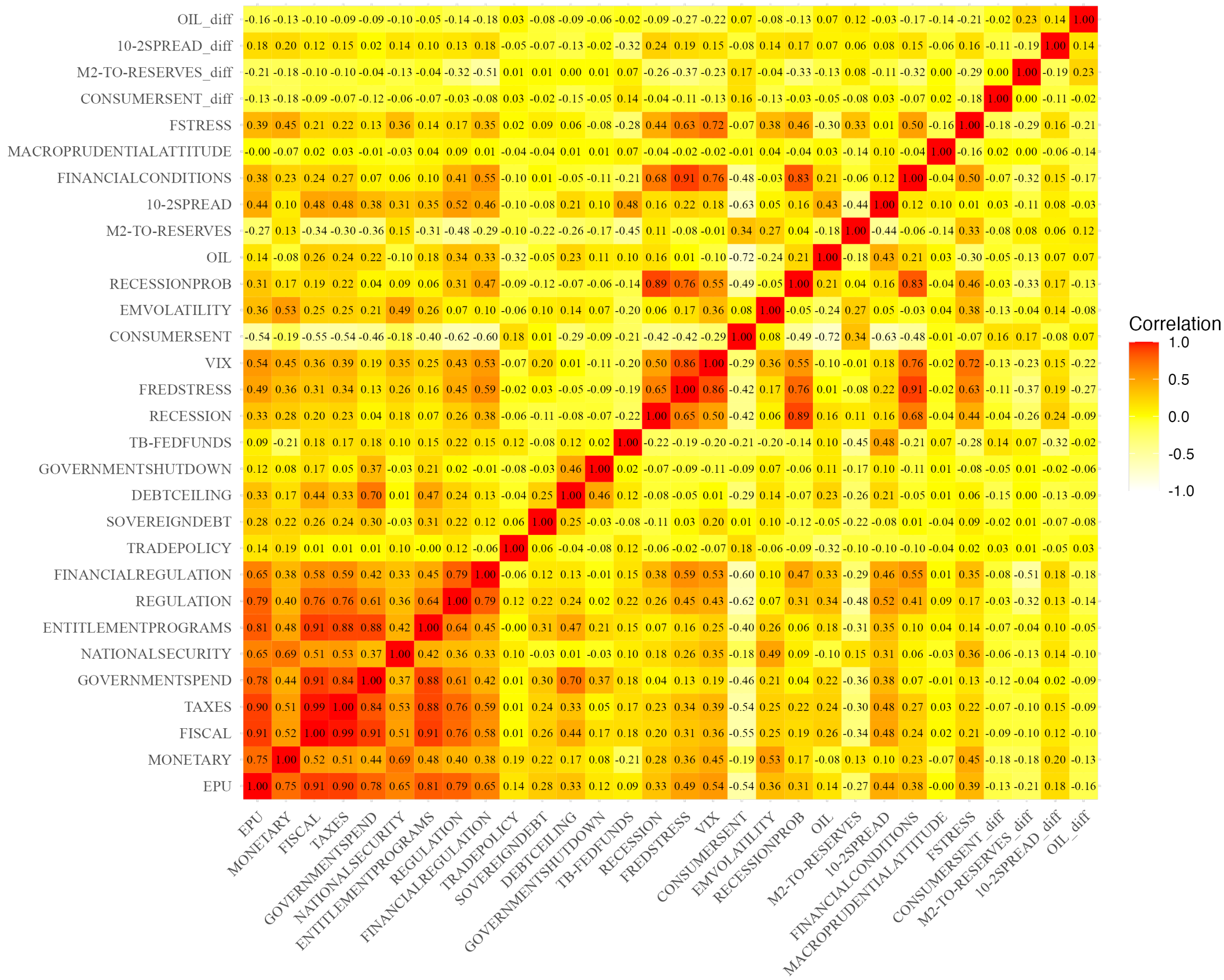

Figure 1.9: Bivariate Correlation

4.4 Modelling the Determinants of Cross-Asset Spillovers

4.4.1 Total Connectedness

The first 6 models involve using the corrected total connectedness as the dependent variable. These models therefore assess the extent to which the explanatory variable contribute to the overall spillovers between all four asset classes. The relationship between specific pairs of variables is focused on in the following section.

Model 1

The first model regresses the total connected index on the explanatory variables: economic policy uncertainty, financial regulation uncertainty, sovereign debt uncertainty, VIX, trade policy uncertainty, consumer sentiment, recession probability, first differenced oil price, the first differenced M2-Reserves ratio, macroprudential attitude and the financial conditions indicator.

Table 1.4: Total Connectedness as the Dependent Variable

	OLS		First Differenced OLS	PC-OLS	beta	glm: quasibinomial link = logit
	(1)	(2)	(3)	(4)	(5)	(6)
First Lag		0.877***	0.208***	0.888***	4.080***	4.077***
		(0.030)	(0.063)	(0.035)	(0.144)	(0.148)
EPU	0.081***	0.004	−0.008**		−0.0001	−0.0001
	(0.008)	(0.005)	(0.004)		(0.0002)	(0.0002)
FINANCIALREGULATION	−0.010**	0.002	0.003		0.0001	0.0001
	(0.004)	(0.002)	(0.002)		(0.0001)	(0.0001)
SOVEREIGNDEBT	0.005*	0.001	0.001		0.0001*	0.0001
	(0.003)	(0.001)	(0.001)		(0.0001)	(0.0001)
VIX	−0.311***	0.106***	0.171***		0.004**	0.004**
	(0.082)	(0.041)	(0.040)		(0.002)	(0.002)
TRADEPOLICY	−0.003*	0.001	0.001*		0.00005	0.00005
	(0.002)	(0.001)	(0.001)		(0.00003)	(0.00004)
PCuncertainty1				−0.168**		
				(0.076)		
PCfstress1				−0.004		
				(0.156)		
PCequity1				0.007		
				(0.248)		
PCequity2				−0.025		
				(0.337)		
CONSUMERSENT_diff	0.042	−0.031	−0.021	0.031	−0.002	−0.002
	(0.081)	(0.037)	(0.038)	(0.036)	(0.002)	(0.002)
RECESSIONPROB	0.038	0.052***	0.048***		0.003***	0.003***
	(0.028)	(0.013)	(0.013)		(0.001)	(0.001)
OIL_diff	−0.037	−0.074	−0.073	0.045	−0.004	−0.004
	(0.130)	(0.058)	(0.059)	(0.055)	(0.003)	(0.003)
‘M2-TO-RESERVES_diff‘	0.013					
	(0.056)					
‘TB-FEDFUNDS‘		−2.036***	−2.235***	−0.674	−0.094***	−0.095**
		(0.761)	(0.768)	(0.690)	(0.036)	(0.037)
MACROPRUDENTIALATTITUDE	−2.296*	−0.409	−0.027	2.546**	−0.009	−0.008
	(1.167)	(0.537)	(0.540)	(1.035)	(0.025)	(0.026)
FINANCIALCONDITIONS	2.312	−3.436***	−4.006***		−0.151***	−0.154***
	(1.509)	(0.759)	(0.755)		(0.036)	(0.037)
Constant	29.349***	−1.021	−5.032***	3.257***	−2.265***	−2.268***
	(1.778)	(1.369)	(0.930)	(1.029)	(0.065)	(0.066)
Observations	233	232	231	172	232	232
R^2	0.410	0.877	0.242	0.826	0.861	
Adjusted R^2	0.380	0.870	0.201	0.817		
Log Likelihood					545.502	
Residual Std. Error	5.151 (df = 221)	2.344 (df = 219)	2.372 (df = 218)	1.992 (df = 162)		
F Statistic	13.938*** (df = 11; 221)	130.348*** (df = 12; 219)	5.814*** (df = 12; 218)	85.739*** (df = 9; 162)		
Ljung-Box P-Value	2.2e-16	1.543e-06	0.09418	0.004477	1.896e-07	5.543e-08

Note: *p<0.1; **p<0.05; ***p<0.01

For most variables, the coefficient values are as expected. The positive and statistically significant coefficient on economic policy uncertainty suggests that heightened levels of uncertainty in the United States contribute to greater financial market volatility spillovers between the four asset classes, a result that has consensus with the literature (Chang et al., 2022). This relationship is consistent also for sovereign debt concerns. The coefficients on financial regulation uncertainty and the VIX indicator are more questionable. The VIX is commonly referred to as a 'fear' index. The negative and significant coefficient suggests that as fear in the equity market increases, total market connectedness decreases. This may indicate investors harbouring more conservative attitudes to investing which could lead to reduced leveraging positions and lower diversification if investors shift their portfolios towards safer assets such as treasury bills, reducing the interconnectedness of the market. Given that the data is monthly, it is difficult to discern the immediate effect of VIX on the total connectedness index. It may be the case that an increase in VIX immediately increases spillovers as investors shift their portfolios in response to the shock, but over the monthly aggregate the general connectedness decreases.

The M2-Reserves ratio is an indicator of liquidity in an economy, and the positive coefficient suggests that increased liquidity serves to increase financial market connectedness. In other words, greater cash in an economy is associated with a growth in total connectedness. The coefficient is not statistically significant, however.

The recession probability variable coefficient is positive but also not significant. This result is certainly to be expected. It is documented in the literature that financial contagion increases during crisis periods. Longin and Solnik (2001) for example found an asymmetric effect of market interconnectedness: correlation is higher in bear markets than bull markets. Indeed, despite the global financial crisis originating in the housing market it rapidly spread to other sectors of the economy, including equities, foreign exchange, commodities and bonds. The positive coefficient on the probability of recession suggests that during crisis periods, the connectedness of asset classes increases. This suggests that crises are a double-edged sword; not only do they involve a negative impact on the volatility of asset classes which are most relevant to the origination of the crisis (often equities), but the presence of a crisis increases the connectedness of asset classes which increases the overall severity of the recession for the financial system as a whole.

There is a concern of endogeneity with the recession probability variable and reverse causality, but performing the Granger causality test of the total connectedness index on the probability of recession does not yield a statistically significant test result (p-value of 0.84) meaning total connectedness does not Granger cause recessions. The direction of causality is again consistent with Longin and Solnik's (2001) findings. Higher connectedness index does not necessarily require financial turmoil but rather just a higher proportion of forecast error variance explained by innovations to other asset classes. In this way, while it does make sense that higher connectedness might accelerate the onset and spread of a recession, spillovers are a symptom rather than a cause, certainly when considering only cross-asset spillovers and not contagion overseas.

Finally, the coefficient on macroprudential attitude is of interest. The negative coefficient on macroprudential attitude suggests that financial regulation has a significant effect on taming the effects of spillovers. Significant to the 90% confidence level, the greater the level of macroprudential tightenings to loosenings in the US economy the lower the connectedness between asset classes. In fact, if a policy maker makes only macroprudential tightenings within a month (macroprudential attitude = 1), total volatility spillovers decrease by 2.3%. This is a promising result for regulatory agencies. It suggests regulation like limits on the loan-to-value ratio will have a significant effect at limiting the amount of contagion that can be generated by a financial crisis.

Model 2

The second model estimated follows the same structure to the first but substitutes the first differenced M2-Reserves ratio for the spread between the treasury bill and the federal funds rate as an alternative indicator for liquidity. A lag of the dependent variable is also included to reduce the autocorrelation of the residuals from the first model which had a Ljung-Box test p-value of near 0. The BIC suggested the optimal lag length to include is 1, both for total connectedness in levels and first differenced.

The first improvement from introducing a lag of the connectedness index and substituting the liquidity indicator over the first model is with respect to the R^2. The value suggests that 88% of the variation of the total connectedness is now explained by the combination of variables, an increase from the 41% in Model 1. The lag is also positive, statistically significant, and close to 1, reflecting the unit root identified in the TCI series with the ADF test.

Economic policy uncertainty remains positive, though is now statistically insignificant, but the magnitude is a twentieth of the first model, suggesting it was capturing some of the autocorrelation of the dependent variable. Financial regulation uncertainty and sovereign debt concerns have the expected positive effect on total connectedness but are also statistically insignificant. VIX now has the expected positive sign, suggesting 'fear' increases volatility spillovers, and the liquidity indicator, the Treasury Bill-Fed Funds spread is negative and significant, at odds with the interpretation from Model 1, instead suggesting that liquidity decreases spillovers.

Macroprudential attitude ceases to be statistically significant, but the coefficient remains negative. There has also been a sign change for financial conditions. In Model 1, the financial conditions variable was positive but statistically insignificant. However, in Model 2 the Chicago Fed's financial conditions indicator is negative and statistically significant. This is in line with the literature detailing reduced spillovers during periods of relative financial tranquillity (Longin & Solnik, 2001; Chang et al., 2022).

Model 3

Because the ADF test on the TCI leads to a failure to reject the null hypothesis with no constant or trend (seen in Table A.5), Model 3 is estimated with TCI in first differences to subside concerns of spurious regression where long-run trends in connectedness falsely indicate a causal effect with the explanatory variables. Model 3 has the same composition of control variables as Model 2, but the lag of the dependent is now the lag of the first difference of TCI.

Judging by the test statistic of the Ljung-Box test on the residuals, the null hypothesis of no autocorrelation cannot be rejected. This suggests that the inclusion of the first lag, as prescribed by the BIC, is sufficient in capturing the persistence in the first differenced series. Although the R^2 is much lower than the variable in levels in Model 1 and 2 more variables are statistically significant.

Little is changed between Model 2 and 3 in terms of the magnitude of the parameters except for the first lag. The same positive effect is observed for VIX and recession probability, and the same negative effects are observed for the liquidity indicator and financial conditions indicator. The coefficients for economic policy uncertainty and trade policy are now significant with negative and positive values respectively. These results are opposite to the first model where economic policy uncertainty has a positive effect on spillovers and trade policy uncertainty a negative effect.

Model 4

The fourth model involves employment of the first principal component for the uncertainty variables, the first principal component for the financial stress variables and two principal components for the equity market volatility variables for a PC-OLS regression. The PCA variables do not fare well, with only the first principal component of the uncertainty variables being statistically significant. In fact, this model sees a violation of many of the expected signs, like that on the first principal component of the uncertainty variables, the financial stress principal component, and the second principal component for the equity market volatility trackers. Like the first model, the coefficient for consumer sentiment is positive, albeit insignificant, and suggests that as the consumer outlook on the economy improves, financial market interconnectedness increases.

There is also a high R^2, most of which can be attributed to the inclusion of the first lag of the total connectedness index which remains highly positive with a coefficient close to 1, similar to Model 2.

Models 5 & 6

Total spillovers to and from variables cannot exceed 400%, which is the value that would result from 100% of the volatility forecast error variance of each variable is attributed to innovations in variables other than itself. Hence, the total spillover index cannot exceed 100%. Having a non-binary dependent variable that, when decimalised, is bounded between 0 and 1 lends itself to alternative regression techniques. Beta regression assumes the dependent variable is beta distributed and imposes a link function, here logit, for the mean of the dependent variable conditional on the covariates x. It is the link function that restricts the conditional mean of the otherwise unrestricted linear combinations of the covariates between 0 and 1 (Stata, 2024).

The results of this regression lend confirmation to many of the inferences from the previous models. As a robustness check, the same model was estimated with a fractional-logit model (Model 6). Fractional logit is similar to using a beta regression with a logit link function, but models only the mean using a binomial distribution with a logit link, not the mean and the dispersion of the parameters. The results were almost exactly the same in significance, and almost all parameter values were identical to two significant figures.

From the two models there is little additional insight offered. The coefficient on the VIX is positive and significant, as is the coefficient on recession probability. The negative effect of liquidity on spillovers that was observed in Models 2 to 4 is ratified by Models 5 and 6, both having significant negative coefficients. The same can be said for financial conditions with a negative coefficient estimate for both.

4.4.2 Pairwise Connectedness

The pairwise connectedness models use many of the same explanatory variables as the TCI models, but the dependent variables are the pairwise connectedness series of the six combinations of variable pairs. Unlike the total connected index, the ADF tests suggest stationarity of the series with all constant and trend and constant only p-values being 0 (Table A.5). The ADF test with neither a constant nor trend's null hypothesis can also be rejected for all series but commodities-bonds and commodities-FOREX. To ensure comparative interpretability of the results, the dependent variables were left in levels for all models.

Preliminary regressions again indicated autocorrelation of the residuals, so the first lag is included as deemed optimal by the BIC.

Table 1.5: Pairwise Connectedness as the Dependent Variable

	'Stocks-Commodities'	'Stocks-Bonds'	'Stocks-FOREX'	'Commodities-Bonds'	'Commodities-FOREX'	'Bonds-FOREX'
	(1)	(2)	(3)	(4)	(5)	(6)
First Lag	0.830***	0.838***	0.843***	0.769***	0.701***	0.914***
	(0.034)	(0.037)	(0.035)	(0.042)	(0.042)	(0.026)
EPU	0.009	−0.005	0.006	0.009**	0.011**	0.006
	(0.006)	(0.007)	(0.005)	(0.004)	(0.004)	(0.007)
FINANCIALREGULATION	0.001	0.003	0.002	−0.003*	−0.002	0.004
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
SOVEREIGNDEBT	−0.0002			0.002	0.002	
	(0.002)			(0.001)	(0.001)	
DEBTCEILING		−37.254				37.895
		(185.270)				(180.602)
VIX	0.064	0.315***	0.047	0.034	0.001	−0.005
	(0.053)	(0.060)	(0.048)	(0.040)	(0.042)	(0.064)
TRADEPOLICY	0.001		0.001	0.001	−0.001	−0.001
	(0.001)		(0.001)	(0.001)	(0.001)	(0.001)
CONSUMERSENT_diff	−0.049	−0.030	−0.089*			
	(0.051)	(0.059)	(0.046)			
RECESSIONPROB	0.048***	0.033*	0.040***	0.023*	0.075***	0.047**
	(0.017)	(0.019)	(0.015)	(0.013)	(0.014)	(0.019)
OIL_diff	0.054	−0.032	−0.138*	−0.007	0.019	−0.283***
	(0.079)	(0.091)	(0.071)	(0.060)	(0.062)	(0.091)
'TB-FEDFUNDS'	−1.234	−1.494	−1.434	−1.353*	−2.104***	−1.216
	(1.037)	(1.197)	(0.935)	(0.766)	(0.801)	(1.180)
MACROPRUDENTIALATTITUDE	−0.269	−0.297	−1.560**	−0.364	0.117	−0.441
	(0.729)	(0.851)	(0.668)	(0.552)	(0.570)	(0.840)
FINANCIALCONDITIONS	−2.452**	−4.647***	−2.470***	−0.940	−2.847***	−2.722**
	(1.008)	(1.157)	(0.936)	(0.751)	(0.782)	(1.172)
Constant	−0.746	−4.820***	−0.752	1.053	1.285	−0.056
	(1.350)	(1.529)	(1.256)	(1.064)	(1.152)	(1.734)
Observations	232	232	232	232	232	232
R^2	0.798	0.803	0.827	0.741	0.721	0.876
Adjusted R^2	0.787	0.793	0.819	0.729	0.707	0.870
Residual Std. Error	3.207 (df = 219)	3.696 (df = 220)	2.891 (df = 220)	2.401 (df = 220)	2.510 (df = 220)	3.696 (df = 220)
F Statistic	72.181*** (df = 12; 219)	81.589*** (df = 11; 220)	95.732*** (df = 11; 220)	57.364*** (df = 11; 220)	51.569*** (df = 11; 220)	141.606*** (df = 11; 220)
Ljung-Box P-Value	2.307e-06	8.839e-07	9.887e-05	0.0004522	0.0005347	8.312e-07

Note: *p<0.1; **p<0.05; ***p<0.01

Stocks-Commodities

The purpose of the pairwise models is to provide greater insight into the effect of the explanatory variables on the connectedness of the assets. In the total connectedness models, we can identify the effect of a variable on the overall financial market connectedness and degree of contagion, but this section allows examination of asymmetric effects of the variables on the relationships between different assets.

The degree of persistence in spillovers for the pairwise connectedness is representative of the total connectedness models: both are highly significant and have coefficient values around 8. Significant results for the remaining variables are depressingly scarce. Financial conditions has a negative and significant effect on the volatility spillovers between stocks and commodities, and recession probability's parameter is also positive but of lower magnitude. The opposite signs are coherent: an improvement in financial conditions reduces spillovers just as an increase in recession probability will increase spillovers. This again points to the asymmetric effect of volatility connectedness during crises versus otherwise.

Other variables of interest, such as economic policy uncertainty, VIX and macroprudential attitude have expected signs and reflect the total connectedness models but suffer from a lack of statistical significance. The R^2 is relatively high at 0.8 suggesting the combination of variables explains much of the variation in the dependent variable but most of this is because of the inclusion of the first lag.

Stocks-Bonds

The coefficient on the first lag is almost equal to the other models, suggesting uniform persistence in the connectedness of the asset classes. In this model, trade policy uncertainty is replaced with the more relevant debt ceiling concern. The control variables for liquidity and economic fundamentals remain. Surprisingly, financial regulatory uncertainty is insignificant although the coefficient is positive. The debt ceiling coefficient is large in magnitude and negative although also insignificant. The sign of the variable is puzzling and indicates that spillovers decrease when concern surrounding the government's ability to honour debts increases. The positive coefficient for VIX suggests that volatility spillovers increase between the stock and bond market when investor fear increases. The coefficient on financial conditions is negative and also significant which is coherent with previous models. The magnitude for financial conditions is greatest for the stocks-bonds spillovers. This is intuitive because the financial condition reflects, to some extent, the risk profile of the U.S. government, so a worsened financial condition may mean that investors view turbulence in the stock market as more relevant for the risk of the government bonds which causes volatility in the yield. It could also indicate uncertainty surrounding monetary policy decisions. With a worsened financial condition or an increase in the probability of a recession, the stock and bond market may become more interlinked because investors may become more risk averse and be more willing to purchase safe government bonds when faced with volatility shocks in the stock market which reflects greater connectedness through volatility spillovers.

Stocks-FOREX

For the pairwise connectedness in volatility between the stock and foreign exchange markets, the most significant variable is the probability of recession. The coefficient suggests that spillovers between the stock and foreign exchange markets are among the most sensitive to recessions. The volatility of equities is naturally related to recessions as demand becomes uncertain, consumption declines and the financial stress increases, but the changes in the relationship of the volatility with the foreign exchange market is less clear cut. Much of the financial stress of a recession is realised by the equity market first (Kroencke, 2022). The volatility may channel to the foreign exchange market if international risk averse investors withdraw investments in U.S. equity markets, anticipating a decline in returns and heightened risk. Hence, the equity market's volatility spills over to the foreign exchange market. The same conclusion can be drawn from the negative and significant coefficient on the financial conditions index.

The effect identified here is also supported by the coefficient on the liquidity and credit-risk control variable, the treasury bill-Federal funds rate spread. The difference between the treasury bill yield and the federal funds rate indicates the willingness of banks to lend to each other. A positive spread suggests lower risk perception in the economy with banks lending to each other below the return of the safe treasury bill. The negative coefficient suggests the spillovers are less pronounced when there is sufficient liquidity and risk averse international investors may be less inclined to withdraw investments in equities and transfer shocks to the foreign exchange market.

The spillovers are also contained when the macroprudential attitude is positive. This is the only model where macroprudential attitude has a significant effect on the spillovers and there are two interpretations of this. The first is that a positive macroprudential attitude may increase investors' confidence in the resilience of the financial system which may make withdrawals or exchanges to other currencies less sensitive when there are shocks to the stock market. The second explanation concerns the type of regulation imposed. One of the instruments recorded in the iMAPP database is lending and borrowing in foreign currency (Alam et al., 2019) and so greater restrictions on financial institutions in these areas will necessitate a lower connectedness between the stock market and the foreign exchange market. When faced with equity market shocks, greater restrictions on foreign currency transactions for banks and investment funds will prevent some of the contagion to the foreign exchange market, hence the negative coefficient.

Commodities-Bonds

There is little explanatory power for the independent variables when modelling the connectedness between the commodities and bonds market. Forging a link between the commodities market and the bond market is difficult qualitatively and the regression model does not perform well. Despite the R^2 being high, much of this explanatory power is due to the inclusion of the first lag of the connectedness index, which is again close to 0.8 and highly significant.

There is a positive and significant effect of economic policy uncertainty, and many of the signs on the coefficients are consistent with the other models. However, the coefficient for financial regulation uncertainty is negative (but significant only with 90% confidence). This implies that while uncertainty surrounding economic policy in general contributes to the ease of contagion of volatility between commodities and bonds, financial regulation uncertainty specifically reduces the effect. Nevertheless, the coefficient on economic policy dominates this effect both in magnitude and statistical significance.

Commodities-FOREX

Modelling the relationship between commodities and foreign exchange reveals more about the relationship of commodities to the other assets. The connectedness is positively associated with the probability of recession and a decline in the financial condition. Notably, the coefficient on the probability of recession is significant and is larger in magnitude than any of the previous pairwise models. This suggests that a significant portion of the variation in the total connectedness index caused by recession can be attributed to the connectedness between the commodity market and foreign exchange market. When exchange rates fluctuate during recessions, this volatility can be translated to the sectors that are export dependent like commodities: volatility in the foreign exchange can spillover into commodity market because it affects their demand and prices.

The liquidity indicator is also important here. The coefficient is similar in magnitude to the coefficient estimated in the Stocks-Bonds model. It suggests that pairwise connectedness of other asset classes with commodities in particular is sensitive to the level of liquidity in the economy. The negative coefficient suggests that liquidity and the spillover of volatility shocks to and from the commodity market are negatively associated. An explanation for this is the "safe haven effect" (Balcilar et al., 2020) where investors are inclined to hold safer assets during periods of lessened liquidity, reducing the risks posed by liquidity shortages.

Bonds-FOREX

The bonds-FOREX model has the highest R^2 of all the models so far. Observation of the plot of the pairwise connectedness between the bond and foreign exchange market in Figure 1.6 displays significant variation in times of recession. For example, the series peaks in 2020 with the pandemic and subsequent recession. This relationship is confirmed in the regression model with a significant and positive coefficient on recession probability and a negative and significant coefficient on the financial condition. The connectedness between the bonds and forex markets is also highly persistent with an AR(1) coefficient close to 1. Overall, the results suggest a persistent relationship and high sensitivity to crises.

The volatility of both bonds and foreign exchange is sensitive to financial stability individually with investors preferring risk free assets or foreign currency when domestic financial risk increases (Min et al., 2016), but why their pairwise connectedness is sensitive to the financial condition is less obvious. What the negative coefficient suggests is that a shock to the bond (foreign exchange) market spills over more to the foreign exchange (bond) market during recessions than during times of relative economic tranquillity. During the pandemic especially, the connectedness in Figure 1.6 appears to show the spillovers to flow more from the bond market to the foreign exchange market than the other way around. This seems to indicate that investors take volatility in the bond market with greater concern during recessions, perhaps indicating a greater propensity to 'fly to safety' (Baur & Lucey, 2009) by moving funds out of the US dollar denomination, inducing volatility in the market.

