Sectoral Interdependences in the Bond Market

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Hypothesis Development
H1: Hedging Properties

- The first hypothesis (H1) examines the **hedging properties** of the bonds in the pairwise correlation timeseries. Based on average correlation levels over the entire sample, assets are classified as
- diversifiers (H1a) if they are *positively* but not perfectly correlated,
- and as strong or weak hedges (H1b) if they are *negatively* correlated (strong hedge) or *uncorrelated* (weak hedge).

	Interdependence type	
Correlation dynamics	Hedging property	Hypo
Positively and not perfectly correlated (overall average: $+, < 1$)	Diversifier	H1a
Negatively correlated or uncorrelated (overall average: $-$ or ≈ 0)	Strong or Weak Hedge	H1b

Average Levels in the Crisis Subsample

- Focusing on the average levels in the crisis subsample, we identify strong or weak safe havens (H1c) if the bond indices involved are:
- negatively correlated (strong safe haven) or uncorrelated (weak safe haven) during crisis periods.
- Uncorrelated pairs are the ones with an average correlation equal or close to zero, using a threshold of $|0.05|(-0.05 < \rho < 0.05)$.

Crisis negatively correlated or uncorrelated (during crisis: $-$ or ≈ 0)	Strong or Weak Safe haven	H1c

H2: Bonds Interdependence

- The second hypothesis (H2) explores the nature of bonds interdependence. Based on the change in the correlation average level from the pre- to the in-crisis period, we diagnose:
- contagion (H2a) when there is a significant increase in correlation, maintaining a positive level during crises.
- Conversely, in the case of a significant decrease in correlation, with a negative in-crisis level, we have a flight to quality (H2b).
- The final type of interdependence is the well-established phenomenon of decoupling (H2c), which entails a significant change of the in-crisis correlation average but without the level corresponding to either contagion or flight to quality.
- Therefore, decoupling occurs when correlations significantly increase (decrease) during crises with a negative (positive) in-crisis average level.

Bonds Interdependence

Crisis increase and positive level (during crisis: $\uparrow, +$)	Contagion	H2a
Crisis decrease and negative level (during crisis: $\downarrow, -$)	Flight to quality	H2b
Crisis significant change without the matching level	Decoupling	H2c

Market Interdependencies through Macro Fundamentals

- Moreover, we associate the sectoral bond correlation timeseries pattern with US business cycle dynamics.
- At first, we test the uncertainty impact as expressed by Economic Policy Uncertainty (EPU) and Financial Uncertainty (FU), both of which are major drivers of economic conditions (Baker et al., 2016)
- Then, we include the disease news effect (ID), which captures the influence of the news about a health crisis on the macro environment (Baker et al., 2020).
- A further significant aspect we associate is the credit channel (CR), which is a potent catalyst of economic fluctuations (Gilchrist and Zakrajšek, 2012).
- Furthermore, the impact of News Sentiment (NS) and Economic Activity (EA) is considered important in driving the business cycle (Aruoba et al., 2009). Higher (lower) sentiment scores and activity indicators decisively contribute to economic booms (recessions).

Pro and Counter Cyclicality

- Based on the correlations' drivers, our macro sensitivity exercise tests one final hypothesis (H3): the procyclicality (H3a) and the countercyclicality (H3b) of sectoral interlinkages.
- When fundamentals are strong (weak), procyclical correlations are expected to rise (fall).
- Conversely, countercyclical correlations increase (decrease) in economic slowdowns/turmoils (growth/booms).

	Sign of correlation determinants	
Macro impact on correlations	H3a: procyclicality	H3b: countercyclicality
Economic policy uncertainty (EPU)	−	+
Financial uncertainty (FU)	−	+
Infectious disease news impact (ID)	−	+
Credit conditions (CR)	−	+
News sentiment (NS)	+	−
Economic activity (EA)	+	−

Sectoral Bond Indices

For the bond market dataset, we use the following widely recognized iBoxx benchmarks to represent each bond sector:

- Corporates (CPT)
- Financials (FIN)
- ✓ Banks (BNK); Insurance (INS); Financial Services (FIN_SRV); Real Estate (RE)

Corporates→Non-Financials

- Non-Financials (NON_FIN)
- ✓ Oil & Gas (OG)
- ✓ Basic Materials (BMAT)
  - Chemicals (BMAT_CHEM); Basic Resources (BMAT_BRS)
- ✓ Industrials (IND)
  - Construction & Materials (IND_CM); Industrial Goods & Services (IND_GS)
- ✓ Consumer Goods (CG)
  - Automobiles & Parts (CG_AUT); Food & Beverage (CG_FB); Personal &Household Goods (CG_PHHG)
- ✓ Consumer Services (CS)
  - Retail (CS_RET); Media (CS_MED); Travel & Leisure (CS_TL)
- ✓ Utilities (UTL)
- ✓ Health Care (HC)
- ✓ Telecommunications (TEL)
- ✓ Technology (TEC