4.5 Summary

Overall, while the pairwise connectedness is more difficult to explain, both intuitively and with the explanatory variables, there are valuable inferences to be drawn from the models. The main variables of interest relate to uncertainty, 'fear' and macroprudential attitude. Economic policy uncertainty's effect on the total connectedness of the asset classes remains unclear with little significance across the models but a large positive coefficient in Model 1. For the pairwise connectedness, economic policy uncertainty does have a significant and positive effect on the bi-directional spillovers between commodities and bonds and commodities and foreign exchange. The other measures of uncertainty including sovereign debt concern and trade policy uncertainty are rarely significant and small in magnitude, even when considering spillovers concerning the bond and commodity markets which are more likely to be affected by trade and sovereign debt uncertainty.

The fear index, VIX, has a clear positive effect on spillovers and is one of the strongest variables. For almost all models of total connectedness the coefficient ranges between 0.004 and 0.17 suggesting an increase of one unit of the VIX index is associated with potentially a 0.17% increase in volatility spillovers. With respect to pairwise connectedness, it appears most of the effect of 'fear' is driven by Stock-Bond market spillovers. In line with previous research, financial stress measured by the recession indicator and financial conditions index has a positive effect on spillovers (Longin & Solnik, 1995).

Finally, the results for macroprudential attitude are promising in most specifications. In four of the six total connectedness models, macroprudential attitude has a negative effect on volatility spillovers and is significant in the first model. The coefficient's sign holds across five of the six pairwise regressions but has significance only for connectedness between stocks and foreign exchange. Overall, the results suggest that policy makers can have a detectable effect on cross-asset spillovers and more tightenings of macroprudential policy instruments than loosenings will serve to reduce volatility spillovers and limit contagion.

5 Part 2: Cross-Border Volatility Spillovers

5.1 Country Sample

Part 2 of this paper models the connectedness between countries' equity markets. The purpose of this section is to provide greater insight into the factors that may ease or inhibit cross-border spillovers. Part 1 has provided answers to questions surrounding cross-asset spillovers and the factors affecting contagion within a country. Part 2 will assess the same variables against cross-border spillovers.

The countries chosen are the United States, United Kingdom, France, Germany, Japan, Australia and Mexico. The country choice was intended to capture varying levels of relationship status with the United States with regards to trade, geography, diplomatic cooperation and popularity of American financial or economic news. This allows a comparison of the effect of many of the variables examined in Part 1, like uncertainty and macroprudential attitude, with cross-border spillovers.

All series were downloaded up to March 15th 2024. For the United States, the same stock market series is employed as in Part 1. Daily high and low prices are available from Yahoo! Finance (2024) for the United States' S&P 500 from January 2nd 1962. For the United Kingdom, daily high and low prices for the FTSE 100 are retrieved with a start date of the 4th January 2000 from the Wall Street Journal (2024). The DAX performance index represents Germany's stock market. Data is downloaded from Yahoo! Finance (2024) with high and low prices available from December 14th 1993. For France, the benchmark stock index CAC40's high and low data is extracted from Yahoo! Finance (2024) beginning March 1st 1990. Japan's Nikkei 250 is used to represent the Japanese equity market. High and low prices for the index are sourced from Yahoo! Finance (2024) and begin April 8th 1988. High and low prices for Mexico's IPC Mexico are from the same source and begin March 19th 1993. Finally, Australia's S&P/ASX 200's high and low prices are available from July 7th 2005 and are also extracted from Yahoo! Finance (2024). Like in Part 1, for missing days the last observation is carried forward.

The same transformations for volatility as also applied. Volatility is calculated as $\tilde{\sigma}^2_{it} = \frac{1}{4ln2}\left[lnP^{High}_{it} - lnP^{Low}_{it}\right]^2$ (Brooks, 2019; Parkinson, 1980). Overall, daily volatility data for the estimation of spillovers is available from July 7th 2005 to March 15th 2024, 4,705 days and 32,935 total observations.

Figure 2.1 shows the evolution of each of the seven country's stock market volatility over the sample period. There appears to be a high correlation between the stock markets, with each appearing subject to most of the same shocks. For example, all display the inevitably large volatility shock with the onset of the global financial crisis. There is also heightened volatility in early 2020 with the global recession associated with the pandemic. The European, Australian and perhaps Japanese volatilities show increases around the time of the Brexit referendum. Described as the "Black Friday for Britain", the vote led to stock market crashes around the world and investors globally lost more than two trillion US dollars (David, 2016). The Japanese shock in 2016 is

Table 2.1: Volatility Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Max	Skewness	Kurtosis
United States	4,705	0.0000925205	0.0002418281	0.0000007650	0.0042884150	9.289034	118.2005
United Kingdom	4,705	0.0000944841	0.0002194366	0.0000019613	0.0047802260	9.84672	138.7926
Japan	4,705	0.0000869379	0.0002437739	0.0000013482	0.0068322670	13.24607	248.2857
Germany	4,705	0.0001146342	0.0002330785	0.0000007458	0.0044769900	8.111154	97.27949
France	4,705	0.0001086093	0.0002039484	0.0000006950	0.0030931760	6.662428	65.592
Australia	4,705	0.0000661713	0.0001731192	0.0000015548	0.0059106400	14.27978	344.9402
Mexico	4,705	0.0001044185	0.0002014485	0.0000027633	0.0043811610	8.950525	127.0608

far more short lived while the European markets have a more sustained increases in volatility. There is also quite a significant spike in the European markets in the early 2010s which is most likely associated with the European sovereign debt crisis and the United States debt ceiling debates.

The maximum volatility across all markets is recorded in Japan in mid-March 2011. This is in response to the Tohoku earthquake and tsunami. However, the volatility of the Japanese stock market is one of the lowest on average with a mean daily volatility of 0.00008694, exceeding only Australia's 0.00006617. The most volatile stock market on average is the German market. The maximum volatility of the German market is not particularly large compared to the rest of the seven-country sample and the standard deviation of the volatility is fairly low, with the German market reacting less on average to shocks but exhibiting higher volatility in general. The same can be said for the French stock market. France's maximum volatility is the lowest of the sample, suggesting France's equity market has been the most resilient to the shocks of the global financial crisis, Brexit, the European debt crisis and the pandemic, all of which are visible on the time series. Like Germany, France has a relatively stable but high volatility. The mean volatility of France is 0.0001086, which is close to that of Germany and similar to Mexico's which is almost equally high at 0.0001044. Being European, France and Germany have experienced similar shocks over sample period with almost all shocks to volatility in one's market coinciding with a shock of almost equal magnitude in the other's market.

The United States occupies the middle-ground of the sample in all aspects. The mean of the United States' equity market is between that of the European countries and Japan. The standard of the volatility is similar to that of Japan's but slightly below, and the maximum again is close to being the lowest of the sample, above only France.

Observation of the Pearson's correlation coefficients reveals the Japanese market to be the least correlated with the others. It highest correlation is with Germany at 0.55 which is low compared to the rest of the sample. The three European countries, the UK, France and Germany, are all very highly correlated. The correlation of the volatility of the UK's stock market with Germany is 0.78 and is even higher for France at 0.82. France and Germany are also extremely highly correlated with each other, and the Pearson's correlation coefficient is 0.89, the highest of the sample. With both being in an economic union and sharing monetary policy, a currency and a border, the coefficient is no less than what is expected.

The United States' market's volatility is most highly correlated with that of Mexico's, although not quite to the same degree as Germany and France. The United Kingdom's stock market volatil-

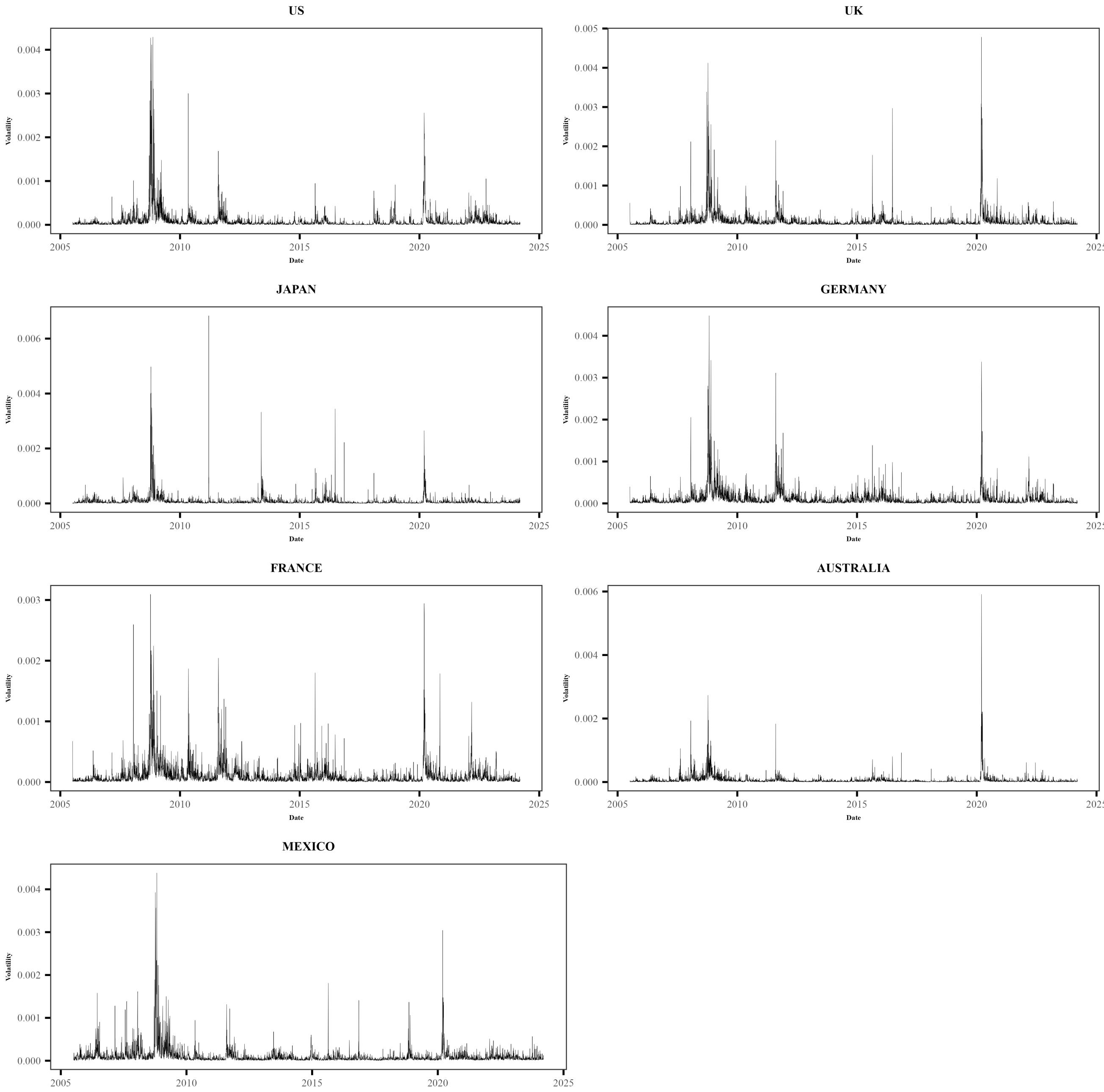

Figure 2.1: Volatility of the Sample Countries

ity appears the most connected overall with the rest of the sample, correlated highly with the US (0.67), Australia (0.67), Germany (0.78) and France (0.82). Indeed, the only stock markets with which the UK does not exhibit high volatility correlation with is Japan (0.54) and Mexico (0.62). The lowest correlation overall is between Australia and Mexico (0.42).

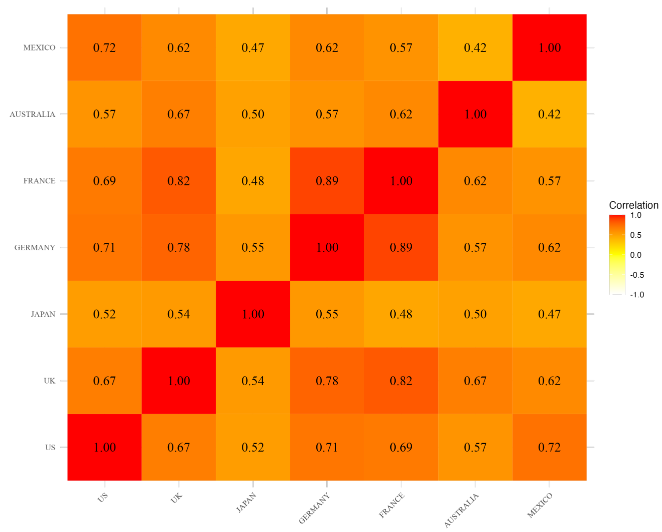

Figure 2.2: Bivariate Correlation Matrix

Table 2.2: Augmented Dickey-Fuller Test Results on volatility

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
US	−19.1344	0.0000	−20.8820	0.0000	−21.0001	0.0000
UK	−20.0034	0.0000	−22.4659	0.0000	−22.5663	0.0000
JAPAN	−22.9359	0.0000	−25.0362	0.0000	−25.2274	0.0000
GERMANY	−18.8479	0.0000	−21.5944	0.0000	−21.7871	0.0000
FRANCE	−18.6071	0.0000	−21.8311	0.0000	−22.0239	0.0000
AUSTRALIA	−21.5219	0.0000	−23.5927	0.0000	−23.7069	0.0000
MEXICO	−21.6648	0.0000	−25.6245	0.0000	−26.0992	0.0000

5.2 Connectedness

5.2.1 Model Specification

Much like the asset volatility in Part 1, although to the same degree, the volatility of all countries' stock markets are positively skewed and leptokurtic, especially Japan because of the volatility shock in 2011. All series are stationary with the ADF tests' null hypotheses being rejected in all cases. Furthermore, all test statistics for the ERS tests are statistically significant, again signalling stationarity. However, equally significant are the test statistics for the Jarque-Bera test of normality. While there is absence of a unit root in the series, the series are not normally distributed and are logged prior to the VAR estimation. While this does not change the results of the Jarque-Bera test for the series, it moderates the skewness to below 0.44 for all series and the kurtosis close to 3. Plots of the logged series, the correlation matrix, summary statistics and ADF tests are presented in Appendix B.

The generalised VAR model is estimated with the same 200-day rolling window and 10-step ahead forecast. However, the optimal lag length, p, specified by the BIC is 4.

5.3 Connectedness Table

Table 2.3: Connectedness

	US	UK	JAPAN	GERMANY	FRANCE	AUSTRALIA	MEXICO	FROM
US	49.74	11.77	3.21	11.74	11.31	3.17	9.07	50.26
UK	13.60	40.55	3.20	15.45	17.27	3.35	6.58	59.45
JAPAN	8.60	7.09	62.61	5.23	5.31	5.48	5.69	37.39
GERMANY	11.94	14.45	2.46	37.76	26.33	2.04	5.02	62.24
FRANCE	11.82	16.04	2.48	25.76	36.76	2.05	5.08	63.24
AUSTRALIA	12.29	9.63	4.37	8.03	7.79	51.26	6.63	48.74
MEXICO	12.33	8.59	3.31	6.66	6.45	2.62	60.03	39.97
TO	70.59	67.56	19.03	72.88	74.46	18.71	38.06	361.30
Inc.Own	120.32	108.11	81.64	110.64	111.22	69.97	98.09	cTCI/TCI
NET	-20.32	-8.11	18.36	-10.64	-11.22	30.03	1.91	60.22/51.61

The average connectedness table is structured in the same way as Part 1. The values running down the columns show the spillovers received by the country heading the column, while the values running across the rows give the spillovers contributed by the country in the first column. It is important to note that the values of the spillovers are dependent on the selection of the sample and the spillover index is therefore sensitive to the countries chosen. In other words, spillovers TO and FROM the United States captures only the spillovers relating to the countries in the sample. Therefore, while the connectedness index is showing the United States to be the median contributor of spillovers (50.26), this is sensitive to the sample selection. Including countries like Canada or more Latin American countries would most likely result in the United States' contribution of spillovers being greater. The results are still insightful and will give an indication of the capacity of a country to absorb spillovers from other countries with the sample being sufficiently diverse geographically, but future research would benefit from the inclusion of more countries.

This sensitivity to sample selection does not have significant empirical implications on the pairwise models in the following section, however. Total connectedness and overall spillovers received and contributed is sensitive to the sample selection, but the pairwise connectedness is not. Pairwise connectedness measures bivariate connectedness and is insensitive to the inclusion of more variables. For example, the pairwise connectedness of France with the United States is calculated from the contribution of innovations to the log volatility of the United States' stock market on the forecast error variance of the log volatility of France's stock market and vice-versa. The contributions are isolated from the innovations of all other sample countries and inclusion of more countries or different countries will not change the pairwise connectedness significantly.

5.3.1 Spillovers Received

Figure 2.3 shows the evolution of the spillovers received by the countries in the sample. It is evident from the plot and the connectedness table that the United States is among one of the largest receivers of spillovers in the sample. Towards the beginning of the sample, the spillovers received by the United States are high but stable. Around the time of the global financial crisis, the United States, like all other countries in the sample, received spillovers. While the global financial crisis

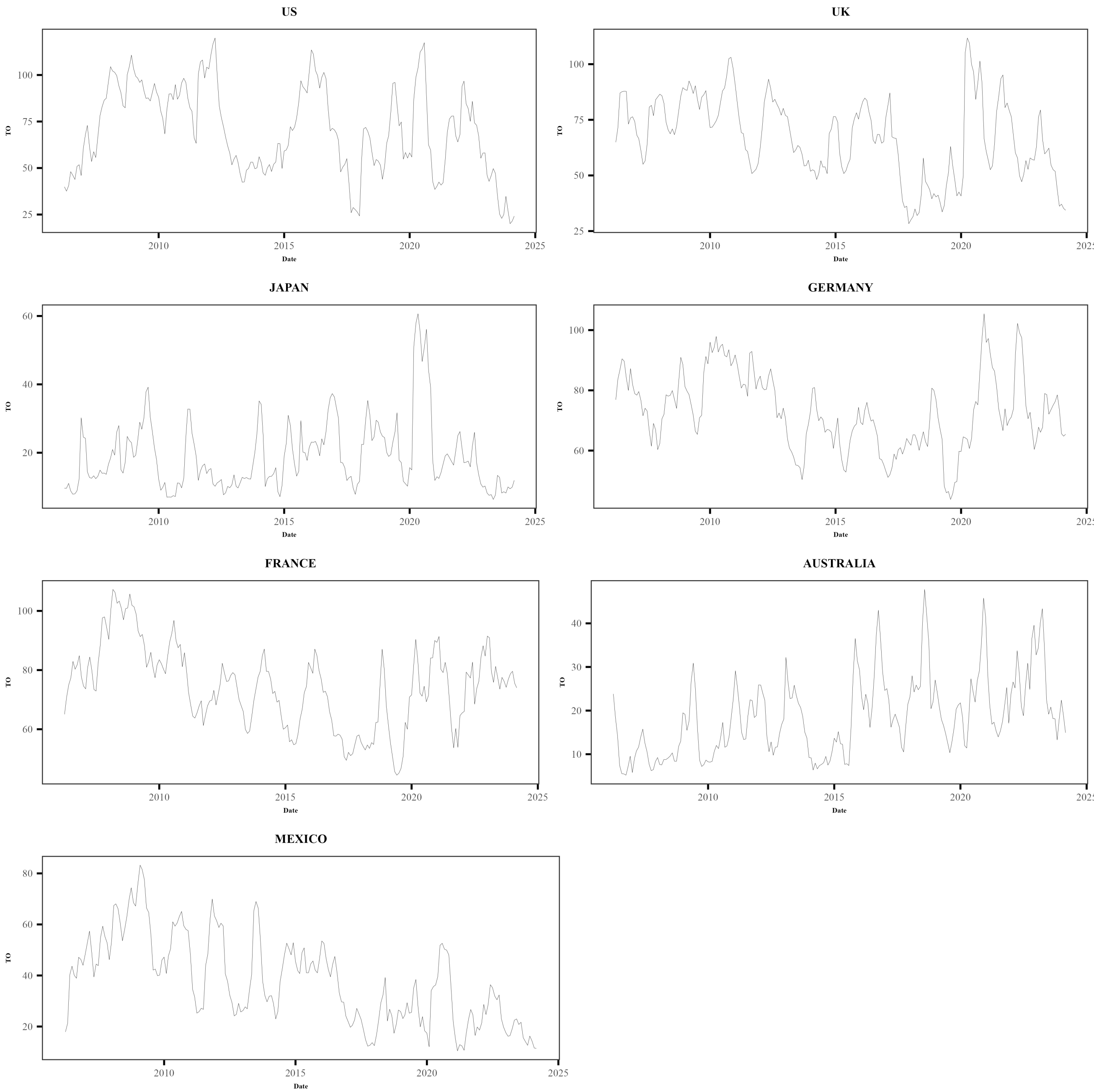

Figure 2.3: Spillovers TO

originated in the United States, and the United States was a net contributor of spillovers during that time, the United States was also on the receiving end of volatility spillovers that originated in other markets. In a way, the spillovers received captures a feedback effect of the global financial crisis: the effect of the crisis on the stock markets of the other countries in the sample in turn affected the volatility of the stock market in the United States.

All countries also show the receival of spillovers from the Brexit referendum in 2016. The Brexit referendum's effect on the volatility of stock markets globally was both direct and through spillovers. In Figure 2.4 the United Kingdom was naturally a large contributor of spillovers, but not the only contributor. The Brexit vote had an impact on European countries not just through volatility spillovers from the British stock market. The DY framework will capture the effect through the British stock market, but will not capture the direct effect of the vote on European stock markets. Hence, other countries in the sample can also be contributors of spillovers as a result of the vote, observable in Figure 2.4.

5.3.2 Spillovers Contributed

The plots of spillovers FROM in Figure 2.4 coincide closely with spillovers TO in Figure 2.3 again reflecting the feedback effect between countries in the sample. Spillovers FROM does allow greater identification of the origin of the volatility, however. For example, spillovers from the United Kingdom in 2022 were far more sustained and stable than spillovers received. This spike coincides with the disastrous government mini budget which rapidly devalued sterling and destabilised the British stock market (BBC, 2022). Similarly, spillovers FROM in 2016 both larger and longer lasting than those from other countries.

5.3.3 Pairwise Connectedness with the United States

One of the focuses of this paper is the effect of stock market volatility in the United States on partner countries. Figure 2.5 shows the pairwise connectedness index of the United States with the six other countries in the sample, showing the overall ability of the United States and country j to transmit spillovers to one another. An increase in the pairwise connectedness index in the above figure indicates that the cross-border spillover transmission between the United States and the country has increased.

There are a number of significant events which are visible in the connectedness. In 2016, President Trump threatened to withdraw from the North American Free Trade Agreement (Corasaniti et al., 2016) which directly affects the trade relationship with Mexico, and proposed a withdrawal from the Trans-Pacific Partnership Agreement, which affects not only Mexico but also Japan and Australia. In the pairwise connectedness plots, all countries show significant jumps in pairwise connectedness coinciding with these turbulent and uncertain times in American politics.

While France and Germany appear to have longer lasting pairwise spillovers from the financial crisis, Australia's connectedness declines rapidly in the years following the crisis but increases again around the time of the debt ceiling crisis in the United States in 2012. There is a secondary spike in late 2012 and early 2013 that is coherent with the fiscal cliff: the combined effect of a number of tax and spending laws that came into effect simultaneously at the beginning of 2013 (Calmes, 2012).

Overall, the connectedness of the United States with the other countries in the sample can be well explained qualitatively with significant events in America's or the partner country's economic and political history. There appear to be a number of spikes around times of crisis, policy uncertainty and trade relationship uncertainty or decline. The events mentioned in this section motivate the choice of many of the variables for the following section and suggest that the strength of spillover effects between countries can be well explained by uncertainty, sentiment, crisis and cooperation indicators.

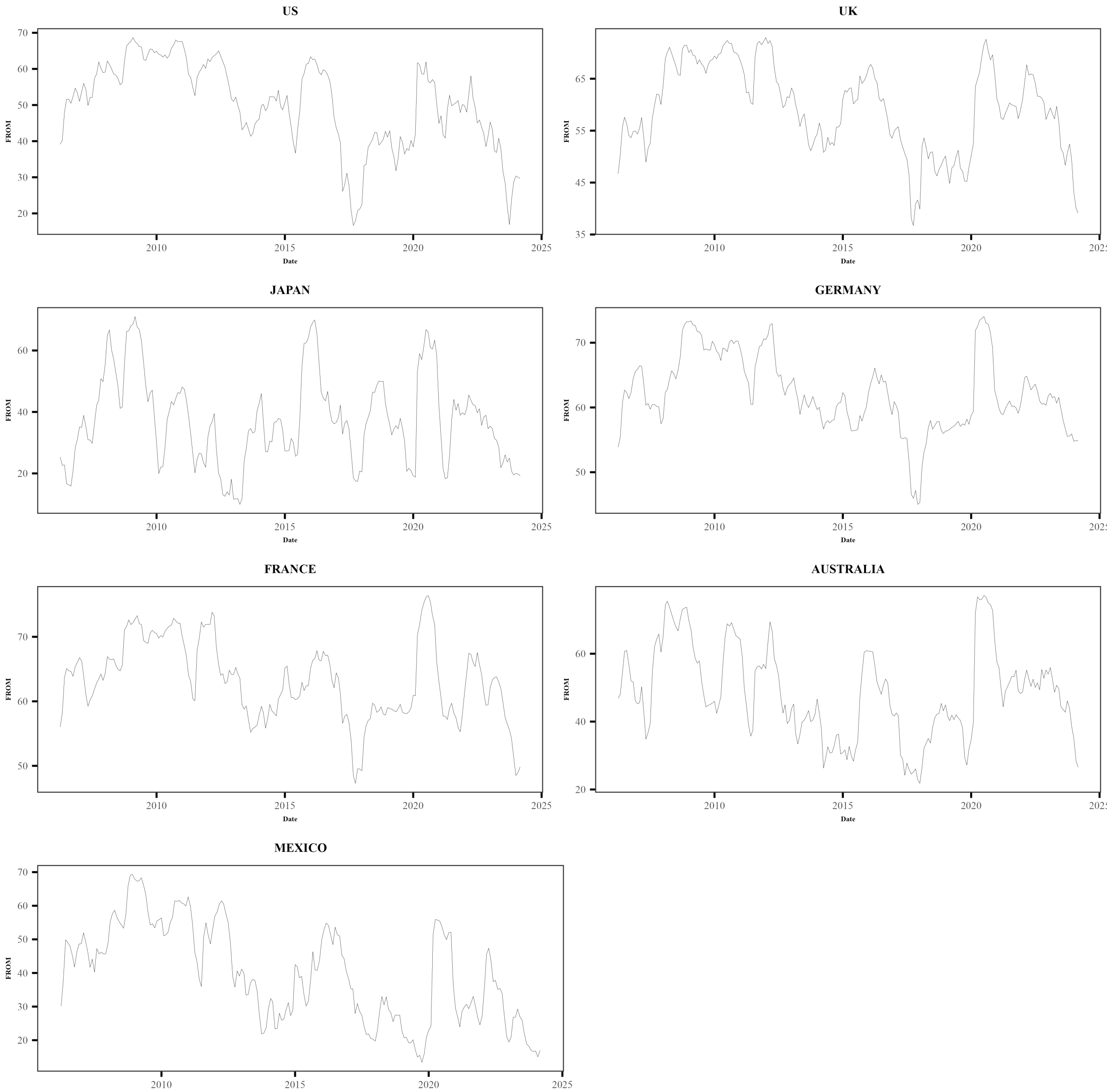

Figure 2.4: Spillovers FROM

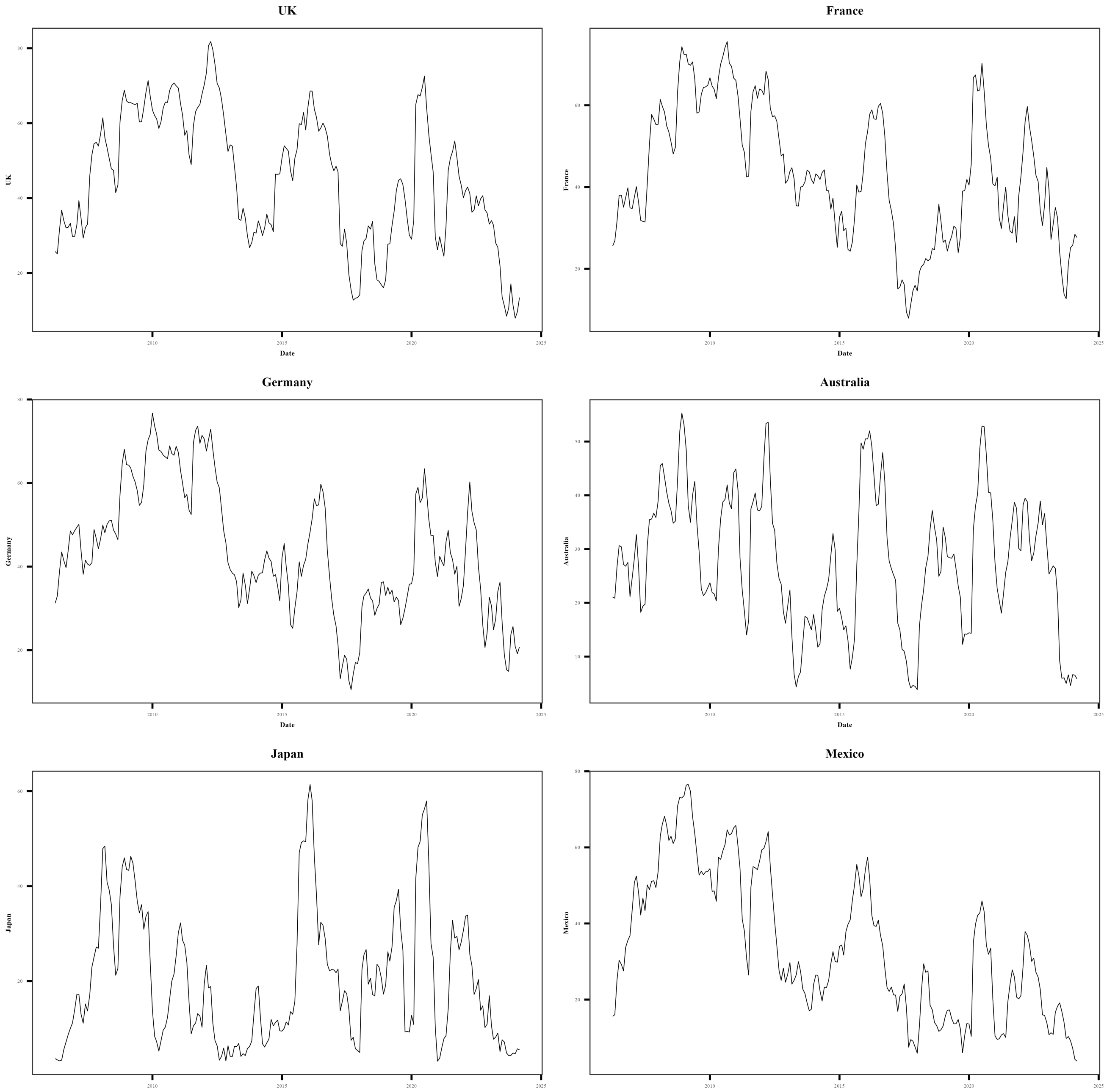

Figure 2.5: Partner Country Pairwise Connectedness with the United States

5.4 Explanatory Variables

5.4.1 Variable Description

The explanatory variables utilised in this section cover several broad categories both for the United States and the partner country. The variables are chosen both to explain the sensitivity of each country to receive spillovers from abroad and to explain the spillover relationship between the United States and each of the six partner countries.

Sentiment and Uncertainty

In line with the analysis in Part 1, for each country a number of variables reflecting uncertainty and fear are utilised. For all countries the Baker et al. (2024) monthly economic policy uncertainty index is employed. For the United States, the series is the same as in Part 1 and is available from January 1985 to February 2024. For France, the data is available from January 1987 to February 2024. The series for the United Kingdom begins in January 1997 and terminates also in February 2024. Germany's economic policy uncertainty index also finishes in February 2024 but begins in January 1993. For the pairwise relationship with the United States, the monthly trade policy uncertainty index from Part 1 is also utilised. The series begins January 1985, ends in February 2024 and is also from Baker et al. (2024).

The VIX from Part 1 is employed also in Part 2 to reflect fear in global equity markets. As mentioned in Part 1, the daily data is averaged over the month for a monthly series and is available from FRED from January 2nd 1990.

The final variable employed in this category is a sentiment indicator. A comparable indicator is selected for each of the partner countries, excluding Japan and Mexico due to lack of suitable measure, from Macrobond (2024). For the United Kingdom, France and Germany, the Eurostat business sentiment indicator is used. This indicator is available monthly from January 1980 to December 2020 for the United Kingdom, January 1980 to February 2024 for Germany and from January 1985 to February 2024 for France. For Australia, the monthly Melbourne Institute Consumer Surveys Index is retrieved from September 1974 to February 2024, also from Macrobond (2024).

Financial Conditions and Crisis Indicators

For the United States, the continuous recession probability variable is used. As detailed in Part 1, the monthly series from FRED is between June 1976 and February 2024. For all other partner countries, the Macrobond (2024) binary business cycle indicator variable is used, equal to one when the country is in recession. This is a quarterly variable that is extrapolated into a monthly format by all months in a quarter taking the quarter's value. All series for this variable terminate in the final quarter of 2023. For the United Kingdom, the variable is available from the 3rd quarter of 1955. For Germany, the series begins in the third quarter of 1970. France's begins in the third quarter of 1949. For Japan the start date is the fourth quarter of 1980, Mexico the third quarter of 1980, and Australia the first quarter of 1960.

Monetary Indicators

For liquidity, the M2-Reserves ratio from Part 1 is used for the United States. Available from Fred between November 1980 and January 2024. For the partner countries, a similar liquidity indicator is used. The M2 money supply was not available universally for all countries, so the M1-Reserves ratio was used as a substitute. The M1 money supply series were all monthly and sourced from Macrobond (2024) directly but originally sourced from each partner country's central bank. The M1 money supply series are converted to US dollars and begin in September 1986 for the United

Kingdom, January 1980 for Germany, December 1977 for France, January 1989 for Japan, December 2000 for Mexico and February 1975 for Australia. The reserves series for each partner country are downloaded directly from Macrobond (2024) but sourced from the World Bank. All series are monthly, beginning in May 1994 and ending February 2024. Naturally, the reserves are also converted into US dollars before calculation of the ratio.

To model the effect of spillovers the reliance of an economy on foreign capital flows must be captured. To do this, the Foreign Direct Investment (FDI) inflows to Gross Domestic Product (GDP) ratio is used. A higher ratio reflects a greater reliance of a country's economy on capital investment from abroad. FDI inflows in current prices are available annually for all partner countries from Macrobond (2024) sourced originally from the World Bank. The series span 1970 to 2023, are converted into US dollars and are linearly interpolated for monthly series. For the GDP series, the OECD's annual data is available for all partner countries from 1981 to 2022 from Macrobond (2024) in US dollars. Like FDI, this series is linearly interpolated for monthly data. The FDI-GDP ratio is then available from January 1981 to December 2022.

As a measure of the partner countries' financial condition, the OECD's private sector debt as a percentage of GDP indicator is downloaded from Macrobond (2024). The annual series are linearly interpolated for a monthly frequency spanning January 1995 to December 2022 for France, Germany, Japan and Mexico, and to December 2023 for the United Kingdom and Australia.

The penultimate monetary indicator is the Foreign Currency Reserves-GDP ratio. The Foreign Reserves-GDP ratio reflects the ability of a country to defend their currency against a currency crisis, indicating financial stability and resilience to international shocks (Obstfelt et al., 2010) and also reflects the country's relative presence in global financial markets. The GDP data is as above, but the monthly foreign reserves data is sourced from the partner country's central bank but again retrieved directly from Macrobond (2024). All series terminate in February 2024, beginning July 1999 for the United Kingdom, December 1998 for Germany, December 1999 for France, January 1957 for Japan, January 2000 for Mexico, and July 1969 for Australia. All series are in current prices and are converted into US dollars for the ratio. Like the FDI-GDP ratio, the Foreign Currency Reserves-GDP ratio is limited only by the end date of GDP and therefore end in December 2022.

The final monetary indicator for each country is the z-score. The z-score is an indicator of financial stress and compares the buffers of a country's banking system (capitalisation and returns) with the volatility of those returns. Calculated as $\frac{ROA+\frac{Equity}{Assets}}{\sigma(ROA)}$, it is the number of standard deviations return on assets would have to fall to deplete equity (World Bank, 2015). Hence, a higher z-score is indicative of a stronger and more resilient financial system and is expected to be negatively correlated with equity market volatility spillovers. The z-score is an annual measure from the World Bank but retrieved from Macrobond (2024). Series for the United States and all partner countries are employed between the years 2000 and 2021. The data is linearly interpolated to coincide with the monthly frequency of other explanatory variables.

Macroprudential Policy

In Part 1, macroprudential policy was observed to have a significant effect on limiting spillovers between asset classes. For the examination of cross-border spillovers, the same Macroprudential Attitude variable is used but for all partner countries as well as the United States. The data availability is uniform for all countries, including all months from January 1990 to December 2021 (Alam et al., 2019). As in Part 1, macroprudential attitude (iMAPP attitude) is calculated as the ratio of macroprudential tightenings less loosenings to all changes in macroprudential instruments. Hence, the ratio is contained between -1 and +1, with positive numbers indicating more tightenings than loosenings, negative indicating the opposite, and a value of 0 indicating a neutral attitude with either no changes or an equal number of tightenings as loosenings.

World Oil Price

The same indicator of economic fundamental is included in Part 2 as in Part 1. The West Texas Intermediate (WTI) adjusted against the producer price index for the United States is downloaded from FRED from January 1946 to provide an indicator of global economic fundamentals.

International Trade

Connectedness of international markets is highly dependent on trade (Bracker et al., 1999). As seen in the previous section, there is a noticeable increase in spillovers following the election of Trump and uncertainty surrounding trade agreements. Stock markets are more interconnected for countries with greater levels of bilateral trade flows (Chen & Zhang, 1997), so an export-weighting variable is constructed as an explanatory variable for the sample countries' pairwise connectedness with the United States. The ratio of US exports to total exports in US dollars is used as an indicator of export dependence on the United States. A higher ratio would indicate that the United States is the destination for a greater proportion of the country's total exports. For the value of exports to the United States, import data from the United States International Trade Commission (USITC) is utilised. The USITC Dataweb (2024) gives monthly data from January 1989 to January 2024 of the custom's value of general imports for each partner country in US dollars. This series is then divided by each country's value of exports, also in US dollars which are unanimously available with monthly frequency and are extracted from Macrobond (2024). For the United Kingdom, the total goods and services exports value is used. The series is originally sourced from the Office of National Statistics has the dates ranging from January 1997 to February 2024. For Germany, data on total export value between January 1950 and February 2024 is sourced from the Bundesbank. France's total export value is available from January 1992 and terminates the same date. The original source for France's series is the French National Institute of Statistics & Economic Studies. The Japanese Ministry of Finance publishes Japan's total export data starting January 1955 to February 2024. Mexico's total export value is available from January 1980 to February 2024 and is published by the Mexican National Institute of Geography and Statistics. Finally, the Australian Bureau of Statistics publishes total export value for goods from July 1971 to February 2024. Overall, the US Export-Total Exports ratio is calculated for all countries from at least January 1998 to February 2024.

The Fraser Institute's trade freedom ranking is employed as an additional indicator of trade openness, also downloaded from Macrobond (2024). It is an annual statistic available for all countries from 2000 to 2021 and is linearly interpolated for a monthly series. Each country is awarded a ranking between 0 and 10 indicating the openness of their trade measured by tariffs, non-tariff barriers and regulatory restrictions on international trade. A higher ranking indicates fewer barriers to international trade (Fraser Institute, 2022).

Preliminary models were also estimated using the Chinn-Ito measure of financial openness (Chinn Ito, 2006) and Ilzetzki, Reinhart, and Rogoff's (2022) FX-regime measure, but a lack of variation within and between the sample countries led to high collinearity with each other and the constant. For this reason, the series were excluded from the following models.

The Corndog Index

An original contribution of this paper is the Corndog Index. The Corndog index measures the incidence of American topics in the domestic news sources of the partner countries and is used to proxy for the degree of interconnectedness of the countries. An increase in the Corndog index indicates that news articles containing American topics, defined by a dictionary of American terms and names, have increased as a proportion of total articles. To construct this index, the Global Database of Events, Language and Tone (GDELT) is used through Google's Big Query. The GDELT database monitors news media, identifying and compiling themes, tone, events, sentiment, quotes, counts, people, organisations and locations, in all articles published globally. The Corndog Index uses GDELT's Global Knowledge Graph (GKG) which tracks mentions of names, organisations, topics and themes, providing a broader data source of relationships between actors.

The Corndog Index uses a dictionary-based approach to calculate a ratio of the number of articles containing mention of American actors, organisations, and institutions to the total number of articles published in the country per day. In the dictionary (which is viewable in Appendix B) are names of American companies, geographical areas, Presidents, economic terms, notable businesspeople and acts of Congress. In sum, the dictionary contains more than 200 terms is used to identify an article as relating to American topics. Examples of words included in the dictionary are 'wall street', 'alan greenspan', 'new york stock exchange' and 'federal trade commission'. The dictionary is constructed to cover a range of topics, most related at least loosely to economics and finance, but all America-specific so no words like 'interest rates' or 'inflation' are included. Furthermore, the query is written to only flag a theme if the entire word or name is present in the article, preventing false flagging of parts of the words. The index tracks not the number of mentions of each term, nor the number of terms in the dictionary identified in each article, but rather categorises articles as containing American topics if any of the words in the dictionary is present in the article. The GKG begins 18th February 2015, and the daily Corndog Index runs from this date till March 31st 2024. However, the index is averaged over the month to match the frequency of all other explanatory and dependent variables.

The evolution of the monthly Corndog Index is illustrated in Figure 2.6. Although the time span for the index is relatively short compared to the explanatory variables above, the length is sufficient to identify significant events in America. The index for each country is fairly highly correlated, following the same pattern but different in mean. News in Mexico is the most Amer-

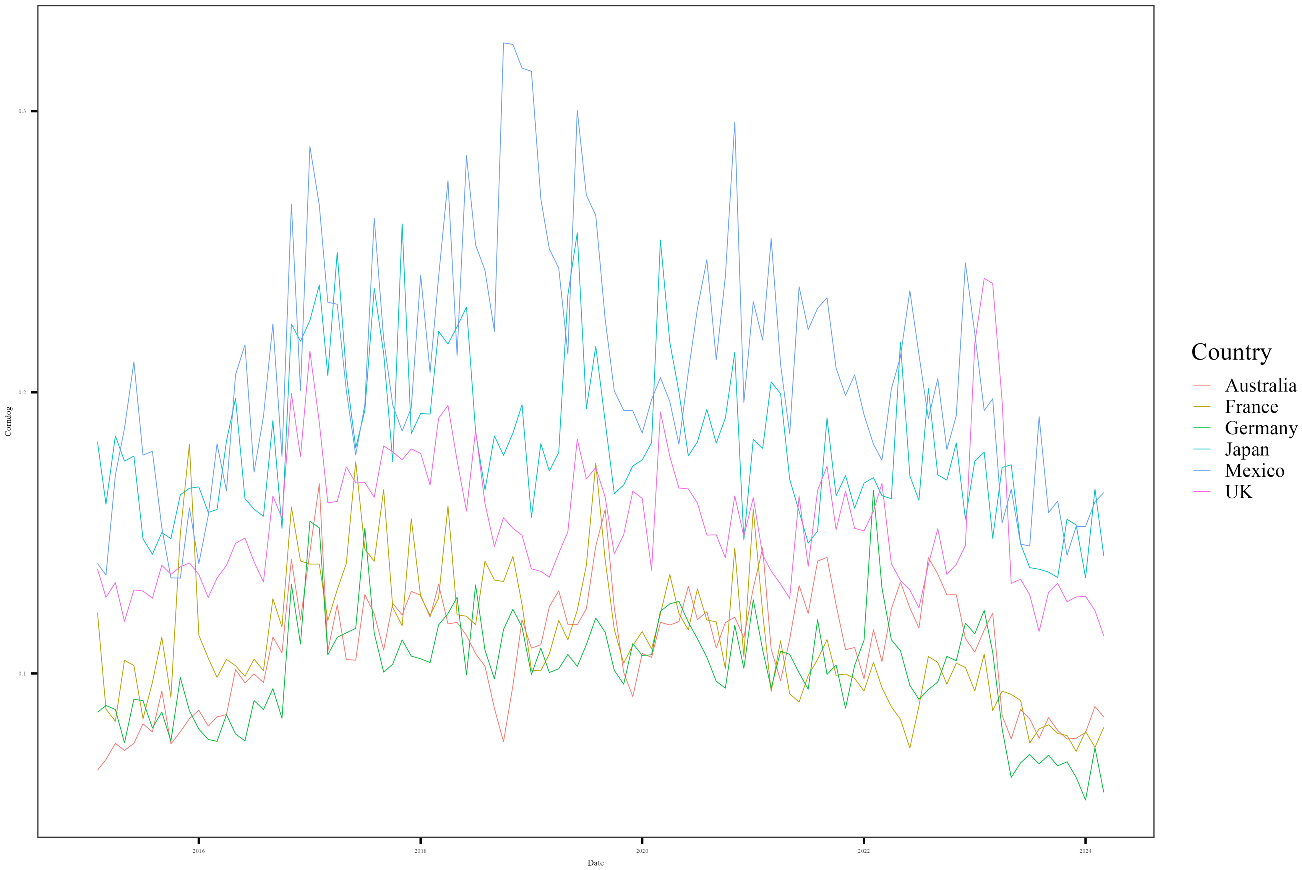

Figure 2.6: The Corndog Index

icanised, and on average 21% of all translated articles contain at least one of the words in the dictionary. Germany is the least, with only 11% of translated articles flagging as containing an American concept or theme. The maximum incidence of American topics occurs in October 2018, this is amid rising trade tensions with China and the United States' withdrawal from the Joint Comprehensive Plan of Action (Landler, 2018), a nuclear deal with Iran. 'Chapter 11 bankruptcy' is also included in the dictionary and it was also in October 2018 that Sears, an American department store chain, filed for bankruptcy which would also have contributed to the peak in the index in this month. Overall, the news sources of all six partner countries appear to respond to the same events with the index for each country experiencing spikes that coincide with the indexes for the other countries, but with varying degrees of intensity.

The Cooperation Index

The events database was used from GDELT to construct an index of cooperation between the United States and each partner country. The Cooperation Index, unlike the Corndog Index, focuses not only on the incidence of American topics in news but rather on intentions and actions of actors in the United States and each partner country to generate a time series that reflects the closeness of the relationship between the partner countries with the United States and any turbulence between key actors. Creation of the index began with identifying verbs relevant to business and the economy and listing the Conflict and Mediation Event Observation (CAMEO)

Table 2.4: Corndog Index Summary Statistics

Country	N	Mean	StDev	Min	Max
UK	110	0.154	0.025	0.113	0.241
Japan	110	0.181	0.029	0.134	0.260
Germany	110	0.102	0.020	0.055	0.165
France	110	0.113	0.024	0.072	0.182
Australia	110	0.109	0.021	0.066	0.167
Mexico	110	0.209	0.044	0.134	0.324

codes (Schrodt, 2012) which are then manually categorised as either cooperative or uncooperative in nature. A full list of the actions and their categories is in Appendix B. Cooperative actions include appeals for economic cooperation, cooperation economically, easing economic sanctions or boycotts, or easing administrative sanctions. In sum 36 actions were identified as cooperative. On the other hand, uncooperative actions included to reduce or break diplomatic relations, impose embargo, boycott or sanctions, and refusals to ease administrative sanctions. In total 29 actions were identified as uncooperative in nature.

To avoid assigning equal weight to actions of varying levels of severity, the absolute value of the Goldstein scale was used as a weight. The Goldstein scale (Goldstein, 1992) assigns values to actions based on the intensity of conflict or cooperation. Negative values are assigned to CAMEO codes that reference actions that contribute to instability and positive values are assigned to codes that contribute to stability. The higher value (in absolute), the more severe the action for stability or instability. For example, state invitations are 2.5 on the scale, a break of diplomatic relations is -7.5 and an extension of economic aid is 7.4.

The Cooperation Index is then calculated as $CooperationIndex_{it} = \Sigma_{j=1}^{J}(CooperativeAction_{j,t} \times |GoldsteinScale_j|) - (UncooperativeAction_{j,t} \times |GoldsteinScale_j|)$ where i is the partner country ($i \in \{United\ Kingdom, Germany, France, Australia, Japan, Mexico\}$), j identifies a specific action and J is the total number of actions for that day. This 'net impact' of cooperation with the United States is then averaged over the month for a monthly index ranging from January 2000 to February 2024 for each partner country.

Figure 2.7 the evolution of the cooperation index for each partner nation. The index goes through cycles identifiable every four years, the most severe of which is in 2017. The maximum value for the UK, Mexico and Japan coincides with the inauguration of President Trump in January 2017, which will have resulted in state invitations and diplomatic 'public displays of affection'. A similar evolution is visible in 2012 with the election of the incumbent President Obama and again in 2008 when he was first elected to the house. Noticeably, Mexico's index declines to almost its lowest value towards the end of the sample in April 2023 which could be explained by the Mexican President accusing the United States of espionage (Reuters, 2023).

Overall, the United Kingdom tends to have the greatest diplomatic connectedness with the United States by a large margin. Japan, France and Mexico all have similar Cooperation Index averages, with Australia having the lowest. It is worth noting that, like macroprudential attitude,

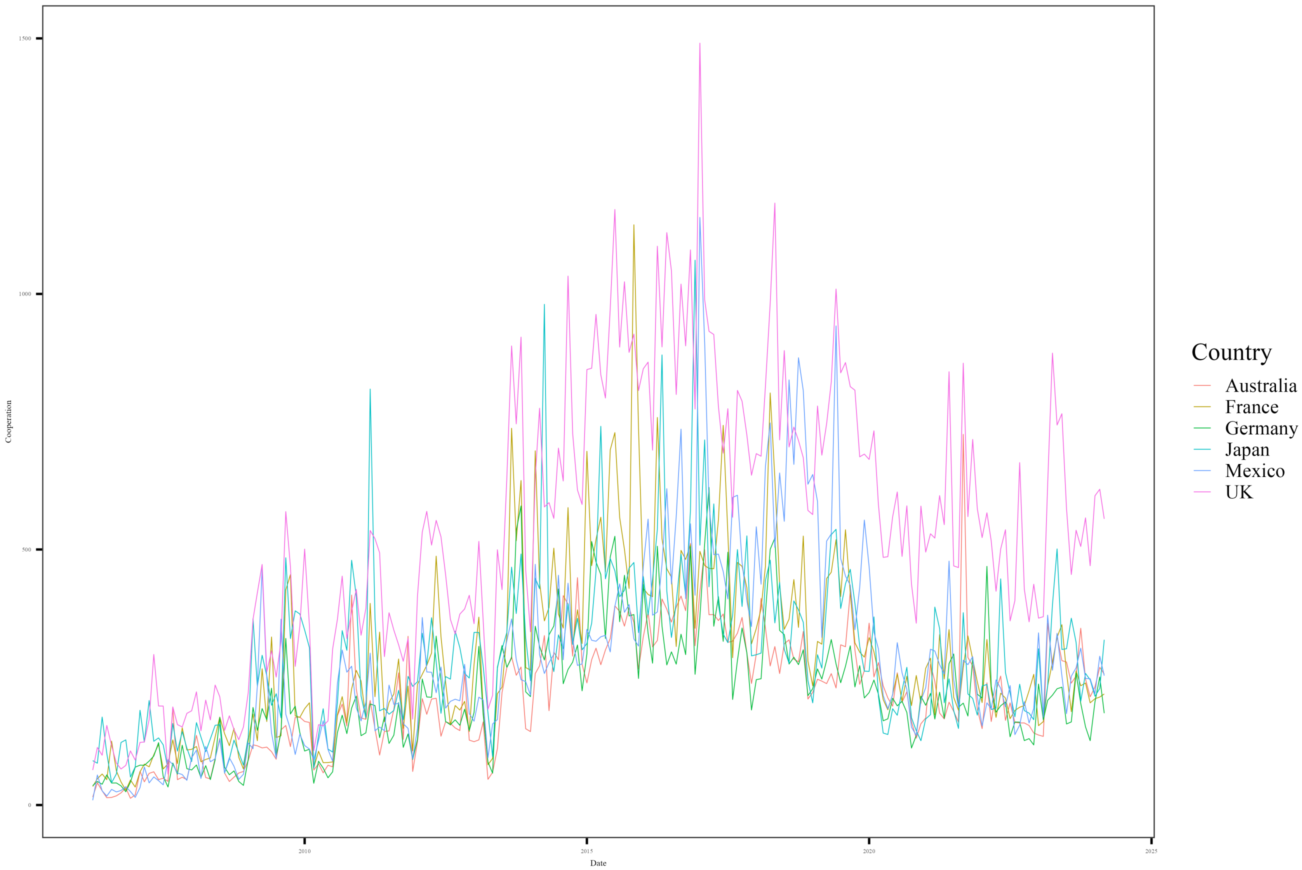

Figure 2.7: The Cooperation Index

Table 5.1: Figure 2.5: Cooperation Index Summary Statistics

Country	N	Mean	StDev	Min	Max
UK	216	535.822	276.478	60.619	1,490.716
Japan	216	293.206	158.245	43.671	1,066.039
Germany	216	219.170	122.919	26.013	621.384
France	216	291.274	176.982	28.900	1,135.327
Australia	216	214.389	116.627	13.248	725.207
Mexico	216	285.534	194.608	9.339	1,149.732

the Cooperation Index does not indicate the overall extent of diplomatic cooperation between countries and captures only the changes in cooperation (the ‘attitude’) that are identified in global news sources by GDELT.

5.4.2 Bivariate Correlation

The bivariate correlation matrix for the panel of partner is displayed in Figure 2.8. Individual country bivariate correlations as well as summary statistics and ADF test results are displayed in Appendix B. The Cooperation Index and the Corndog index are positively but not strongly corre-

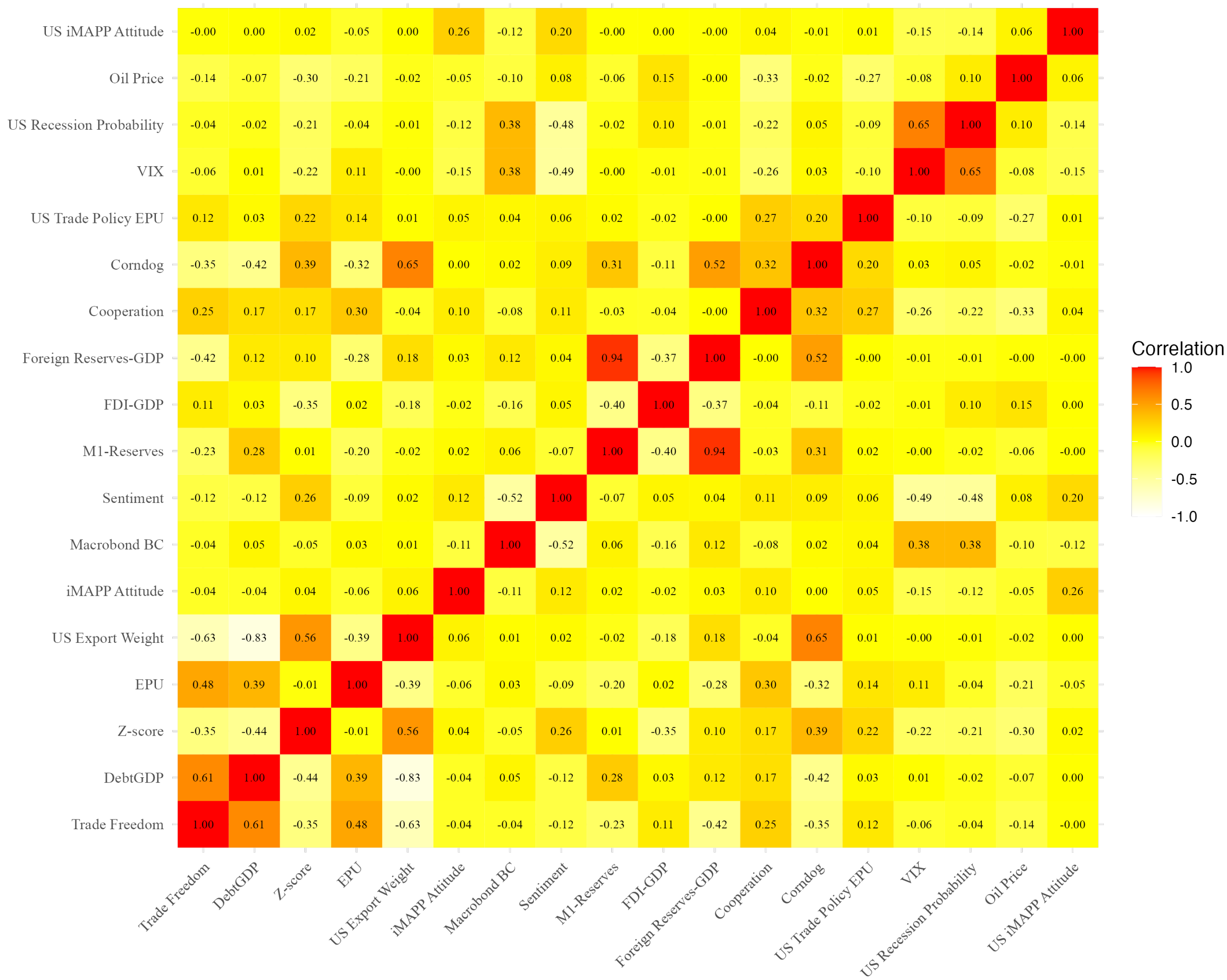

Figure 2.8: Average Bivariate Correlation Matrix

lated with a Pearson's correlation coefficient of 0.32. The positive value indicates that diplomatic relations captured by the Cooperation Index and incidence of American news are positively associated, as one would expect, but there is little concern of collinearity. Interestingly, the Corndog Index is highly related to the ratio of U.S. exports to total exports, which suggests that themes relating to main trading partners feature more heavily in domestic news. The Cooperation Index is positively correlated with trade freedom, albeit weakly, and is negatively correlated with US-Export weight which at first glance suggests almost no relationship between international trade with the United States and the diplomatic cooperation of the partner countries with the United States. iMAPP Attitude indicates tightenings of macroprudential instruments and has correlation coefficients that are expected. An increase in iMAPP Attitude is associated with a fall in Trade Freedom, the Private Sector Debt to GDP ratio and FDI to GDP, suggesting that macroprudential tightenings restrict trade and investment inflows but improves the financial condition with respect to debt.

5.5 Modelling the Determinants of Cross-Border Spillovers

5.5.1 Spillovers Received

The first models estimated concern the spillovers received by (TO) each partner country from all other countries. The spillovers indicate the sensitivity of domestic stock markets to volatility in the other partner countries and the United States and estimation of these models will supplement the analysis from Part 1 by allowing comparisons of the effect of the explanatory variables on cross-asset volatility spillovers with cross-border volatility spillovers.

A number of preliminary tests were undertaken. For concern of spurious regression, the ADF test was performed on the dependent variable. With the variable in levels, the null hypothesis of presence of a unit root could not be rejected with over 95% confidence for all partner countries. The results are shown in Table 2.6. This suggests that the dependent variable TO is non-stationary in levels. The same tests were estimated also with the dependent variable first differenced, to ensure stationarity and dispel concerns of spurious regression. The results for the first-differenced ADF tests are shown also in Table 2.6. The models estimated in each section were performed both with the dependent variable in levels and first differences for robustness.

Table 2.6: Augmented Dickey-Fuller Test Results on TO as a Dependent Variable

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
In Levels						
US	−1.1557	0.1239	−3.6263	0.0001	−4.1291	0.00002
UK	−1.2634	0.1032	−4.1464	0.00002	−4.6744	0.000001
JAPAN	−2.2009	0.0139	−5.0518	0.000000	−5.0485	0.000000
GERMANY	−0.8454	0.1990	−3.8830	0.0001	−3.9909	0.00003
FRANCE	−0.5447	0.2930	−3.2553	0.0006	−3.5697	0.0002
AUSTRALIA	−2.1914	0.0142	−5.3216	0.000000	−6.4133	0.0000
MEXICO	−1.4797	0.0695	−3.5731	0.0002	−5.7106	0.0000
First Differenced						
US	−9.7316	0.0000	−9.7095	0.0000	−9.7416	0.0000
UK	−9.4939	0.0000	−9.4832	0.0000	−9.4574	0.0000
JAPAN	−9.4296	0.0000	−9.4072	0.0000	−9.3900	0.0000
GERMANY	−10.3287	0.0000	−10.3088	0.0000	−10.2846	0.0000
FRANCE	−9.5802	0.0000	−9.5565	0.0000	−9.5334	0.0000
AUSTRALIA	−11.3168	0.0000	−11.2900	0.0000	−11.2617	0.0000
MEXICO	−9.7144	0.0000	−9.6953	0.0000	−9.6716	0.0000

In addition to the ADF tests, preliminary regressions indicated autocorrelation of the residuals, identified by a rejection of the null hypothesis of the Ljung-Box test. Testing the models with the BIC indicated that the BIC was minimised on the first lag, both for the variable in levels and in first differences. Hence, for every model, in levels and differences, the first lag of the dependent variable is included, reducing autocorrelation in the residuals and leading to a failure of rejection of the Ljung-Box test for most models.

A separate regression is estimated for each partner country and as well as an entity fixed effects panel regression to account for unobserved factors that vary across the partner countries but do not vary over the sample period. Such unobserved factors may be cultural or regulatory that are stable over time but explain differing effects of spillovers to the countries' stock markets. To test the suitability of the fixed effects regression, the Durbin-Wu-Hausman test was performed. In levels, the p-value of the test is 0.00, indicating that random effects is more appropriate but in first differences the p-value is 0.99 strongly suggesting fixed effects are more appropriate. Both panel models are estimated with fixed effects.

The robustness of the regressions with the dependent variable in levels is questionable. The R^2 for almost all countries near 0.9, most of which can be attributed to the first lag. The regressions in levels also yield Ljung-Box test statistics that imply autocorrelation in the residuals and misspecification of the model. Furthermore, the suitability of the fixed effects model is disputed by the Durbin-Wu-Hausman test. All robustness tests suggest the models in differences are more suitable, so the regression results for TO in levels are presented in the Appendix B.

The results of the separate partner country regressions and the panel regression with TO in first differences as a dependent variable are presented in Table 2.7.

Table 2.7: TO first differenced as a Dependent Variable

	OLS						*panel linear*
	United Kingdom	France	Germany	Japan	Mexico	Australia	Panel Fixed Effects
TO_difflag1	0.187^{**}	0.159^{**}	0.178^{**}	0.210^{***}	0.129^{*}	0.327^{***}	0.231^{***}
	(0.073)	(0.077)	(0.075)	(0.073)	(0.074)	(0.071)	(0.029)
TradeFreedom	−6.384	3.395	4.919	2.285	1.330	−4.475	1.695^{*}
	(7.331)	(3.635)	(5.073)	(6.581)	(6.010)	(7.038)	(0.966)
DebtGDP	-0.177^{**}	−0.007	0.058	0.038	−0.127	−0.012	−0.004
	(0.071)	(0.033)	(0.099)	(0.106)	(0.258)	(0.066)	(0.012)
Zscore	0.934^{*}	0.755^{*}	0.050	0.766^{*}	−0.045	0.822	0.212^{***}
	(0.477)	(0.435)	(0.367)	(0.410)	(0.537)	(0.680)	(0.078)
EPU	0.003	0.000	0.007	0.020	−0.008	−0.006	−0.002
	(0.005)	(0.005)	(0.006)	(0.020)	(0.017)	(0.007)	(0.002)
iMAPPAttitude	1.935	1.019	−0.244	0.718	0.451	−1.249	0.745
	(1.618)	(1.284)	(1.206)	(1.180)	(1.714)	(1.193)	(0.538)
MacrobondBC	5.560^{**}	1.113	−0.779	−0.990	−1.609	2.068	−0.597
	(2.470)	(1.233)	(1.323)	(1.554)	(1.366)	(2.154)	(0.521)
Sentiment	0.315^{***}	0.068	0.035			−0.058	
	(0.077)	(0.054)	(0.074)			(0.047)	
M1Reserves	-1.293^{**}	−0.063	0.024	−0.467	0.007	−0.019	−0.002
	(0.591)	(0.251)	(0.154)	(0.329)	(0.017)	(0.130)	(0.006)
FDIGDP	50.819	135.499	−107.836	−441.138	-596.840^{*}	42.256	−4.747
	(40.833)	(107.109)	(87.004)	(315.014)	(340.286)	(49.226)	(14.917)
ForeignReservesGDP	-876.947^{***}	−47.701	7.967	97.195	−8.557	−77.671	−8.280
	(329.807)	(112.834)	(870.600)	(121.208)	(42.968)	(54.758)	(17.655)
VIX	0.488^{***}	0.172^{**}	0.072	0.192^{**}	0.244^{***}	−0.049	0.125^{***}
	(0.087)	(0.074)	(0.063)	(0.082)	(0.082)	(0.061)	(0.023)
OilPrice	0.020	0.078	0.055	0.051	0.064	−0.084	0.022
	(0.089)	(0.070)	(0.062)	(0.087)	(0.067)	(0.057)	(0.022)
Constant	83.888	−53.770	−59.891	−33.994	12.324	38.878	
	(82.008)	(39.582)	(47.594)	(38.871)	(97.042)	(58.624)	
Observations	175	187	187	187	187	187	1,122
R^2	0.328	0.106	0.065	0.136	0.103	0.157	0.094
Adjusted R^2	0.274	0.039	−0.005	0.076	0.042	0.094	0.080
Residual Std. Error	6.422 (df = 161)	4.798 (df = 173)	4.717 (df = 173)	6.314 (df = 174)	5.500 (df = 174)	4.215 (df = 173)	
F Statistic	6.057^{***} (df = 13; 161)	1.577^{*} (df = 13; 173)	0.925 (df = 13; 173)	2.276^{**} (df = 12; 174)	1.674^{*} (df = 12; 174)	2.486^{***} (df = 13; 173)	9.544^{***} (df = 12; 1104)
Ljung-Box P-Value	0.9884	0.01331	0.02514	0.007259	0.06428	0.0006944	

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Many of the coefficients have expected signs and are statistically significant, but inevitably the R^2 declines from the regressions in levels. Immediately noticeable is the regression for the United Kingdom. We see a negative effect of the Private Sector Debt – GDP ratio on spillovers received which is puzzling because the debt-GDP ratio is an indicator of macroeconomic fundamentals. It suggests that a decline in the financial condition is associated with a decrease in the tendency for the United Kingdom's stock market to absorb volatility shocks. This coefficient is significant at the 95% level but is insignificant for all other countries and for the panel regression. An explanation for this could be the reverse of the 'flight to safety' where a declining financial condition decreases the connectedness of the United Kingdom because of investors withdrawing from the volatile domestic stock market for more stable returns abroad. It is difficult to test this hypothesis without high frequency data however, and the lack of significance for this variable across the board suggests this is not a homogenous effect.

Financial condition proxied by the z-score is an equally puzzling result. Recall that the z-score is a measure of the resilience of the banking sector to shocks, and the positive coefficient suggests that spillovers received tend to increase with an improvement in the z-score. One interpretation for the results both for z-score and debt to GDP is that countries with a stronger financial condition may be more suitable substitutes for investors faced with increased stock market risk in other economies. Investors may look to countries with stronger financial sectors as more suitable investment destinations, which may ease the transmission of volatility contagion across borders in the long-term if investors are moving money across these borders in response to volatility shocks: the 'safe haven' effect (Baur & Lucey, 2009). The coefficient remains positive in the panel.

Key variables of interest including domestic macroprudential attitude, economic policy uncertainty and Foreign Direct Investment to GDP have little significance across the models. Equity market volatility or investor 'fear' reflected in the VIX is almost unanimously significant across the sample with expected signs. The positive and significant coefficients for the UK, France, Japan, Mexico and the panel suggests that volatility spillovers increase when investors anticipate greater volatility. This is also coherent with the results in Part 1, and we can conclude that investor fear contributes to spillovers both across asset classes and borders. The coefficient is highest for the United Kingdom suggesting that volatility spillovers for the United Kingdom are most sensitive to global investor fear.

Like in Part 1, it can also be observed for the United Kingdom that recession increases the spillovers received. This is coherent with literature documenting negative spillovers being more fluid than positive spillovers (Longin & Solnik, 2001; BenSaïda, 2019). Recession probability for the United States was identified as having a positive association with cross-asset spillovers in Part 1, and the effect appears to hold for cross-border spillovers, but only for the United Kingdom.

The coefficient on the Fraser Institute's trade freedom ranking is also significant and positive in the panel, suggesting lower barriers to trade are associated with greater international spillovers. The intuition behind this is perfectly understandable: countries with greater international openness with respect to trade will be more sensitive to changing economic conditions in export destination countries which is a transmission mechanism for equity market volatility. This effect is observed in much of the volatility spillover literature concerning gravity models (Chen & Zhang, 1997). The trade freedom indicator will also likely reflect the countries attitude to capital flows across borders which can also transmit volatility shocks across borders.

Overall, the confidence in the explanatory power of the models is weakened by the low R^2, but some there are still some valuable interpretations to make from the models. Spillovers received are persistent, exhibiting significant and positive AR(1) coefficients, openness to trade makes countries more susceptible to volatility spillovers and investor fear has a positive association with spillover transmission. Of the variables that are identified as being significant, parallels can be drawn with Part 1. Unlike Part 1 however, macroprudential attitude has little effect and the presence of a crisis in the recipient country has no significant effect on the country's capacity to absorb spillovers.

5.5.2 Pairwise Connectedness with the United States

The following models assess not just a country's spillovers received from the other countries in the sample but assesses the relationship with the United States in more detail. Hence, the dependent variable is the pairwise connectedness (PCI) of each county with the United States. The United States dollar is the dominant global currency and the United States is the most significant contributor of spillovers to the rest of the world (Ahmed et al., 2021). For this reason, investigating the causes and transmission mechanisms of spillovers originating in the United States has important implications for domestic governments, institutions and regulators.

The dependent variable is bi-directional, capturing spillovers not just contributed by the United States to the partner countries but also received, so explanatory variables both for the partner country and United States are used. It is in these regressions that the United States-specific Corndog Index and Cooperation Index are employed.

In line with the previous section, preliminary tests were performed prior to estimation of the final models. Table 2.8 displays the ADF test statistics for pairwise connectedness in levels and first differences. The non-stationarity of these series is even easier to accept than with spillovers TO, with an almost unanimous failure to reject the null hypothesis. Furthermore, with the variables in levels, preliminary regressions on the explanatory variables and including the first lag (as deemed optimal by the BIC) still led to a rejection of the null hypothesis for the Ljung-Box test, indicating autocorrelation in the residuals. As with the previous section, the regression results for PCI in levels are displayed in Appendix B.

Table 2.8: Augmented Dickey-Fuller Test Results on Pairwise Connectedness as a Dependent Variable

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
In Levels						
US-UK	−1.0773	0.1407	−2.8379	0.0023	−3.5779	0.0002
US-JAPAN	−2.2825	0.0112	−4.2121	0.00001	−4.2249	0.00001
US-GERMANY	−1.0203	0.1538	−2.7921	0.0026	−3.6975	0.0001
US-FRANCE	−1.0142	0.1552	−2.9890	0.0014	−3.6946	0.0001
US-AUSTRALIA	−1.8664	0.0310	−4.5268	0.000003	−4.7095	0.000001
US-MEXICO	−1.2258	0.1101	−2.3801	0.0087	−4.2916	0.00001
First-Differenced						
US-UK	−9.5154	0.0000	−9.4961	0.0000	−9.5197	0.0000
US-JAPAN	−8.4675	0.0000	−8.4474	0.0000	−8.4473	0.0000
US-GERMANY	−10.4811	0.0000	−10.4604	0.0000	−10.4631	0.0000
US-FRANCE	−10.6090	0.0000	−10.5839	0.0000	−10.5874	0.0000
US-AUSTRALIA	−9.3251	0.0000	−9.3072	0.0000	−9.2953	0.0000
US-MEXICO	−9.1689	0.0000	−9.1515	0.0000	−9.1673	0.0000

Following first differencing, the pairwise connectedness series are stationary. Models are estimated in the same format as the TO regressions: separate regressions for each country and a fixed effects model for the panel. Despite a failure to reject the null hypothesis of the Durbin-Wu-Hausman test with PCI with the United States as a dependent variable, fixed effects are included regardless to avoid potential omitted variables bias of unobserved country-specific factors.

Regressions with the Corndog Index and regressions without the Corndog Index are presented. Given that the Corndog Index has no observations prior to February 2015, inclusion of the variable is significantly limiting for the degrees of freedom and reduces the estimation to only 83 observations when included in conjunction with other variables that terminate prior to the February 2024, like macroprudential attitude and ratios including GDP.

Table 2.9 shows the regression results of the estimation with the inclusion of the Corndog Index. Even in first differences, the R^2 is still reasonable and is over 0.3 for all countries, implying at least 30% of the variation in the first-differenced PCI is explained by the variation of the explanatory variables for each partner country.

The coefficient on export weight to the U.S. is significant only for France and takes the expected sign. The positive value indicates that a 1% increase in the proportion of exports going to the U.S. out of all exports increases volatility spillovers by about the same amount. Z-score is also significant only for France and suggests an inverse relationship between the banking sector resilience and spillover transmission with the United States.

The most important variables are the VIX, Corndog Index and Cooperation Index. The VIX is again widely significant across the panel and the sign is consistent with both Part 1 and the previous section. So far, investor fear is one of the most powerful variables explaining spillover transmission across asset classes and borders. The Corndog Index is not significant for any model, and the sign changes depending on the partner country. Therefore, it cannot be said that the relative intensity of American themes in domestic news sources ease the transmission of spillovers. It is possible with a wider sample or a broader dictionary this variable may offer more insight.

The Cooperation Index also suffers from lack of significance across the individual country regressions but has a positive and significant coefficient for the panel, giving some weight to the argument that diplomatic cooperation with the United States increases the sensitivity of the domestic stock market's volatility to the volatility of American equities.

For the most part, the Ljung-Box test of the residuals leads to a failure to reject the null hypothesis. This suggests that the inclusion of the first lag, as suggested by the BIC, has been sufficient to capture most of the autocorrelation in first differences. Indeed, it is only for the United Kingdom that the null hypothesis can be rejected, and only with 95% confidence.

Considering now the same models estimated without the Corndog Index, the results do not change drastically but some variables that had little variation over the 83 months in the previous model, like export weight, trade freedom, and the recession indicator are now significant. Estimating now with 187 observations has led to better fitting models.

The variable measuring the proportion of total exports going to the United States, U.S. Export Weight, is now significant and positive for France and for the panel model. Trade freedom is also highly significant for the panel regression, also suggesting liberalisation of trading barriers

Table 2.9: PCI first differenced as a Dependent Variable (including Corndog Index
)

	OLS						*panel linear*
	United Kingdom	France	Germany	Japan	Mexico	Australia	Panel Fixed Effects
PCI_difflag1	0.146	−0.031	0.060	0.216*	0.111	0.318**	0.168***
	(0.118)	(0.123)	(0.129)	(0.109)	(0.113)	(0.138)	(0.043)
USExportWeight	−75.235	102.506*	−135.802	26.022	13.460	−70.311	6.239
	(115.812)	(55.524)	(92.210)	(52.493)	(19.119)	(72.186)	(12.291)
USTradePolicyEPU	−0.006	−0.004*	−0.001	−0.009***	−0.002	−0.003	−0.002**
	(0.004)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.001)
TradeFreedom	−2.880	8.368	−20.833	−21.449	−2.667	11.035	2.142
	(10.375)	(13.478)	(14.655)	(44.366)	(9.356)	(24.881)	(1.840)
DebtGDP	−0.260	−0.014	−0.762**	−0.940	−0.423	0.247	−0.058*
	(0.195)	(0.175)	(0.355)	(1.357)	(0.491)	(0.290)	(0.031)
Zscore	−0.291	2.872**	−0.585	−3.165	−0.063	0.720	0.044
	(1.025)	(1.199)	(0.937)	(2.299)	(2.236)	(4.812)	(0.229)
EPU	0.007	−0.019***	−0.005	0.029	0.011	−0.002	−0.005
	(0.006)	(0.007)	(0.008)	(0.034)	(0.028)	(0.013)	(0.003)
MacrobondBC	−3.374	−3.517	2.932	−3.827	−0.668	1.409	−0.753
	(3.257)	(3.151)	(2.612)	(3.689)	(1.834)	(3.568)	(0.780)
USRecessionProbability	−0.004	−0.040	0.076	0.034	0.067	0.012	0.057**
	(0.075)	(0.061)	(0.061)	(0.086)	(0.060)	(0.060)	(0.022)
M1Reserves	0.126	−0.846*	0.079	−0.009	0.104	−0.815**	−0.004
	(1.041)	(0.487)	(0.264)	(0.094)	(1.183)	(0.392)	(0.010)
FDIGDP	48.009	−154.012	602.478	154.418	221.543	−242.047*	45.813
	(73.883)	(265.847)	(674.345)	(1,453.228)	(2,930.533)	(122.438)	(27.841)
ForeignReservesGDP	−893.586**	−577.913	475.795	−286.666	−154.771	−337.932	−35.945
	(446.306)	(577.341)	(2,889.130)	(314.513)	(178.661)	(245.654)	(57.429)
VIX	0.661***	0.653***	0.326**	0.568**	0.361**	0.412***	0.387***
	(0.198)	(0.162)	(0.152)	(0.237)	(0.168)	(0.146)	(0.056)
OilPrice	0.198	0.191	0.291	0.810***	0.269	0.288	0.316***
	(0.251)	(0.156)	(0.174)	(0.276)	(0.203)	(0.212)	(0.064)
Corndog	−2.562	−21.622	−18.780	28.487	2.102	13.600	−14.288
	(48.926)	(31.085)	(39.350)	(41.835)	(21.187)	(35.649)	(9.559)
Cooperation	0.005	0.007	0.003	−0.013	0.000	−0.003	0.004**
	(0.005)	(0.005)	(0.007)	(0.008)	(0.005)	(0.008)	(0.002)
iMAPPAttitude	1.878	1.237	0.139	−0.464	0.232	−1.694	0.563
	(1.815)	(1.423)	(1.327)	(2.400)	(1.280)	(1.502)	(0.585)
USiMAPPAttitude	−0.788	0.074	−0.842	1.104	−0.649	−0.395	−0.729
	(1.554)	(1.244)	(1.182)	(1.830)	(1.428)	(1.273)	(0.522)
Constant	104.610	−115.364	301.638*	473.008	39.584	−124.517	
	(140.731)	(166.058)	(167.657)	(617.274)	(97.191)	(144.502)	
Observations	83	83	83	83	83	83	498
R^2	0.415	0.460	0.332	0.414	0.368	0.445	0.289
Adjusted R^2	0.250	0.308	0.144	0.250	0.190	0.288	0.254
Residual Std. Error (df = 64)	5.440	4.252	4.287	6.178	4.644	4.347	
F Statistic	2.522*** (df = 18; 64)	3.028*** (df = 18; 64)	1.764* (df = 18; 64)	2.515*** (df = 18; 64)	2.068** (df = 18; 64)	2.845*** (df = 18; 64)	10.694*** (df = 18; 474)
Ljung-Box P-Value	0.04277	0.1337	0.182	0.1745	0.2627	0.04376	
Notes:	***Significant at the 1 percent level. **Significant at the 5 percent level. *Significant at the 10 percent level.						

will ease volatility spillovers across borders. The Cooperation Index becomes significant for the United Kingdom and France, but the effect of cooperation on spillovers is less clear-cut and the positive relationship does not hold for the other partner countries nor for the fixed effects regression. Macroprudential regulatory attitude (iMAPP attitude) has a significant negative effect only for Australia, and indeed this is only with a confidence interval of 90%.

There are some more puzzling results when estimating across the longer sample period. Z-score is highly significant and positive for the fixed effects regression: an improvement in banking resilience increases spillovers with the United States. This may be explained by the substitution

Table 2.10: PCI first differenced as a Dependent Variable (excluding Corndog Index)

	OLS						*panel linear*
	United Kingdom	France	Germany	Japan	Mexico	Australia	Panel Fixed Effects
PCI_difflag1	0.132*	−0.004	0.132*	0.259***	0.133*	0.322***	0.223***
	(0.070)	(0.072)	(0.074)	(0.072)	(0.072)	(0.071)	(0.029)
USExportWeight	53.374	97.370***	5.861	17.194	4.676	−25.173	16.886**
	(55.517)	(34.162)	(43.803)	(23.330)	(12.107)	(41.247)	(7.521)
USTradePolicyEPU	−0.006***	−0.001	−0.003*	−0.005**	−0.002	−0.005***	−0.001*
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
TradeFreedom	−0.071	2.357	5.607	6.068	7.122	30.899***	2.855***
	(4.530)	(3.296)	(4.879)	(6.587)	(5.288)	(8.766)	(0.838)
DebtGDP	−0.250***	−0.002	0.085	−0.135	−0.045	0.207**	−0.005
	(0.064)	(0.025)	(0.093)	(0.311)	(0.097)	(0.085)	(0.010)
Zscore	0.180	1.331***	0.601*	0.012	0.664**	0.841	0.273***
	(0.373)	(0.369)	(0.314)	(0.608)	(0.304)	(0.731)	(0.067)
EPU	−0.001	−0.012***	0.002	0.014	0.031**	0.016**	−0.004*
	(0.004)	(0.004)	(0.005)	(0.017)	(0.015)	(0.008)	(0.002)
MacrobondBC	−1.351	−0.515	0.687	−1.196	−2.007*	−0.659	−1.243***
	(1.606)	(0.985)	(1.129)	(1.302)	(1.170)	(2.554)	(0.444)
USRecessionProbability	−0.032	−0.010	−0.027	−0.025	−0.024	−0.012	−0.024***
	(0.022)	(0.020)	(0.020)	(0.030)	(0.019)	(0.021)	(0.007)
M1Reserves	−0.521	−0.481**	−0.007	0.014	−0.487*	−0.397***	−0.002
	(0.330)	(0.211)	(0.138)	(0.020)	(0.258)	(0.146)	(0.005)
FDIGDP	35.580	158.233*	−10.660	−695.725**	−193.393	−222.078***	−0.903
	(22.449)	(81.059)	(74.186)	(352.334)	(236.332)	(57.107)	(12.640)
ForeignReservesGDP	−338.605	23.344	452.240	−22.009	71.184	32.407	1.548
	(236.391)	(90.111)	(802.467)	(40.819)	(102.978)	(61.459)	(14.828)
VIX	0.389***	0.439***	0.252***	0.328***	0.257***	0.264***	0.258***
	(0.068)	(0.065)	(0.059)	(0.091)	(0.072)	(0.075)	(0.025)
OilPrice	0.027	0.059	0.058	0.158**	0.036	0.175***	0.050***
	(0.063)	(0.059)	(0.060)	(0.067)	(0.064)	(0.062)	(0.018)
Cooperation	0.005**	0.004*	0.005	−0.005	0.005	−0.000	0.002
	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)	(0.004)	(0.001)
iMAPPAttitude	1.638	1.042	0.708	−0.312	0.135	−2.349*	0.311
	(1.203)	(1.045)	(1.049)	(1.693)	(0.886)	(1.298)	(0.459)
USiMAPPAttitude	−0.906	−0.194	−0.451	0.213	−0.553	1.036	−0.701
	(1.106)	(0.886)	(0.970)	(1.262)	(1.192)	(1.094)	(0.426)
Constant	58.252	−54.527	−83.673*	−33.515	−70.463**	−297.226***	
	(53.842)	(35.924)	(45.890)	(112.019)	(32.734)	(74.331)	
Observations	187	187	187	187	187	187	1,122
R^2	0.320	0.363	0.201	0.278	0.258	0.333	0.200
Adjusted R^2	0.251	0.299	0.120	0.205	0.184	0.266	0.183
Residual Std. Error (df = 169)	4.559	3.862	3.949	5.055	4.494	4.384	
F Statistic	4.669*** (df = 17; 169)	5.660*** (df = 17; 169)	2.496*** (df = 17; 169)	3.819*** (df = 17; 169)	3.460*** (df = 17; 169)	4.957*** (df = 17; 169)	16.112*** (df = 17; 1099)
Ljung-Box P-Value	0.01676	1.244e-06	3.621e-05	0.003232	0.009273	0.0008715	
Notes:	***Significant at the 1 percent level.						
	**Significant at the 5 percent level.						
	*Significant at the 10 percent level.						

effect suggested in the previous section where volatility in one country's stock market may induce a flight to safety or safe haven effect (Baur & Lucey, 2009; Bampinas et al., 2023) as investors look to more resilient economies or assets for their investments, creating short-term volatility in this recipient market. This theory is also supported by the negative coefficient on the recession indicator which is a binary variable and equal to 1 during a recession. Hence, the presence of a recession in the partner country reduces the connectedness of the partner country to the United States.

5.6 Summary

To summarise, a number of variables have been identified as being relevant to a country's stock market's susceptibility to volatility spillovers. With regards only to spillovers received, freedom of trade and the VIX are significant. Based on the fixed effects model, an increase in the trade freedom ranking by 1 is associated with a 1.7% increase in spillovers received by country i from all other countries ji in the sample. The effect of 'fear' captured by the VIX is weaker, but the significance of the variable is found in individual country regressions as well as in the fixed effects model. Furthermore, an increased resilience of the banking sector measured by the z-score is also associated with heightened volatility spillovers.

For the pairwise connectedness of the partner countries with the United States, the 'fear' index is equally significant but with a larger coefficient. A one unit increase in the VIX increases a country's stock market volatility spillovers from the rest of the countries in the sample by 0.125% but increases the pairwise spillover directly with the United States by 0.387%. Hence, the VIX is more relevant for a country's connectedness with the United States than for connectedness in general. The Corndog and Cooperation Indexes were not entirely successful at explaining the variation in the levels of volatility spillovers, with the Corndog Index's parameter sign varying with each country regression and remaining statistically insignificant throughout. The Cooperation Index was more successful, being significant and positive in the PCI regression with the Corndog Index and the shorter sample period, and being positive but mostly insignificant for the country and panel regressions without the Corndog Index.

6 Conclusion

There are several methodological limitations to the research presented in this paper. Firstly, while the methodology of Diebold and Yilmaz is widely used and is versatile in application, the spillover indexes are sensitive to the sample selection. In order to increase the robustness of this investigation, future research would benefit from a broader sample selection. Indeed, in Diebold and Yilmaz's own paper from 2009 they employed series on 19 countries for cross-border spillover analysis. Additionally, the Corndog Index could be supplemented. The dictionary used to devise the Corndog index is fairly elementary, containing roughly 200 words and could easily be expanded for greater accuracy. Not only this, but the Global Knowledge Graph also tracks the mention of a theme through time, and the Corndog Index could be improved by measuring the intensity of the American themes by their persistence in the partner country's news, rather than just counting articles. This would vastly improve the information content of the index by giving greater weight to more important themes mentioned a greater number of times over a longer period.

Despite these weaknesses, this paper had three main objectives that it fulfilled with varying levels of success. The first was to determine the factors influencing the volatility spillovers across the stock, bond, foreign exchange and commodities markets in the United States. It has largely been successful in this regard. Economic policy uncertainty was identified as a contributor to spillovers, but the strongest factors were the probability of recession and investor 'fear', measured by the VIX. This is consistent with previous literature and shows that spillovers can be explained by indicators broader than just those reflecting economic fundamentals.

The second objective of this paper was to discuss what factors ease the transmission of spillovers to a country's stock market, and what factors contribute to the United States' status as the epicentre of spillovers (Ahmed, 2021). The paper has been less successful in achieving this objective, but some factors were highlighted as important. Among these was the VIX. A higher VIX is associated with more spillovers TO a country. Additionally, the z-score of financial resilience was also identified as a contributing factor for volatility spillovers received: higher resilience of a country's banking sector is associated with a higher intake of volatility spillovers, compatible with the flight to safety effect identified in Bampinas et al. (2023). While 'fear' had a significant effect across the board, 'loathing', measured by the Cooperation Index, was significant only for select models and the Corndog Index was not significant throughout.

Consensus was also drawn with the literature regarding the impact of international trade on spillovers. Where the effect was significant, the weight of exports going to the United States had a positive effect on spillovers, suggesting those countries that are closer trading partners with the United States lubricates the transmission mechanisms for international volatility spillovers. More generally, trade freedom also had a positive and significant coefficient, but only for the fixed effects model, also showing that openness to trade increases the transmission of stock market volatility shocks.

The final objective of this paper was to provide a comparative analysis discussing factors that contribute to cross-border and cross-asset spillovers symmetrically or asymmetrically. While macroprudential attitude, recession probability, economic policy and financial condition were identified as having a significant effect on cross-asset spillovers, only VIX had a significant effect on cross-border spillovers as well. There was some significance for probability of recession in the fixed effects panel models and other financial condition indicators, but the effect of economic policy uncertainty and macroprudential attitude was not robustly identified. This suggests that policy makers are able to limit cross-asset contagion within their country, but their ability to inhibit cross-border contagion is limited.

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A Cross-Asset Appendix

Table A.1: Log Volatility Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Max	Skewness	Kurtosis
Stocks	5,595	−10.1759800000	1.2639640000	−14.0833600000	−5.4518380000	0.258229	3.104495
Commodities	5,595	−10.0393900000	0.9450782000	−13.9035900000	−4.3387530000	0.259296	3.448212
Bonds	5,595	−8.7623070000	1.1651420000	−12.7048000000	−3.4677600000	0.242427	3.273113
Foreign Exchange	5,595	−11.0460500000	0.9419951000	−14.2176700000	−7.6288460000	0.035459	3.057114

Table A.2: Augmented Dickey-Fuller Test Results for Log Volatility

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
Stocks	−2.2076	0.0136	−20.9378	0.0000	−21.3007	0.0000
Commodities	−2.1892	0.0143	−30.0210	0.0000	−30.2776	0.0000
Bonds	−2.8312	0.0023	−25.8027	0.0000	−27.0977	0.0000
Foreign Exchange	−1.9947	0.0230	−29.1906	0.0000	−30.4146	0.0000

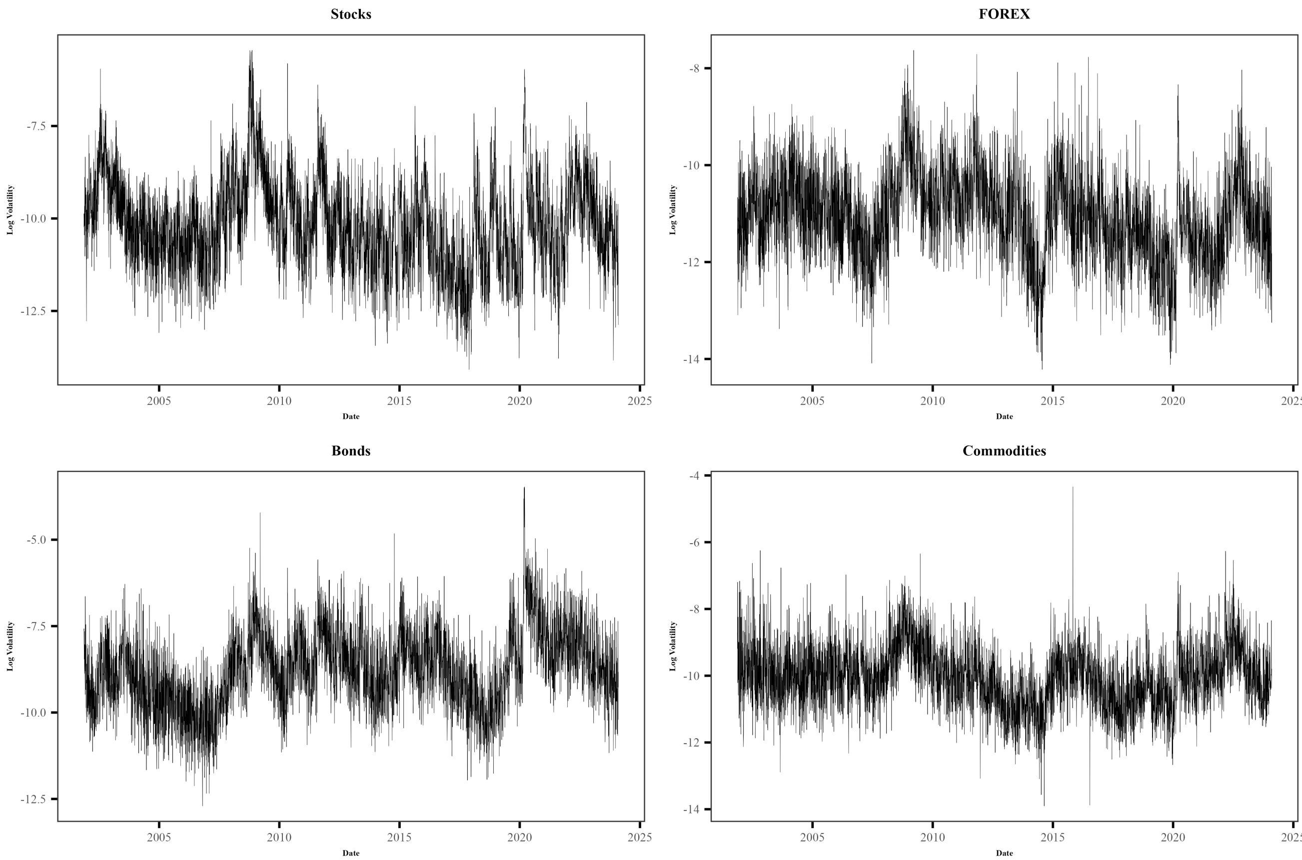

Figure A.1: Log Volatility

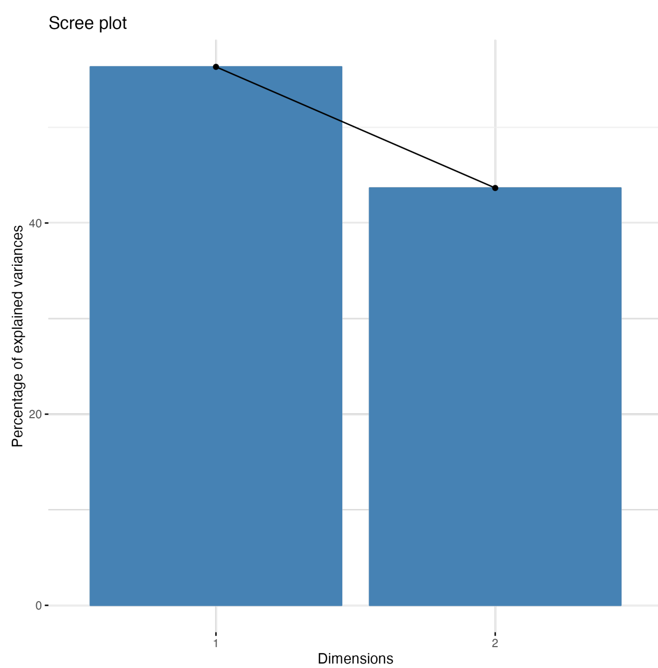

Figure A.2: Principal Components Analysis: Equity

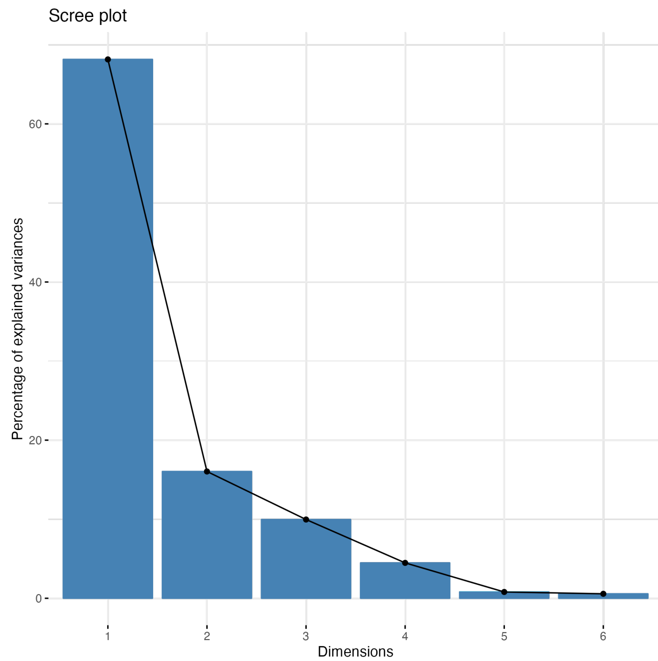

Figure A.3: Principal Components Analysis: Financial Stress

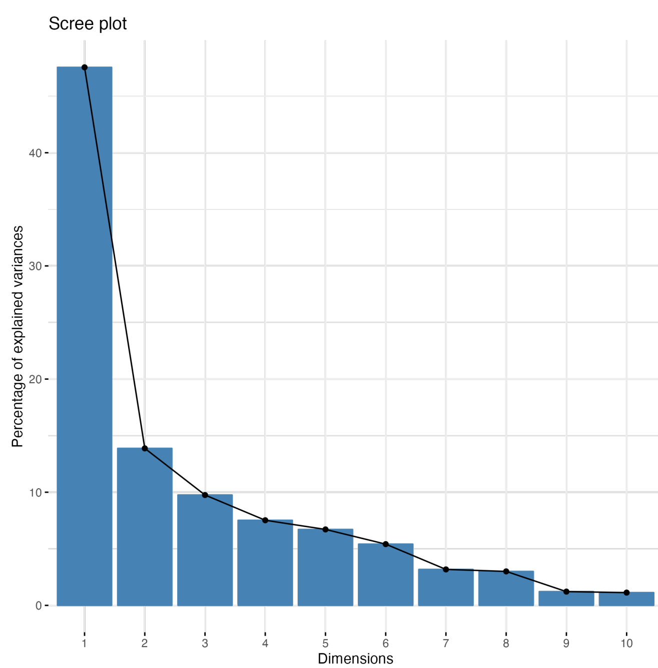

Figure A.4: Principal Components Analysis: Uncertainty

Table A.3: Explanatory Variable Summary Statistics

	N	Mean	StdDev	Min	Max	Skewness	Kurtosis
EPU	470	106.089	51.721	37.266	503.012	2.543	15.132
MONETARY	470	96.521	60.245	16.575	407.941	1.553	6.356
FISCAL	470	109.110	66.238	23.052	433.294	1.609	6.065
TAXES	470	110.288	67.221	24.441	471.900	1.761	7.159
GOVERNMENTSPEND	470	101.526	94.270	5.777	635.272	2.456	10.584
NATIONALSECURITY	470	96.013	76.012	23.737	758.263	3.793	24.484
ENTITLEMENTPROGRAMS	470	125.820	119.384	11.051	1,118.785	3.569	21.576
REGULATION	470	110.811	55.556	28.193	384.390	1.495	6.135
FINANCIALREGULATION	470	105.412	115.570	0	877.546	2.864	13.822
TRADEPOLICY	470	122.848	177.655	6.467	1,946.683	4.741	35.455
SOVEREIGNDEBT	470	101.524	179.724	0	1,492.835	4.380	27.721
DEBTCEILING	460	0.0003	0.001	0	0.013	8.212	83.627
GOVERNMENTSHUTDOWN	460	0.0004	0.002	0	0.029	14.846	266.768
TB-FEDFUNDS	470	−0.256	0.358	−1.380	0.640	−1.070	3.785
RECESSION	470	0.077	0.266	0	1	3.184	11.139
FREDSTRESS	362	0.002	0.978	−1.113	8.272	4.032	27.059
VIX	410	19.562	7.545	10.125	62.669	1.994	9.658
CONSUMERSENT	470	86.507	12.720	50	112	−0.545	2.688
EMVOLATILITY	470	0.380	0.367	0	3.952	3.277	23.736
RECESSIONPROB	469	5.406	19.131	0	100	4.010	18.316
OIL	470	27.061	11.885	8.922	66.798	0.797	2.798
M2-TO-RESERVES	469	59.311	53.459	4.018	176.749	0.626	2.125
10-2SPREAD	470	1.015	0.879	−0.929	2.834	0.173	2.071
FINANCIALCONDITIONS	470	−0.355	0.501	−1.115	2.770	2.552	12.896
MACROPRUDENTIALATTITUDE	384	0.008	0.245	−1	1	0.438	16.668
FSTRESS	384	101.128	0.794	99.543	105.891	1.244	7.204
CONSUMERSENT_diff	469	−0.041	4.033	−17.300	17.300	−0.163	4.540
M2-TO-RESERVES_diff	468	−0.109	5.959	−93.329	26.659	−9.838	144.720
10-2SPREAD_diff	469	−0.004	0.142	−0.718	0.592	0.059	6.006
OIL_diff	469	0.012	2.296	−11.647	7.048	−0.820	6.230

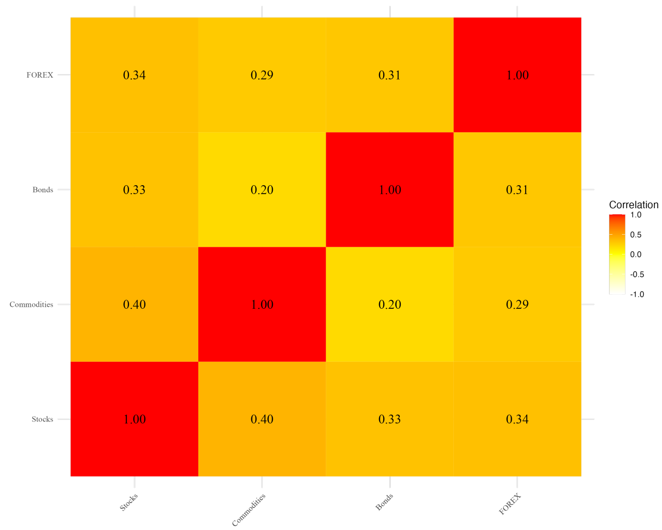

Figure A.5: Log Volatility Bivariate Correlation Matrix

Table A.4: Augmented Dickey-Fuller Test Results on Explanatory Variables

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
EPU	−2.9393	0.0016	−7.1801	0.0000	−7.2414	0.0000
MONETARY	−4.3247	0.00001	−9.2088	0.0000	−9.2189	0.0000
FISCAL	−3.6134	0.0002	−7.4311	0.0000	−7.4990	0.0000
TAXES	−3.4688	0.0003	−7.1243	0.0000	−7.2784	0.0000
GOVERNMENTSPEND	−5.6458	0.0000	−8.9388	0.0000	−9.0558	0.0000
NATIONALSECURITY	−4.1227	0.00002	−7.2474	0.0000	−7.2704	0.0000
ENTITLEMENTPROGRAMS	−4.6953	0.000001	−7.2903	0.0000	−7.7811	0.0000
REGULATION	−2.9130	0.0018	−7.5683	0.0000	−7.9523	0.0000
FINANCIALREGULATION	−5.2509	0.0000	−7.8995	0.0000	−7.9541	0.0000
TRADEPOLICY	−4.3362	0.00001	−5.5065	0.0000	−5.5266	0.0000
SOVEREIGNDEBT	−6.9032	0.0000	−8.2639	0.0000	−8.2941	0.0000
DEBTCEILING	−9.8224	0.0000	−10.4395	0.0000	−10.6715	0.0000
GOVERNMENTSHUTDOWN	−10.2859	0.0000	−10.7748	0.0000	−10.9314	0.0000
TB-FEDFUNDS	−3.2266	0.0006	−3.9672	0.00004	−5.3435	0.0000
RECESSION	−5.3968	0.0000	−5.6405	0.0000	−5.6375	0.0000
FREDSTRESS	−4.8134	0.000001	−4.8066	0.000001	−4.8434	0.000001
VIX	−2.1232	0.0169	−6.0211	0.0000	−6.0140	0.0000
CONSUMERSENT	−0.6809	0.2480	−3.4314	0.0003	−3.6896	0.0001
EMVOLATILITY	−5.1465	0.0000	−8.3988	0.0000	−8.4288	0.0000
RECESSIONPROB	−5.3054	0.0000	−5.5322	0.0000	−5.5266	0.0000
OIL	−1.1120	0.1331	−2.9069	0.0018	−3.5783	0.0002
M2-TO-RESERVES	−1.1934	0.1164	−1.4426	0.0746	−1.8146	0.0348
10-2SPREAD	−1.6921	0.0453	−2.1354	0.0164	−2.1414	0.0161
FINANCIALCONDITIONS	−3.8986	0.00005	−4.8370	0.000001	−4.8601	0.000001
MACROPRUDENTIALATTITUDE	−12.3771	0.0000	−12.3779	0.0000	−12.4766	0.0000
FSTRESS	−0.0786	0.4687	−5.6556	0.0000	−5.7499	0.0000
CONSUMERSENT_diff	−17.8858	0.0000	−17.8693	0.0000	−17.8502	0.0000
M2-TO-RESERVES_diff	−14.2808	0.0000	−14.2711	0.0000	−14.2743	0.0000
10-2SPREAD_diff	−14.0690	0.0000	−14.0614	0.0000	−14.0636	0.0000
OIL_diff	−13.1328	0.0000	−13.1188	0.0000	−13.1049	0.0000

Table A.5: Augmented Dickey-Fuller Test on Dependent Variables

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
TCI	−0.5439	0.2933	−4.6818	0.000001	−5.2483	0.0000
Stocks-Commodities	−1.7149	0.0432	−5.6259	0.0000	−5.7303	0.0000
Stocks-Bonds	−2.0740	0.0190	−6.0890	0.0000	−6.1848	0.0000
Stocks-FOREX	−2.0510	0.0201	−5.5329	0.0000	−5.7761	0.0000
Commodities-Bonds	−1.1107	0.1333	−5.2808	0.0000	−5.4706	0.0000
Commodities-FOREX	−1.8087	0.0353	−6.2101	0.0000	−6.3686	0.0000
Bonds-FOREX	−0.7605	0.2235	−3.6892	0.0001	−4.3925	0.00001

B Cross-Border Appendix

Table B.1: Log Volatility Summary Statistics

	N	Mean	StdDev	Min	Max	Skewness	Kurtosis
US	4,705	−10.240	1.286	−14.083	−5.452	0.322	3.148
UK	4,705	−10.006	1.105	−13.142	−5.343	0.463	3.400
JAPAN	4,705	−10.121	1.103	−13.517	−4.986	0.482	3.674
GERMANY	4,705	−9.806	1.151	−14.109	−5.409	0.243	3.142
FRANCE	4,705	−9.840	1.139	−14.179	−5.779	0.256	3.088
AUSTRALIA	4,705	−10.380	1.097	−13.374	−5.131	0.541	3.550
MEXICO	4,705	−9.765	1.003	−12.799	−5.430	0.436	3.506

Table B.2: Augmented Dickey-Fuller Test Results on Log Volatility

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
US	−2.0759	0.0190	−19.1755	0.0000	−19.3282	0.0000
UK	−1.9724	0.0243	−21.7658	0.0000	−22.0168	0.0000
JAPAN	−2.2080	0.0136	−24.2327	0.0000	−24.8434	0.0000
GERMANY	−2.1469	0.0159	−22.0455	0.0000	−22.5334	0.0000
FRANCE	−2.0898	0.0183	−21.6184	0.0000	−22.0227	0.0000
AUSTRALIA	−2.0734	0.0191	−23.5392	0.0000	−24.4179	0.0000
MEXICO	−2.1399	0.0162	−25.4735	0.0000	−26.0352	0.0000

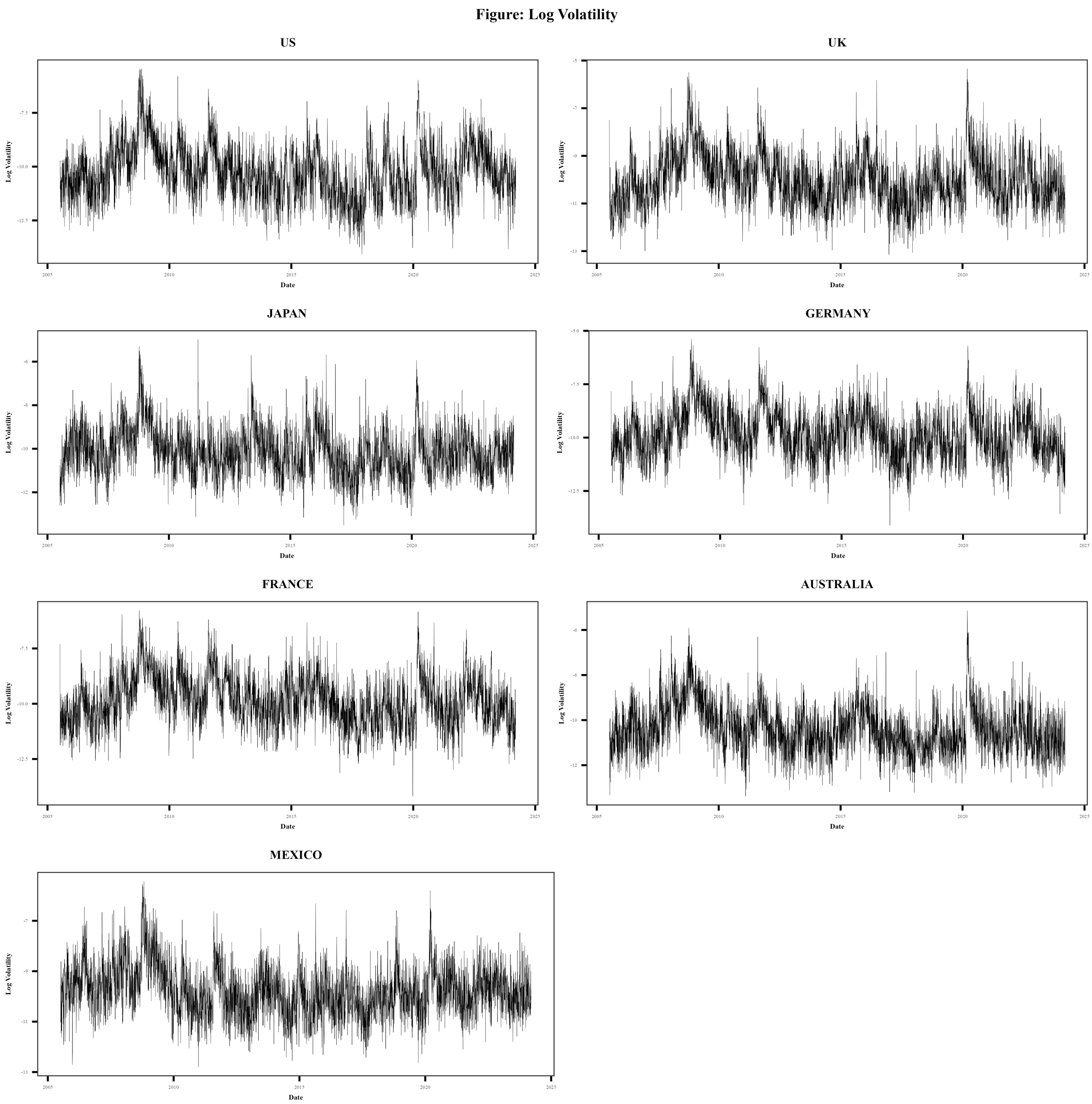

Figure B.1: Log Volatility

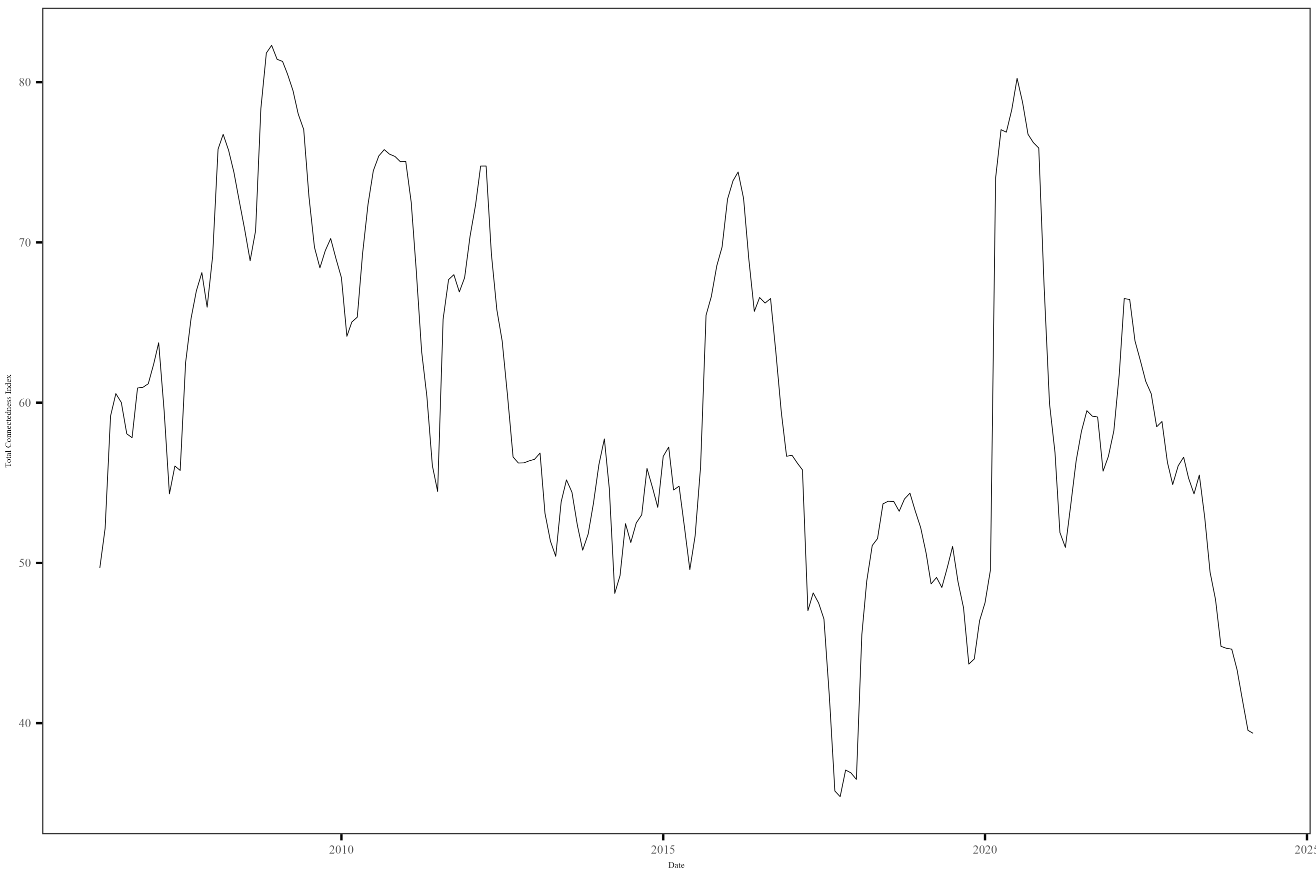

Figure B.2: Total Connectedness Index

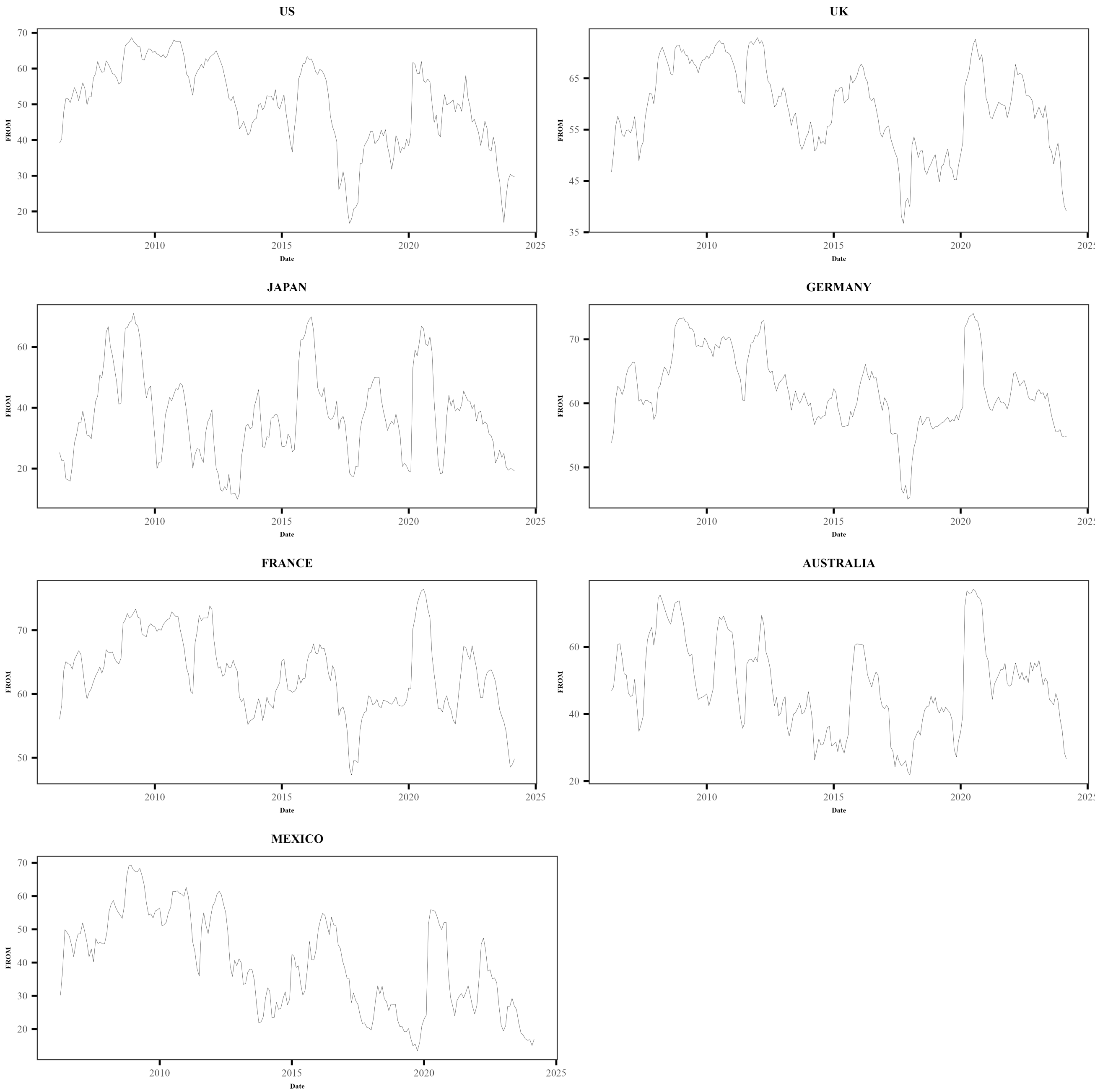

Figure B.3: Net Pairwise Dynamic Connectedness

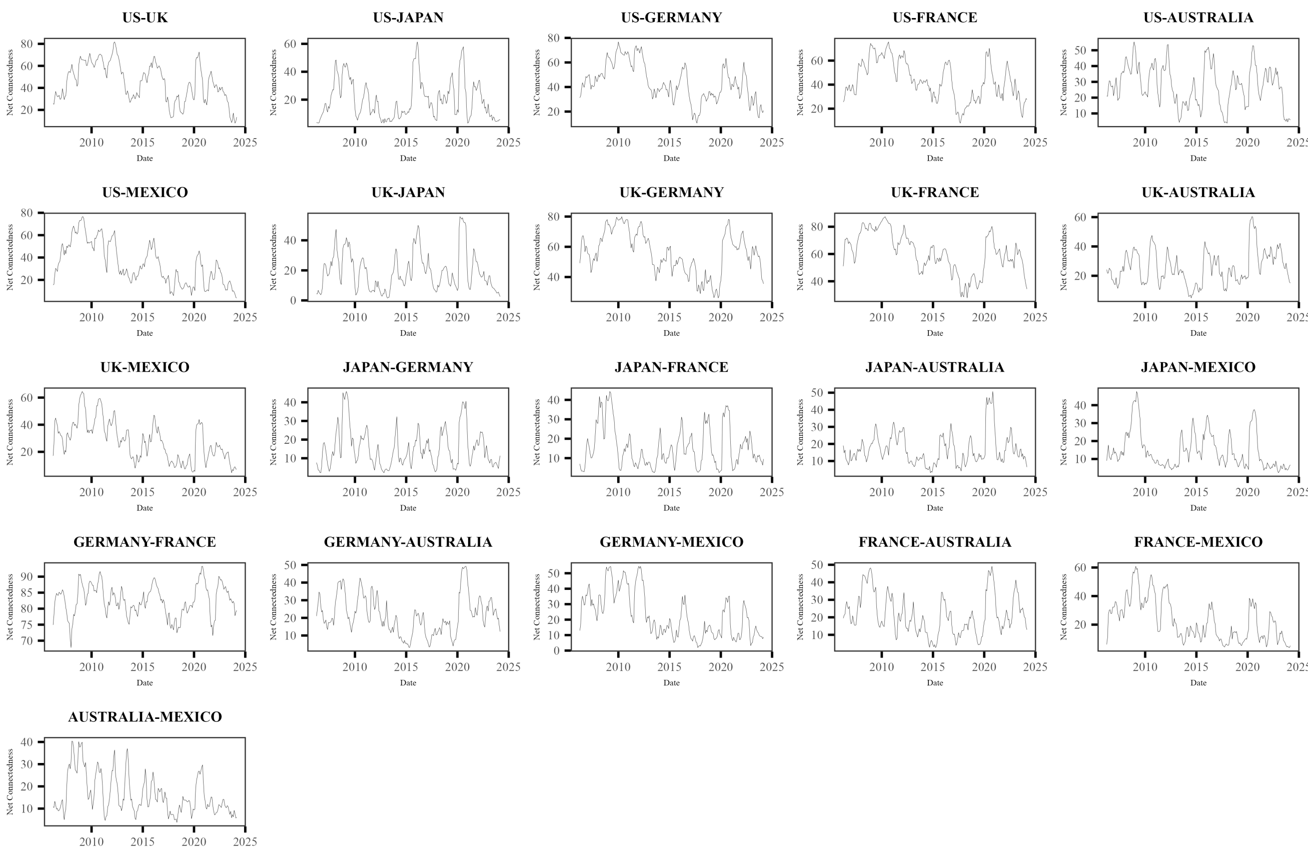

Figure B.4: Comprehensive Pairwise Connectedness Index

Table B.3: ADF Test Results for All Variables

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
TO Connectedness						
US	−1.1557	0.1239	−3.6263	0.0001	−4.1291	0.00002
UK	−1.2634	0.1032	−4.1464	0.00002	−4.6744	0.000001
GERMANY	−0.8454	0.1990	−3.8830	0.0001	−3.9909	0.00003
FRANCE	−0.5447	0.2930	−3.2553	0.0006	−3.5697	0.0002
JAPAN	−2.2009	0.0139	−5.0518	0.000000	−5.0485	0.000000
MEXICO	−1.4797	0.0695	−3.5731	0.0002	−5.7106	0.0000
AUSTRALIA	−2.1914	0.0142	−5.3216	0.000000	−6.4133	0.0000
Pairwise Connectedness						
US-UK	−1.0773	0.1407	−2.8379	0.0023	−3.5779	0.0002
US-JAPAN	−2.2825	0.0112	−4.2121	0.00001	−4.2249	0.00001
US-GERMANY	−1.0203	0.1538	−2.7921	0.0026	−3.6975	0.0001
US-FRANCE	−1.0142	0.1552	−2.9890	0.0014	−3.6946	0.0001
US-AUSTRALIA	−1.8664	0.0310	−4.5268	0.000003	−4.7095	0.000001
US-MEXICO	−1.2258	0.1101	−2.3801	0.0087	−4.2916	0.00001
UK-JAPAN	−2.5740	0.0050	−4.8863	0.000001	−4.8892	0.000001
UK-GERMANY	−0.8888	0.1871	−2.5234	0.0058	−2.9192	0.0018
UK-FRANCE	−0.8929	0.1860	−2.1938	0.0141	−3.0255	0.0012
UK-AUSTRALIA	−1.7629	0.0390	−4.4817	0.000004	−4.5222	0.000003
UK-MEXICO	−1.6936	0.0452	−3.3349	0.0004	−4.5603	0.000003
JAPAN-GERMANY	−2.5754	0.0050	−5.0688	0.000000	−5.0706	0.000000
JAPAN-FRANCE	−2.3341	0.0098	−4.5392	0.000003	−4.6137	0.000002
JAPAN-AUSTRALIA	−2.0323	0.0211	−4.2604	0.00001	−4.2357	0.00001
JAPAN-MEXICO	−2.0580	0.0198	−3.5452	0.0002	−3.7436	0.0001
GERMANY-FRANCE	−0.2057	0.4185	−3.9387	0.00004	−3.9264	0.00004
GERMANY-AUSTRALIA	−1.7548	0.0396	−3.6559	0.0001	−3.6739	0.0001
GERMANY-MEXICO	−1.8017	0.0358	−3.2547	0.0006	−4.5353	0.000003
FRANCE-AUSTRALIA	−1.8957	0.0290	−3.9647	0.00004	−4.0230	0.00003
FRANCE-MEXICO	−1.7403	0.0409	−3.2315	0.0006	−4.5576	0.000003
AUSTRALIA-MEXICO	−2.1135	0.0173	−4.5664	0.000002	−5.2873	0.000000

Table B.4: Dependent Variable Summary Statistics

	N	Mean	StdDev	Min	Max	Skewness	Kurtosis
TO Connectedness							
UK	216	67.445	17.965	28.321	111.754	−0.069	2.337
GERMANY	216	72.889	12.603	43.781	105.438	0.149	2.533
FRANCE	216	74.465	13.626	44.485	107.255	0.063	2.592
JAPAN	216	18.990	10.251	6.342	60.664	1.546	5.901
MEXICO	216	37.903	17.023	10.468	83.217	0.394	2.294
AUSTRALIA	216	18.748	9.129	5.203	47.770	0.789	3.270
US-UK	216	45.127	17.491	7.944	81.773	−0.119	2.064
Pairwise Connectedness							
US-JAPAN	216	20.217	14.071	3.139	61.388	0.890	2.988
US-GERMANY	216	43.788	15.255	10.547	76.752	0.157	2.323
US-FRANCE	216	43.461	16.217	7.930	75.564	0.068	2.077
US-AUSTRALIA	216	28.028	12.604	3.845	55.294	0.002	2.289
US-MEXICO	216	34.392	18.700	3.821	76.513	0.386	2.039
UK-JAPAN	216	19.321	12.901	1.621	55.716	0.938	3.273
UK-GERMANY	216	55.977	13.923	26.138	79.922	−0.167	2.163
UK-FRANCE	216	60.918	14.635	27.745	87.362	−0.213	2.254
UK-AUSTRALIA	216	25.948	11.443	4.866	60.288	0.613	3.140
UK-MEXICO	216	27.884	14.465	4.563	64.495	0.438	2.495
JAPAN-GERMANY	216	15.315	10.150	2.209	45.788	1.050	3.631
JAPAN-FRANCE	216	15.637	10.512	2.467	44.308	0.921	2.969
JAPAN-AUSTRALIA	216	16.880	9.228	3.120	50.697	1.340	4.961
JAPAN-MEXICO	216	14.653	10.140	2.314	47.622	1.215	3.749
GERMANY-FRANCE	216	82.581	4.899	67.845	93.233	−0.221	2.585
GERMANY-AUSTRALIA	216	21.557	10.754	3.160	49.230	0.548	2.770
GERMANY-MEXICO	216	22.804	14.642	1.947	54.484	0.619	2.212
FRANCE-AUSTRALIA	216	21.426	11.392	2.712	49.126	0.602	2.587
FRANCE-MEXICO	216	22.868	14.505	3.946	60.852	0.675	2.476
AUSTRALIA-MEXICO	216	16.476	8.982	3.791	40.391	0.897	2.867

Table B.5: TO Regression in Levels

	OLS						*panel linear*
	United Kingdom	France	Germany	Japan	Mexico	Australia	Panel Fixed Effects
TO_lag1	0.871***	0.841***	0.829***	0.796***	0.764***	0.826***	0.874***
	(0.040)	(0.036)	(0.040)	(0.042)	(0.038)	(0.042)	(0.013)
TradeFreedom	−17.017**	3.000	1.118	2.686	0.380	−7.028	0.742
	(7.559)	(3.461)	(4.957)	(5.677)	(6.074)	(7.071)	(0.963)
DebtGDP	−0.149**	−0.001	0.163	−0.084	−0.002	−0.024	−0.031**
	(0.072)	(0.032)	(0.098)	(0.244)	(0.097)	(0.066)	(0.012)
Zscore	1.047**	0.735*	−0.156	0.104	0.866**	0.389	0.062
	(0.462)	(0.407)	(0.361)	(0.505)	(0.376)	(0.656)	(0.079)
EPU	−0.003	−0.005	−0.000	0.004	−0.005	−0.007	−0.005**
	(0.005)	(0.005)	(0.006)	(0.017)	(0.019)	(0.007)	(0.002)
iMAPPAttitude	1.380	1.010	0.207	0.866	0.237	−1.015	0.483
	(1.603)	(1.232)	(1.175)	(1.616)	(1.090)	(1.200)	(0.532)
MacrobondBC	4.170*	3.008**	−2.834**	−1.043	0.732	1.309	−0.541
	(2.441)	(1.205)	(1.380)	(1.294)	(1.468)	(2.175)	(0.515)
Sentiment	0.166*	0.056	0.056			−0.022	
	(0.085)	(0.052)	(0.072)			(0.048)	
M1Reserves	−2.116***	−0.251	0.059	0.010	−0.710**	0.120	0.002
	(0.597)	(0.243)	(0.149)	(0.016)	(0.300)	(0.129)	(0.006)
FDIGDP	138.605***	274.865***	−42.065	−442.177	−323.817	90.827*	13.716
	(44.120)	(104.348)	(86.268)	(317.118)	(291.605)	(47.082)	(14.594)
ForeignReservesGDP	−1,279.882***	−45.026	26.461	−5.258	79.716	−67.431	−25.765
	(325.858)	(107.989)	(835.784)	(40.141)	(111.993)	(55.171)	(17.353)
VIX	0.493***	0.241***	0.161**	0.274***	0.404***	−0.070	0.183***
	(0.086)	(0.070)	(0.062)	(0.077)	(0.079)	(0.061)	(0.023)
OilPrice	−0.136	0.073	0.020	0.030	0.031	−0.128**	−0.006
	(0.094)	(0.067)	(0.060)	(0.063)	(0.080)	(0.057)	(0.021)
Constant	220.117**	−37.274	−32.736	−10.357	−7.094	64.668	
	(84.758)	(37.921)	(46.658)	(91.611)	(36.206)	(59.301)	
Observations	176	188	188	188	188	188	1,128
R^2	0.888	0.904	0.881	0.771	0.886	0.782	0.850
Adjusted R^2	0.879	0.897	0.873	0.756	0.878	0.766	0.847
Residual Std. Error	6.354 (df = 162)	4.604 (df = 174)	4.574 (df = 174)	5.188 (df = 175)	5.835 (df = 175)	4.247 (df = 174)	
F Statistic	99.115*** (df = 13; 162)	125.917*** (df = 13; 174)	99.486*** (df = 13; 174)	49.159*** (df = 12; 175)	113.404*** (df = 12; 175)	48.059*** (df = 13; 174)	523.306*** (df = 12; 1110)

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table B.6: Pairwise Connectedness in Levels as Dependent Variable (Including Corndog Index)

	OLS						*panel linear*
	United Kingdom	France	Germany	Japan	Mexico	Australia	Panel Fixed Effects
PCI_lag1	0.795***	0.844***	0.842***	0.836***	0.724***	0.836***	0.858***
	(0.047)	(0.048)	(0.048)	(0.061)	(0.058)	(0.048)	(0.018)
USExportWeight	−7.194	138.349**	−123.052	6.801	17.079	−51.392	12.105
	(100.760)	(53.709)	(80.765)	(48.929)	(15.285)	(67.812)	(11.917)
USTradePolicyEPU	−0.001	−0.002	−0.002	−0.003	−0.003	−0.002	−0.001*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
MacrobondBC	0.704	0.228	1.799	−4.170	−0.311	6.466**	−0.410
	(2.403)	(2.620)	(1.712)	(3.409)	(1.456)	(3.223)	(0.748)
USRecessionProbability	−0.001	−0.023	0.057	0.033	0.036	0.014	0.042**
	(0.062)	(0.052)	(0.051)	(0.081)	(0.049)	(0.054)	(0.021)
M1Reserves	0.377	−0.753**	0.021	−0.015	0.030	−1.371***	−0.012
	(0.690)	(0.372)	(0.178)	(0.026)	(0.288)	(0.368)	(0.009)
FDIGDP	−30.049	135.373	279.793	216.858	3,630.576***	−271.403**	6.240
	(36.600)	(232.017)	(296.371)	(1,261.531)	(1,235.246)	(110.117)	(20.861)
ForeignReservesGDP	−664.475**	−428.111	1,880.195	−363.610*	202.784	−857.855***	−65.728
	(256.830)	(524.723)	(1,570.165)	(190.868)	(144.764)	(250.640)	(53.387)
VIX	0.572***	0.468***	0.325***	0.706***	0.380***	0.409***	0.418***
	(0.166)	(0.136)	(0.118)	(0.208)	(0.137)	(0.134)	(0.053)
OilPrice	−0.118	0.019	0.087	0.244	0.096	0.246	0.118*
	(0.219)	(0.159)	(0.148)	(0.270)	(0.156)	(0.158)	(0.066)
Corndog	−20.287	−13.047	−59.764*	−31.233	10.031	9.248	−36.303***
	(41.818)	(27.592)	(35.260)	(33.772)	(18.169)	(33.279)	(9.360)
Cooperation	0.010**	0.002	0.004	−0.003	0.003	−0.005	0.007***
	(0.005)	(0.004)	(0.006)	(0.007)	(0.004)	(0.007)	(0.002)
iMAPPAttitude	0.479	1.301	0.437	1.101	−1.003	−2.494*	0.443
	(1.607)	(1.409)	(1.219)	(2.281)	(1.101)	(1.412)	(0.566)
USiMAPPAttitude	−1.826	−1.045	−0.839	−0.814	−1.568	−0.746	−1.114**
	(1.371)	(1.205)	(1.110)	(1.724)	(1.229)	(1.176)	(0.505)
Constant	21.109	6.676	−6.196	85.469*	−82.977***	58.732***	
	(15.707)	(16.169)	(21.106)	(43.844)	(30.804)	(19.642)	
Observations	83	83	83	83	83	83	498
R^2	0.928	0.936	0.911	0.868	0.933	0.917	0.898
Adjusted R^2	0.913	0.923	0.893	0.841	0.919	0.900	0.894
Residual Std. Error (df = 68)	4.902	4.231	4.036	6.023	4.008	4.232	
F Statistic	62.729*** (df = 14; 68)	70.939*** (df = 14; 68)	49.963*** (df = 14; 68)	31.945*** (df = 14; 68)	67.468*** (df = 14; 68)	53.931*** (df = 14; 68)	300.933*** (df = 14; 478)

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table B.7: Pairwise Connectedness in Levels (excluding Corndog Index)

	OLS						*panel linear*
	United Kingdom	France	Germany	Japan	Mexico	Australia	Panel Fixed Effects
PCI_lag1	0.831***	0.855***	0.859***	0.855***	0.828***	0.848***	0.878***
	(0.025)	(0.023)	(0.026)	(0.033)	(0.028)	(0.031)	(0.010)
USExportWeight	74.460	105.459***	−14.060	25.159	24.519**	44.955	26.911***
	(52.386)	(30.308)	(37.617)	(21.052)	(11.097)	(41.421)	(7.166)
USTradePolicyEPU	−0.002	−0.002	−0.001	−0.002	−0.002	−0.000	−0.002***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)
MacrobondBC	−0.594	−0.392	−0.398	−2.158*	−1.347	2.252	−1.603***
	(1.473)	(0.901)	(1.011)	(1.098)	(1.101)	(2.624)	(0.426)
USRecessionProbability	−0.031	−0.028*	−0.036**	0.001	0.001	−0.025	−0.021***
	(0.021)	(0.017)	(0.018)	(0.025)	(0.019)	(0.019)	(0.007)
M1Reserves	−0.705**	−0.681***	−0.012	−0.000	−0.322***	−0.133	0.004
	(0.283)	(0.166)	(0.114)	(0.008)	(0.103)	(0.120)	(0.004)
FDIGDP	0.055	110.398	63.994	−160.890	168.239	−67.677*	−4.940
	(16.527)	(70.286)	(65.059)	(346.016)	(152.267)	(39.597)	(11.588)
ForeignReservesGDP	−201.886***	−146.031*	302.588	−22.880	−69.012*	−22.882	−19.735
	(76.586)	(79.049)	(432.379)	(32.337)	(38.713)	(57.323)	(14.278)
VIX	0.437***	0.437***	0.324***	0.310***	0.295***	0.297***	0.328***
	(0.063)	(0.054)	(0.052)	(0.072)	(0.056)	(0.061)	(0.023)
OilPrice	−0.029	−0.010	0.019	−0.033	−0.042	0.058	0.043***
	(0.055)	(0.045)	(0.042)	(0.055)	(0.049)	(0.050)	(0.016)
Cooperation	0.003*	0.002	0.005	0.001	−0.000	0.009**	0.001
	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.004)	(0.001)
iMAPPAttitude	0.685	0.891	0.677	2.083	−0.437	−3.032**	0.172
	(1.141)	(0.968)	(0.992)	(1.675)	(0.846)	(1.328)	(0.444)
USiMAPPAttitude	−2.193**	−0.748	−0.972	−0.729	−1.364	0.337	−1.274***
	(1.053)	(0.833)	(0.907)	(1.234)	(1.122)	(1.115)	(0.413)
Constant	10.125	2.736	−3.512	−0.169	−7.950	−1.695	
	(8.288)	(5.410)	(9.066)	(11.386)	(11.072)	(6.815)	
Observations	188	188	188	188	188	188	1,128
R^2	0.936	0.954	0.941	0.882	0.950	0.875	0.922
Adjusted R^2	0.931	0.950	0.937	0.873	0.946	0.865	0.921
Residual Std. Error (df = 174)	4.363	3.647	3.745	5.108	4.312	4.572	
F Statistic	196.076*** (df = 13; 174)	275.016*** (df = 13; 174)	213.373*** (df = 13; 174)	100.302*** (df = 13; 174)	253.837*** (df = 13; 174)	93.329*** (df = 13; 174)	1,010.724*** (df = 13; 1109)

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table B.8: Augmented Dickey-Fuller Test Results on United Kingdom Explanatory Variables

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
Trade Freedom	0.1755	0.4303	−3.2344	0.0006	−4.3895	0.00001
DebtGDP	−0.9011	0.1838	−0.6856	0.2465	−2.3700	0.0089
Z-score	0.4035	0.3433	−1.1906	0.1169	−3.0793	0.0010
EPU	−1.7870	0.0370	−4.0948	0.00002	−4.4731	0.000004
US Export Weight	−0.7304	0.2326	−6.4288	0.0000	−7.6115	0.0000
iMAPP Attitude	−8.6425	0.0000	−8.8216	0.0000	−8.8025	0.0000
Macrobond BC	−2.6731	0.0038	−3.0415	0.0012	−2.9954	0.0014
Sentiment	−0.5305	0.2979	−2.3699	0.0089	−2.3737	0.0088
M1-Reserves	−0.0944	0.4624	−1.9914	0.0232	−1.9711	0.0244
FDI-GDP	−2.1385	0.0162	−2.9543	0.0016	−3.5268	0.0002
Foreign Reserves-GDP	−0.0592	0.4764	−1.0918	0.1375	−1.9367	0.0264
Cooperation	−1.0679	0.1428	−3.1071	0.0009	−3.5264	0.0002
Corndog	−0.5980	0.2749	−3.7953	0.0001	−3.7979	0.0001
US Trade Policy EPU	−2.7766	0.0027	−3.3357	0.0004	−3.4848	0.0002
VIX	−1.7112	0.0435	−4.6233	0.000002	−4.6935	0.000001
US Recession Probability	−3.5097	0.0002	−3.6997	0.0001	−3.9571	0.00004
Oil Price	−1.0030	0.1579	−2.9368	0.0017	−3.6478	0.0001
US iMAPP Attitude	−8.5485	0.0000	−8.5986	0.0000	−8.5754	0.0000

Table B.9: United Kingdom Explanatory Variable Summary Statistics

	N	Mean	StdDev	Min	Max	Skewness	Kurtosis
Trade Freedom	189	8.709	0.197	8.040	8.970	-1.067	4.259
DebtGDP	213	222.682	20.881	160.948	247.237	-1.362	4.260
Z-score	189	12.324	4.728	5.055	18.698	0.145	1.309
EPU	216	261.940	147.415	30.469	1,141.796	1.701	9.138
US Export Weight	215	0.066	0.007	0.050	0.087	0.207	2.822
iMAPP Attitude	189	0.041	0.308	-1	1	1.059	10.080
Macrobond BC	213	0.127	0.333	0.0000	1	2.244	6.034
Sentiment	177	99.134	11.462	61.200	115.200	-1.102	3.970
M1-Reserves	215	13.098	1.990	10.083	20.648	1.070	4.248
FDI-GDP	201	0.031	0.025	-0.021	0.089	0.518	2.634
Foreign Reserves-GDP	201	0.032	0.009	0.018	0.052	0.044	1.735
Cooperation	216	535.822	276.478	60.619	1,490.716	0.306	2.655
Corndog	110	0.154	0.025	0.113	0.241	1.068	4.408
US Trade Policy EPU	215	134.767	234.100	6.467	1,946.683	3.973	23.698
VIX	215	19.740	8.593	10.125	62.669	2.277	10.059
US Recession Probability	214	8.261	25.784	0.0000	100	3.015	10.314
Oil Price	215	36.095	10.595	8.922	66.798	0.284	2.517
US iMAPP Attitude	189	0.026	0.333	-1	1	0.482	8.923

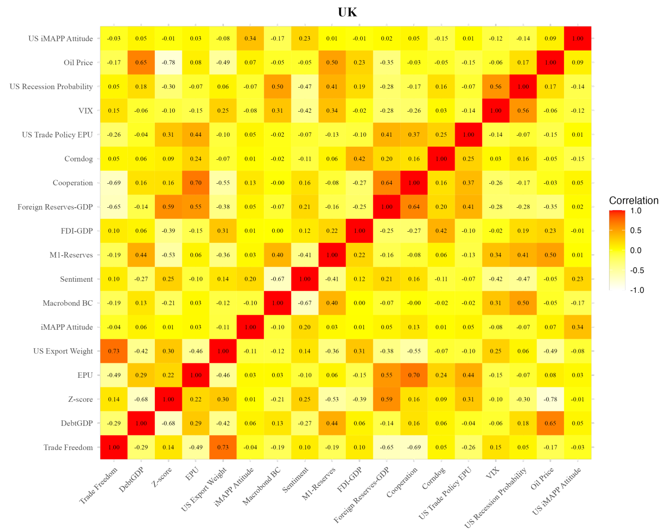

Figure B.5: Bivariate Correlation Matrix for the United Kingdom

Table B.10: Augmented Dickey-Fuller Test Results on Germany Explanatory Variables

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
Trade Freedom	−1.1656	0.1219	−1.6749	0.0470	−1.9874	0.0234
DebtGDP	−0.1788	0.4291	−2.2881	0.0111	−2.2287	0.0129
Z-score	−0.0656	0.4739	−1.9691	0.0245	−3.2390	0.0006
EPU	−0.9107	0.1812	−2.3005	0.0107	−3.8253	0.0001
US Export Weight	−0.5008	0.3083	−4.3694	0.00001	−6.5584	0.0000
iMAPP Attitude	−9.7741	0.0000	−9.8936	0.0000	−9.8991	0.0000
Macrobond BC	−3.2558	0.0006	−3.5644	0.0002	−3.5660	0.0002
Sentiment	−0.5492	0.2914	−3.3423	0.0004	−3.3293	0.0004
M1-Reserves	0.0599	0.4761	−1.3634	0.0864	−0.9778	0.1641
FDI-GDP	−2.1502	0.0158	−3.3590	0.0004	−3.7442	0.0001
Foreign Reserves-GDP	−3.0459	0.0012	−0.9431	0.1728	−3.3078	0.0005
Cooperation	−1.7970	0.0362	−4.3316	0.00001	−4.6331	0.000002
Corndog	−0.7261	0.2339	−2.9774	0.0015	−3.0512	0.0011
US Trade Policy EPU	−2.7766	0.0027	−3.3357	0.0004	−3.4848	0.0002
VIX	−1.7112	0.0435	−4.6233	0.000002	−4.6935	0.000001
US Recession Probability	−3.5097	0.0002	−3.6997	0.0001	−3.9571	0.00004
Oil Price	−1.0030	0.1579	−2.9368	0.0017	−3.6478	0.0001
US iMAPP Attitude	−8.5485	0.0000	−8.5986	0.0000	−8.5754	0.0000

Table B.11: Germany Explanatory Variable Summary Statistics

	N	Mean	StdDev	Min	Max	Skewness	Kurtosis
Trade Freedom	189	8.509	0.153	8.040	8.770	−0.649	3.071
DebtGDP	201	169.944	6.816	159.729	180.481	−0.112	1.596
Z-score	189	14.406	3.488	6.980	22.488	0.095	2.386
EPU	216	229.881	175.086	28.434	844.855	1.715	5.226
US Export Weight	215	0.079	0.011	0.050	0.108	0.063	2.752
iMAPP Attitude	189	0.029	0.293	−1	1	0.951	11.287
Macrobond BC	216	0.153	0.361	0	1	1.930	4.726
Sentiment	216	101.976	9.356	67	118.300	−1.299	5.059
M1-Reserves	215	23.930	7.685	14.281	40.232	0.434	1.928
FDI-GDP	201	0.011	0.007	−0.0001	0.027	0.398	2.250
Foreign Reserves-GDP	201	0.010	0.002	0.007	0.015	0.295	1.877
Cooperation	216	219.170	122.919	26.013	621.384	0.796	3.482
Corndog	110	0.102	0.020	0.055	0.165	0.211	3.560
US Trade Policy EPU	215	134.767	234.100	6.467	1,946.683	3.973	23.698
VIX	215	19.740	8.593	10.125	62.669	2.277	10.059
US Recession Probability	214	8.261	25.784	0	100	3.015	10.314
Oil Price	215	36.095	10.595	8.922	66.798	0.284	2.517
US iMAPP Attitude	189	0.026	0.333	−1	1	0.482	8.923

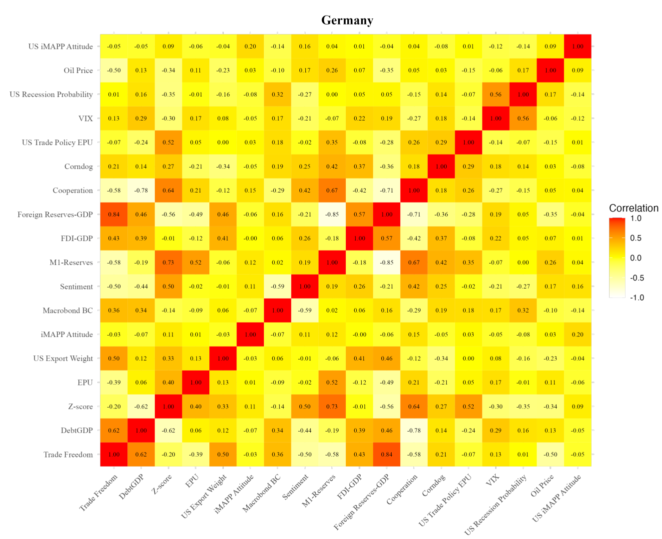

Figure B.6: Bivariate Correlation Matrix for Germany

Table B.12: Augmented Dickey-Fuller Test Results on France Explanatory Variables

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
Trade Freedom	−0.8116	0.2085	−2.1843	0.0145	−2.5403	0.0055
DebtGDP	1.1504	0.1250	−1.1787	0.1193	−3.8803	0.0001
Z-score	−0.2315	0.4085	−2.4680	0.0068	−4.6578	0.000002
EPU	−1.4367	0.0754	−4.8223	0.000001	−6.0100	0.0000
US Export Weight	−0.6231	0.2666	−5.6331	0.0000	−7.8378	0.0000
iMAPP Attitude	−9.6101	0.0000	−9.8440	0.0000	−9.9272	0.0000
Macrobond BC	−3.2158	0.0007	−3.6580	0.0001	−3.6402	0.0001
Sentiment	−0.4387	0.3304	−3.5248	0.0002	−3.5682	0.0002
M1-Reserves	−0.0857	0.4659	−1.9462	0.0258	−3.3543	0.0004
FDI-GDP	−1.6086	0.0539	−3.5731	0.0002	−4.6827	0.000001
Foreign Reserves-GDP	−0.8766	0.1903	−3.1745	0.0008	−4.4458	0.000004
Cooperation	−2.0032	0.0226	−4.4528	0.000004	−4.6248	0.000002
Corndog	−0.7253	0.2341	−3.5008	0.0002	−4.5368	0.000003
US Trade Policy EPU	−2.7766	0.0027	−3.3357	0.0004	−3.4848	0.0002
VIX	−1.7112	0.0435	−4.6233	0.000002	−4.6935	0.000001
US Recession Probability	−3.5097	0.0002	−3.6997	0.0001	−3.9571	0.00004
Oil Price	−1.0030	0.1579	−2.9368	0.0017	−3.6478	0.0001
US iMAPP Attitude	−8.5485	0.0000	−8.5986	0.0000	−8.5754	0.0000

Table B.13: France Explanatory Variable Summary Statistics

	N	Mean	StdDev	Min	Max	Skewness	Kurtosis
Trade Freedom	189	8.735	0.135	8.260	9.040	−1.113	4.557
DebtGDP	201	238.887	29.134	192.455	296.811	0.325	1.964
Z-score	189	17.370	2.446	10.163	20.007	−1.105	3.553
EPU	216	235.459	93.692	45.528	574.633	0.455	3.547
US Export Weight	215	0.083	0.013	0.059	0.129	0.545	3.196
iMAPP Attitude	189	0.037	0.287	−1	1	1.030	10.893
Macrobond BC	216	0.208	0.407	0	1	1.436	3.063
Sentiment	216	98.196	9.995	61.300	116.700	−0.820	4.110
M1-Reserves	215	16.363	3.298	10.569	22.862	−0.019	1.753
FDI-GDP	201	0.011	0.005	0.001	0.029	1.115	4.485
Foreign Reserves-GDP	201	0.022	0.006	0.017	0.054	2.813	13.268
Cooperation	216	291.274	176.982	28.900	1,135.327	1.145	4.996
Corndog	110	0.113	0.024	0.072	0.182	0.649	3.122
US Trade Policy EPU	215	134.767	234.100	6.467	1,946.683	3.973	23.698
VIX	215	19.740	8.593	10.125	62.669	2.277	10.059
US Recession Probability	214	8.261	25.784	0	100	3.015	10.314
Oil Price	215	36.095	10.595	8.922	66.798	0.284	2.517
US iMAPP Attitude	189	0.026	0.333	−1	1	0.482	8.923

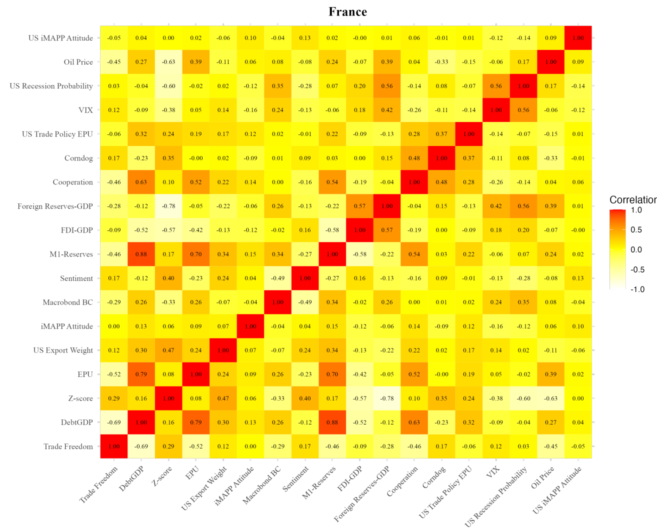

Figure B.7: Bivariate Correlation Matrix for France

Table B.14: Augmented Dickey-Fuller Test Results on Japan Explanatory Variables

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
Trade Freedom	0.3971	0.3456	−1.8298	0.0336	−1.9879	0.0234
DebtGDP	0.4406	0.3298	−1.4571	0.0725	−1.6511	0.0494
Z-score	−0.9179	0.1793	−2.7941	0.0026	−2.7937	0.0026
EPU	−1.1490	0.1253	−5.5148	0.000000	−5.4914	0.000000
US Export Weight	−0.5960	0.2756	−5.1687	0.000000	−5.3933	0.000000
iMAPP Attitude	−6.8007	0.0000	−7.4020	0.0000	−7.5795	0.0000
Macrobond BC	−2.5556	0.0053	−2.9574	0.0016	−3.3123	0.0005
M1-Reserves	2.7082	0.0034	2.2685	0.0116	−1.6075	0.0540
FDI-GDP	−1.6338	0.0512	−3.3549	0.0004	−3.4801	0.0003
Foreign Reserves-GDP	−0.2427	0.4041	−1.2257	0.1102	−0.3301	0.3707
Cooperation	−2.0518	0.0201	−5.3081	0.000000	−5.4817	0.000000
Corndog	−0.5894	0.2778	−3.8963	0.00005	−4.2617	0.00001
US Trade Policy EPU	−2.7766	0.0027	−3.3357	0.0004	−3.4848	0.0002
VIX	−1.7112	0.0435	−4.6233	0.000002	−4.6935	0.000001
US Recession Probability	−3.5097	0.0002	−3.6997	0.0001	−3.9571	0.00004
Oil Price	−1.0030	0.1579	−2.9368	0.0017	−3.6478	0.0001
US iMAPP Attitude	−8.5485	0.0000	−8.5986	0.0000	−8.5754	0.0000

Table B.15: Japan Explanatory Variable Summary Statistics

	N	Mean	StdDev	Min	Max	Skewness	Kurtosis
Trade Freedom	189	8.013	0.314	7.500	8.520	0.167	1.505
DebtGDP	201	225.811	8.134	214.943	245.708	0.853	2.902
Z-score	189	15.730	1.580	11.203	17.892	−0.853	2.841
EPU	216	112.139	31.014	48.399	239.024	1.162	5.331
US Export Weight	215	0.191	0.023	0.130	0.254	−0.093	2.929
iMAPP Attitude	189	0.063	0.244	0	1	3.580	13.818
Macrobond BC	213	0.239	0.428	0	1	1.221	2.491
M1-Reserves	216	576.368	132.717	415.207	910.251	1.115	3.286
FDI-GDP	201	0.002	0.002	−0.002	0.006	0.288	2.240
Foreign Reserves-GDP	201	0.230	0.015	0.191	0.265	−0.331	3.032
Cooperation	216	293.206	158.245	43.671	1,066.039	1.454	7.115
Corndog	110	0.181	0.029	0.134	0.260	0.734	3.143
US Trade Policy EPU	215	134.767	234.100	6.467	1,946.683	3.973	23.698
VIX	215	19.740	8.593	10.125	62.669	2.277	10.059
US Recession Probability	214	8.261	25.784	0	100	3.015	10.314
Oil Price	215	36.095	10.595	8.922	66.798	0.284	2.517
US iMAPP Attitude	189	0.026	0.333	−1	1	0.482	8.923

My Fig. B.1: Figure B.8: Bivariate Correlation Matrix for Japan

Table B.16: Augmented Dickey-Fuller Test Results on Mexico Explanatory Variables

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
Trade Freedom	0.7662	0.2218	−1.0266	0.1523	−3.5588	0.0002
DebtGDP	0.1196	0.4524	−2.1559	0.0155	−1.3020	0.0965
Z-score	−0.4065	0.3422	−2.5928	0.0048	−2.5787	0.0050
EPU	−2.1892	0.0143	−5.8137	0.0000	−5.8229	0.0000
US Export Weight	−0.0988	0.4607	−9.1032	0.0000	−9.7976	0.0000
iMAPP Attitude	−7.9605	0.0000	−8.3629	0.0000	−8.4146	0.0000
Macrobond BC	−3.4319	0.0003	−3.7263	0.0001	−3.7126	0.0001
M1-Reserves	2.7624	0.0029	0.8627	0.1941	−1.0547	0.1458
FDI-GDP	−0.7762	0.2188	−4.3018	0.00001	−5.0566	0.000000
Foreign Reserves-GDP	0.1803	0.4285	−1.2746	0.1012	−0.6745	0.2500
Cooperation	−1.7031	0.0443	−3.4787	0.0003	−3.7950	0.0001
Corndog	−0.4600	0.3227	−3.2117	0.0007	−3.2682	0.0005
US Trade Policy EPU	−2.7766	0.0027	−3.3357	0.0004	−3.4848	0.0002
VIX	−1.7112	0.0435	−4.6233	0.000002	−4.6935	0.000001
US Recession Probability	−3.5097	0.0002	−3.6997	0.0001	−3.9571	0.00004
Oil Price	−1.0030	0.1579	−2.9368	0.0017	−3.6478	0.0001
US iMAPP Attitude	−8.5485	0.0000	−8.5986	0.0000	−8.5754	0.0000

Table B.17: Mexico Explanatory Variable Summary Statistics

	N	Mean	StdDev	Min	Max	Skewness	Kurtosis
Trade Freedom	189	7.684	0.267	7.390	8.160	0.532	1.739
DebtGDP	201	70.525	15.404	43.039	92.430	−0.250	1.676
Z-score	189	20.336	3.009	14.613	26.179	−0.318	2.674
EPU	216	63.904	30.150	8.509	185.571	0.897	4.118
US Export Weight	215	0.770	0.040	0.671	0.981	1.017	6.792
iMAPP Attitude	189	0.090	0.422	−1	1	0.556	5.153
Macrobond BC	216	0.139	0.347	0	1	2.088	5.361
M1-Reserves	216	20.466	6.873	12.631	34.980	0.667	2.105
FDI-GDP	201	0.015	0.003	0.011	0.023	1.190	3.825
Foreign Reserves-GDP	201	0.068	0.010	0.048	0.086	−0.284	2.195
Cooperation	216	285.534	194.608	9.339	1,149.732	1.257	5.137
Corndog	110	0.209	0.044	0.134	0.324	0.569	3.059
US Trade Policy EPU	215	134.767	234.100	6.467	1,946.683	3.973	23.698
VIX	215	19.740	8.593	10.125	62.669	2.277	10.059
US Recession Probability	214	8.261	25.784	0	100	3.015	10.314
Oil Price	215	36.095	10.595	8.922	66.798	0.284	2.517
US iMAPP Attitude	189	0.026	0.333	−1	1	0.482	8.923

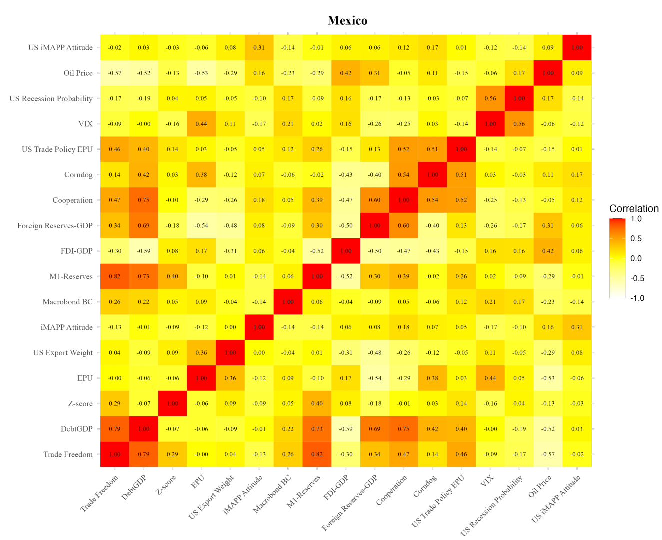

Figure B.9: Bivariate Correlation Matrix for Mexico

Table B.18: Augmented Dickey-Fuller Test Results on Australia Explanatory Variables

Variable	ADF None Stat	ADF None P-Value	ADF Const Stat	ADF Const P-Value	ADF Const & Trend Stat	ADF Const & Trend P-Value
Trade Freedom	0.4630	0.3217	−2.0583	0.0198	−3.6118	0.0002
DebtGDP	−0.3148	0.3765	−2.7364	0.0031	−2.6755	0.0037
Z-score	−0.6095	0.2711	−4.2696	0.00001	−5.1306	0.000000
EPU	−2.1050	0.0176	−5.7983	0.0000	−5.8502	0.0000
US Export Weight	−1.3032	0.0963	−4.8257	0.000001	−5.1325	0.000000
iMAPP Attitude	−8.9685	0.0000	−9.4447	0.0000	−9.4897	0.0000
Macrobond BC	−4.5717	0.000002	−4.6406	0.000002	−4.7099	0.000001
Sentiment	−0.6230	0.2667	−3.0498	0.0011	−3.4993	0.0002
M1-Reserves	0.6860	0.2464	−0.9843	0.1625	−2.6998	0.0035
Foreign Reserves-GDP	−1.6192	0.0527	−2.8523	0.0022	−3.4988	0.0002
FDI-GDP	−1.1362	0.1279	−3.2253	0.0006	−3.5580	0.0002
Cooperation	−1.4112	0.0791	−3.8009	0.0001	−4.5364	0.000003
Corndog	−0.4482	0.3270	−3.4422	0.0003	−3.3146	0.0005
US Trade Policy EPU	−2.7766	0.0027	−3.3357	0.0004	−3.4848	0.0002
VIX	−1.7112	0.0435	−4.6233	0.000002	−4.6935	0.000001
US Recession Probability	−3.5097	0.0002	−3.6997	0.0001	−3.9571	0.00004
Oil Price	−1.0030	0.1579	−2.9368	0.0017	−3.6478	0.0001
US iMAPP Attitude	−8.5485	0.0000	−8.5986	0.0000	−8.5754	0.0000

Table B.19: Australia Explanatory Variable Summary Statistics

	N	Mean	StdDev	Min	Max	Skewness	Kurtosis
Trade Freedom	189	8.019	0.101	7.790	8.200	−0.161	2.031
DebtGDP	213	192.728	9.427	174.483	207.161	0.069	1.636
Z-score	189	14.070	0.860	12.363	17.307	1.412	5.110
EPU	216	119.995	59.720	25.662	337.044	1.176	4.426
US Export Weight	215	0.046	0.011	0.028	0.107	1.367	6.072
iMAPP Attitude	189	0.058	0.276	−1	1	2.136	11.675
Macrobond BC	213	0.028	0.166	0	1	5.703	33.529
Sentiment	216	99.408	10.211	75.644	123.940	−0.107	2.752
M1-Reserves	216	17.155	8.566	4.714	36.087	0.753	2.283
Foreign Reserves-GDP	201	0.036	0.012	0.020	0.084	1.806	7.078
FDI-GDP	201	0.039	0.015	−0.014	0.060	−0.816	3.286
Cooperation	216	214.389	116.627	13.248	725.207	0.470	3.603
Corndog	110	0.109	0.021	0.066	0.167	−0.005	2.494
US Trade Policy EPU	215	134.767	234.100	6.467	1,946.683	3.973	23.698
VIX	215	19.740	8.593	10.125	62.669	2.277	10.059
US Recession Probability	214	8.261	25.784	0	100	3.015	10.314
Oil Price	215	36.095	10.595	8.922	66.798	0.284	2.517
US iMAPP Attitude	189	0.026	0.333	−1	1	0.482	8.923

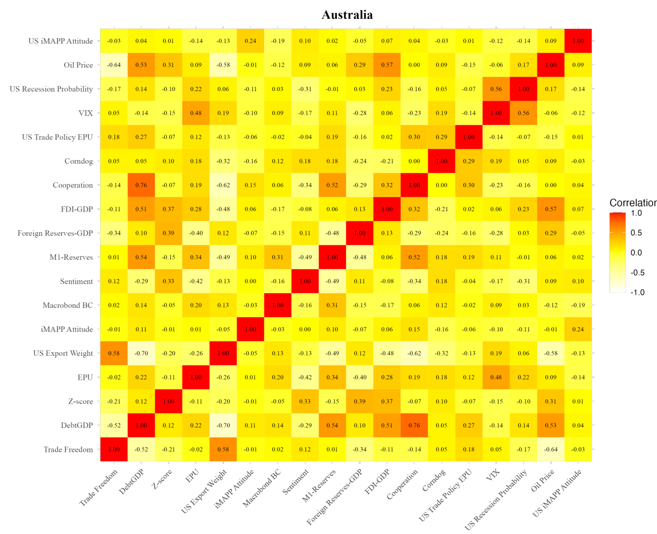

Figure B.10: Bivariate Correlation Matrix for Australia

```
-- Corndog Index Query
WITH RelevantArticles AS (
  SELECT
    DATE(PARSE_TIMESTAMP('%Y%m%d%H%M%S', SUBSTR(GKGRECORDID, 1, 14))) AS
        Date,
    CASE
      WHEN REGEXP_CONTAINS(V2Locations, r'United Kingdom') THEN 'UK'
      WHEN REGEXP_CONTAINS(V2Locations, r'Japan') THEN 'Japan'
      WHEN REGEXP_CONTAINS(V2Locations, r'Germany') THEN 'Germany'
      WHEN REGEXP_CONTAINS(V2Locations, r'France') THEN 'France'
      WHEN REGEXP_CONTAINS(V2Locations, r'Australia') THEN 'Australia'
      WHEN REGEXP_CONTAINS(V2Locations, r'Mexico') THEN 'Mexico'
      ELSE NULL
    END AS Country,
    REGEXP_CONTAINS(LOWER(ALLNAMES), r'\b(usa)\b|\b(united states of
       america)\b|\b( united states)\b|\b(chicago)\b|\b(wall street)\b|\
       b(silicon valley)\b|\b(alabama)\b|\b(alaska)\b|\b(arizona)\b|\b(
       arkansas)\b|\b(california)\b|\b(colorado)\b|\b(connecticut)\b|\b(
       delaware)\b|\b(florida)\b|\b(georgia)\b|\b(hawaii)\b|\b(idaho)\b
       |\b(illinois)\b|\b(indiana)\b|\b(iowa)\b|\b(kansas)\b|\b(kentucky
       )\b|\b(louisiana)\b|\b(maine)\b|\b(maryland)\b|\b(massachusetts)\
       b|\b(michigan)\b|\b(minnesota)\b|\b(mississippi)\b|\b(missouri)\b
       |\b(montana)\b|\b(nebraska)\b|\b(nevada)\b|\b(new hampshire)\b|\b
       (new jersey)\b|\b(new york)\b|\b(north carolina)\b|\b(north
       dakota)\b|\b(ohio)\b|\b(oklahoma)\b|\b(oregon)\b|\b(pennsylvania)
       \b|\b(rhode island)\b|\b(south carolina)\b|\b(south dakota)\b|\b(
       tenessee)\b|\b(texas)\b|\b(utah)\b|\b(vermont)\b|\b(virginia)\b|\
       b(washington)\b|\b(west virginia)\b|\b(wisconsin)\b|\b(wyoming)\b
       |\b(fed funds rate)\b|\b(jerome powell)\b|\b(janet yellen)\b|\b(
       ben bernanke)\b|\b(alan greenspan)\b|\b(paul volcker)\b|\b(
       william miller)\b|\b(arthur burns)\b|\b(g. william miller)\b|\b(
       marriner eccles)\b|\b(george washington)\b|\b(john adams)\b|\b(
       thomas jefferson)\b|\b(james madison)\b|\b(james monroe)\b|\b(
       john quincy adams)\b|\b(andrew jackson)\b|\b(martin van buren)\b
       |\b(william henry harrison)\b|\b(john tyler)\b|\b(james k. polk)\
       b|\b(zachary taylor)\b|\b(millard fillmore)\b|\b(franklin pierce)
       \b|\b(james buchanan)\b|\b(abraham lincoln)\b|\b(andrew johnson)\
       b|\b(ulysses s. grant)\b|\b(rutherford b. hayes)\b|\b(james
       garfield)\b|\b(chester arthur)\b|\b(grover cleveland)\b|\b(
       benjamin harrison)\b|\b(william mckinley)\b|\b(theodore roosevelt
       )\b|\b(william howard taft)\b|\b(woodrow wilson)\b|\b(warren g.
       harding)\b|\b(calvin coolidge)\b|\b(herbert hoover)\b|\b(franklin
        d. roosevelt)\b|\b(harry s. truman)\b|\b(dwight d. eisenhower)\b
       |\b(john f. kennedy)\b|\b(lyndon b. johnson)\b|\b(richard nixon)\
       b|\b(gerald ford)\b|\b(jimmy carter)\b|\b(ronald reagan)\b|\b(
       george h. w. bush)\b|\b(bill clinton)\b|\b(george w. bush)\b|\b(
       barack obama)\b|\b(donald trump)\b|\b(joe biden)\b|\b(dodd-frank
       act)\b|\b(sarbanes-oxley act)\b|\b(glass-steagall act)\b|\b(jobs
       act)\b|\b(smoot-hawley tariff act)\b|\b(affordable care act)\b|\b
       (nancy pelosi)\b|\b(mitch mcconnell)\b|\b(chuck schumer)\b|\b(
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    kevin mccarthy)\b|\b(john mccain)\b|\b(ted kennedy)\b|\b(paul
    ryan)\b|\b(orin hatch)\b|\b(elizabeth warren)\b|\b(bernie sanders
    )\b|\b(alexandria ocasio-cortez)\b|\b(general motors)\b|\b(
    exxonmobil)\b|\b(chevron)\b|\b(at&t)\b|\b(cvs health)\b|\b(
    berkshire hathaway)\b|\b(apple inc.)\b|\b(microsoft)\b|\b(google)
    \b|\b(amazon)\b|\b(facebook)\b|\b(tim cook)\b|\b(jeff bezos)\b|\b
    (satya nadella)\b|\b(sundar pichai)\b|\b(mark zuckerberg)\b|\b(
    elon musk)\b|\b(mary barra)\b|\b(jamie dimon)\b|\b(warren buffett
    )\b|\b(lloyd blankfein)\b|\b(indra nooyi)\b|\b(ginni rometty)\b|\
    b(ray dalio)\b|\b(david tepper)\b|\b(bill ackman)\b|\b(ken
    griffin)\b|\b(steve cohen)\b|\b(george soros)\b|\b(dan loeb)\b|\b
    (jim simons)\b|\b(john paulson)\b|\b(bruce kovner)\b|\b(oracle)\b
    |\b(netflix)\b|\b(linkedin)\b|\b(twitter)\b|\b(snapchat)\b|\b(
    uber)\b|\b(lyft)\b|\b(adobe)\b|\b(nvidia)\b|\b(tesla motors)\b|\b
    (space x)\b|\b(boston dynamics)\b|\b(intuit)\b|\b(palantir
    technologies)\b|\b(zoom video communications)\b|\b(dollar shave
    club)\b|\b(modern meadow)\b|\b(impossible foods)\b|\b(general
    electric)\b|\b(duke energy)\b|\b(fed funds)\b|\b(t bill)\b|\b(t-
    bill)\b|\b(NYSE)\b|\b(new york stock exchange)\b|\b(chicago stock
     exchange)\b|\b(chicago fed)\b|\b(securities and exchange
    comission)\b|\b(sec)\b|\b(dow jones industrial average)\b|\b(
    nasdaq composite)\b|\b(s&p 500)\b|\b(nyse american)\b|\b(russell
    2000)\b|\b(wilshire 5000)\b|\b(nonfarm payrolls)\b|\b(consumer
    price index)\b|\b(producer price index)\b|\b(adp employment
    report)\b|\b(bureau of economic analysis)\b|\b(bureau of labor
    statistics)\b|\b(treasury department)\b|\b(internal revenue
    service)\b|\b(commodity futures trading commission)\b|\b(federal
    trade commission)\b|\b(office of the comptroller of the currency)
    \b|\b(t-bills)\b|\b(t-notes)\b|\b(t-bonds)\b|\b(municipal bonds)\
    b|\b(jumbo loans)\b|\b(fannie mae)\b|\b(freddie mac)\b|\b(ginnie
    mae)\b|\b(federal home loan banks)\b|\b(federal farm credit banks
    )\b|\b(federal deposit insurance corporation)\b|\b(savings and
    loan crisis)\b|\b(credit union)\b|\b(roth ira)\b|\b(401(k) plans)
    \b|\b(529 plan)\b|\b(amt)\b|\b(estate tax)\b|\b(gift tax)\b|\b(
    great recession)\b|\b(savings and loan crisis)\b|\b(black monday)
    \b|\b(dot-com bubble)\b|\b(subprime mortgage crisis)\b|\b(
    american stock exchange)\b|\b(black friday)\b|\b(cyber monday)\b
    |\b(greenback)\b|\b(petrodollar recycling)\b|\b(yankee bond)\b|\b
    (blue chip stocks)\b|\b(pink sheets)\b|\b(chapter 11 bankruptcy)\
    b|\b(chapter 7 bankruptcy)\b') AS HasMatchedTerm
FROM
  `gdelt-bq.gdeltv2.gkg`
WHERE
  GKGRECORDID BETWEEN '20000101000000-0' AND '20240401000000-0'
  AND (
    REGEXP_CONTAINS(V2Locations, r'United Kingdom') OR
    REGEXP_CONTAINS(V2Locations, r'Japan') OR
    REGEXP_CONTAINS(V2Locations, r'Germany') OR
    REGEXP_CONTAINS(V2Locations, r'France') OR
    REGEXP_CONTAINS(V2Locations, r'Australia') OR
```

```
      REGEXP_CONTAINS(V2Locations, r'Mexico')
    )
)

SELECT
  Date,
  Country,
  COUNTIF(HasMatchedTerm) AS ArticlesWithMatchedTerms,
  COUNT(*) AS TotalArticles
FROM
  RelevantArticles
WHERE
  Country IS NOT NULL
GROUP BY
  Date, Country
ORDER BY
  Date, Country
```

B.1 Cooperation Index Cameo Codes

B.1.1 Cooperative Actions

- 013: Make optimistic comment. Express optimism, assurance, confidence. This event form is a verbal act. Only statements with explicit optimistic components should be coded as 013; otherwise, default to 010.

- 014: Make optimistic comment. Express optimism, assurance, confidence. This event form is a verbal act. Only statements with explicit optimistic components should be coded as 013; otherwise, default to 010.

- 0211: Appeal for economic cooperation. Make an appeal for, request, or suggest initiating or expanding economic ties. Use this code for requests to develop or expand trade and other forms of economic exchange. Appeals for provision of economic aid-not mutual exchange are coded as 0231 instead. Actual events of economic cooperation are coded as 061.

- 022: Appeal for diplomatic cooperation (such as policy support). Make an appeal for, request, or suggest expansion of diplomatic ties or cooperation. This event form is typically, although not exclusively, a verbal act. It refers to appeals for expanded diplomatic ties and non-tangible support on particular policies. Appeals for more specific forms of diplomacy, such as mediation and negotiation, are coded elsewhere within category 02.

- 0231: Appeal for economic aid. Make an appeal for, request, or suggest economic assistance. This event form is typically, although not exclusively, a verbal act. Requests or suggestions for loans or debt relief are also coded here. Appeals for reciprocal economic exchange, such as trade, should be coded as 0212 instead. The source could be requesting support for itself or on behalf of another party.

- 0254: Appeal for easing of economic sanctions, boycott, or embargo. Make an appeal for, request, or suggest that target stops or eases economic sanctions, boycott, or embargo.

- 030: Express intent to cooperate, not specified below. Offer, promise, agree to, or otherwise indicate willingness or commitment to cooperate not otherwise specified. This residual category is not coded except when distinctions among codes 031 through 039 cannot be made. All cooperative actions reported in future tense are also taken to imply intentions, if not promises or commitments, to cooperate and are hence coded under this category. These events can be reciprocal or unilateral.
- 031: Express intent to engage in material cooperation, not specified below. Offer, promise, agree to, or otherwise indicate willingness or commitment to engage in or expand material cooperative exchange not otherwise specified.
- 0311: Express intent to cooperate economically. Offer, promise, agree to, or otherwise indicate willingness or commitment to engage in or expand economic ties.
- 032: Express intent to engage in diplomatic cooperation (such as policy support). Offer, promise, agree to, or otherwise indicate willingness or commitment to expand diplomatic ties or cooperation.
- 0331: Express intent to provide economic aid. Offer, promise, agree to, or otherwise indicate willingness or commitment to provide economic support.
- 0351: Express intent to ease administrative sanctions. Offer, promise, agree to, or otherwise indicate willingness or commitment to ease administrative sanctions, such as censorship, curfew, state of emergency, and martial law.
- 0354: Express intent to ease economic sanctions, boycott, or embargo. Offer, promise, agree to, or otherwise indicate willingness or commitment to reduce or eliminate economic sanctions, boycotts, or embargoes.
- 0355: Express intent to allow international involvement (non-mediation). Offer, promise, agree to, or otherwise indicate willingness or commitment to allow access to international actors, such as observers, humanitarian agencies, and peacekeeping forces.
- 036: Express intent to meet or negotiate. Offer, promise, agree to, or otherwise indicate willingness or commitment to meet, visit, or engage in talks or negotiations.
- 037: Express intent to settle dispute. Offer, promise, agree to, or otherwise indicate willingness or commitment to reach a comprehensive settlement, agreement, or resolution to conflict.
- 040: Consult, not specified below. All consultations and meetings not otherwise specified.
- 041: Discuss by telephone. Consult, talk on the telephone.
- 042: Make a visit. Travel to another location for a meeting or other event.
- 043: Host a visit. Host or receive a visitor at residence, office or home country.
- 044: Meet at a 'third' location. Meet, come together, gather with others at a neutral location—some place with which none of the attending parties are associated. If mediation or negotiation is mentioned specifically as having taken place, those events take precedence over unspecified visits or meetings.

- 046: Engage in negotiation. Negotiate or bargain with others.
- 050: Engage in diplomatic cooperation, not specified below. Initiate, resume, improve, or expand diplomatic, non-material cooperation or exchange not otherwise specified.
- 057: Sign formal agreement. Ratify, sign, finalize an agreement, treaty.
- 061: Cooperate economically. Initiate, resume, improve, or expand economic exchange or cooperation.
- 070: Provide aid, not specified below. All provisions, extension of material aid, not otherwise specified.
- 071: Provide economic aid. Extend, provide monetary aid and financial guarantees, grants, gifts and credit.
- 081: Ease administrative sanctions, not specified below. Relax or remove all administrative non-force sanctions and penalties, not otherwise specified.
- 085: Ease economic sanction, boycott, or embargo. Lift, relax, or lessen economic sanctions, boycott, embargoes, or penalties.
- 086: Allow international involvement, not specified below. Allow entry of or intervention by international actors not further specified.
- 1011: Demand economic cooperation. Require, demand that target engages in economic exchange or expands such ties.
- 102: Demand for diplomatic cooperation (such as policy support). Require, demand expansion of diplomatic ties or cooperation.
- 1031: Demand economic aid. Require, demand provision of economic assistance.
- 1051: Demand easing of administrative sanctions. Require, demand that target relaxes administrative restrictions.
- 106: Demand meeting, negotiation. Require, order party(ies) to meet, negotiate.
- : 107: Demand settling of dispute. Order parties to a conflict to reach a settlement, agreement, or resolution of conflict.

Source: Schrodt (2012)

B.1.2 Uncooperative Actions

- 110: Disapprove, not specified below. Express disapprovals, objections, and complaints not otherwise specified.
- 120: Reject, not specified below. All rejections and refusals not otherwise specified.
- 121: Reject material cooperation, not specified below. Refuse to engage in or expand material exchange.

- 1211: Reject economic cooperation. Refuse to engage in or expand economic ties.
- 122: Reject request or demand for material aid, not specified below. Refuse to extend material aid not otherwise specified.
- 1221: Reject request for economic aid. Refuse to extend financial assistance.
- 1241: Refuse to ease administrative sanctions. Reject requests, refuse or decline to ease administrative sanctions, such as censorship, curfew, state of emergency, and martial law.
- 1244: Refuse to ease economic sanctions, boycott, or embargo. Reject requests, refuse, or decline to reduce or eliminate economic sanctions, boycotts, or embargoes.
- 1245: Refuse to allow international involvement (non-mediation). Reject requests, refuse or decline to allow access to international actors such as observers, humanitarian agencies, and peacekeeping forces.
- 125: Reject proposal to meet, discuss, negotiate. Refuse to meet, discuss, or negotiate.
- 127: Reject plan, agreement to settle dispute. Reject a proposal or request for a final, comprehensive settlement, peace proposal, or resolution.
- 128: Defy norms, law. Disobey, challenge, or resist laws or norms.
- 129: Veto. Refuse to assent or formally reject legislative proposal, recommendation, or resolution.
- 1312: Threaten to boycott, embargo, or sanction. Threaten to restrict normal economic interactions by imposing sanctions, boycotts, or embargoes.
- 1313: Threaten to reduce or break relations. Threaten to reduce or formally sever ties.
- 132: Threaten with administrative sanctions, not specified below. Threaten to impose or expand non-force administrative restrictions and penalties not otherwise specified.
- 1321: Threaten with restrictions on political freedoms. Threaten to impose or expand restrictions on fundamental freedoms, such as freedoms of speech, expression, and assembly.
- 134: Threaten to halt negotiations. Threaten to break-up or withdraw from discussion, negotiation, or meeting.
- 136: Threaten to halt international involvement (non-mediation). Threaten to reduce or stop international intervention by expelling or withdrawing observers, humanitarian agencies, peacekeepers, etc.
- 139: Give ultimatum. Give a final warning, ultimate demand or order.
- 160: Reduce relations, not specified below. All reductions in normal, routine, or cooperative relations not otherwise specified.
- 161: Reduce or break diplomatic relations. Curtail, decrease, break, or terminate diplomatic exchange.

- 162: Reduce or stop material aid, not specified below. Reductions or terminations of aid not otherwise specified.
- 1621: Reduce or stop economic assistance. Decrease or terminate provision of economic aid.
- 163: Impose embargo, boycott, or sanctions. Stop or restrict commercial or other material exchange as a form of protest or punishment.
- 164: Halt negotiations. Terminate discussions, negotiations.
- 172: Impose administrative sanctions, not specified below. Formal decrees, laws, or policies aimed at curbing the rights of civilians not otherwise specified.
- 191: Impose blockade, restrict movement. Prevent entry into and/or exit from a territory using armed forces.

Source: Schrodt (2012)

```
-- Cooperation Index Index Query
WITH RelevantInteractions AS (
  SELECT
    PARSE_DATE('%Y%m%d', CAST(SQLDATE AS STRING)) AS EventDate,
    CASE
      WHEN Actor1CountryCode = 'USA' AND Actor2CountryCode IN ('AUS', '
         FRA', 'DEU', 'JPN', 'MEX', 'GBR') THEN Actor2CountryCode
      WHEN Actor2CountryCode = 'USA' AND Actor1CountryCode IN ('AUS', '
         FRA', 'DEU', 'JPN', 'MEX', 'GBR') THEN Actor1CountryCode
      ELSE NULL
    END AS PartnerCountry,
    EventCode,
    IF(EventCode IN ('014', '0211', '061', '022', '0254', '031', '0311',
        '032', '0354', '036', '042', '043', '044', '046', '050', '057',
       '085', '013', '0231', '030', '0331', '0351', '0355', '037', '040'
       , '041', '070', '071', '081', '086', '1011', '102', '1031', '1051
       ', '106', '107'), 'Cooperation',
       IF(EventCode IN ('160', '161', '1621', '163', '164', '172', '191'
          , '110', '111', '120', '121', '1211', '122', '1221', '1241', '
          1244', '1245', '125', '127', '128', '129', '1312', '1313', '
          132', '1321', '134', '136', '139', '162'), 'Uncooperation', '
          Neutral')) AS InteractionType,
    ABS(GoldsteinScale) AS Weight
  FROM
    `gdelt-bq.full.events`
  WHERE
    PARSE_DATE('%Y%m%d', CAST(SQLDATE AS STRING)) BETWEEN DATE('
       2000-01-01') AND CURRENT_DATE()
    AND (
      (Actor1CountryCode = 'USA' AND Actor2CountryCode IN ('AUS', 'FRA',
          'DEU', 'JPN', 'MEX', 'GBR')) OR
      (Actor2CountryCode = 'USA' AND Actor1CountryCode IN ('AUS', 'FRA',
          'DEU', 'JPN', 'MEX', 'GBR'))
```

```
    )
)

SELECT
  EventDate,
  PartnerCountry,
  SUM(CASE WHEN InteractionType = 'Cooperation' THEN Weight ELSE 0 END)
     AS CooperationImpact,
  SUM(CASE WHEN InteractionType = 'Uncooperation' THEN Weight ELSE 0 END
     ) AS UncooperationImpact,
  (SUM(CASE WHEN InteractionType = 'Cooperation' THEN Weight ELSE 0 END)
      - SUM(CASE WHEN InteractionType = 'Uncooperation' THEN Weight ELSE
      0 END)) / NULLIF(SUM(CASE WHEN InteractionType IN ('Cooperation',
     'Uncooperation') THEN Weight ELSE 0 END), 0) AS CooperationIndex
FROM
  RelevantInteractions
WHERE
  PartnerCountry IS NOT NULL
GROUP BY
  EventDate, PartnerCountry
ORDER BY
  EventDate, PartnerCountry
```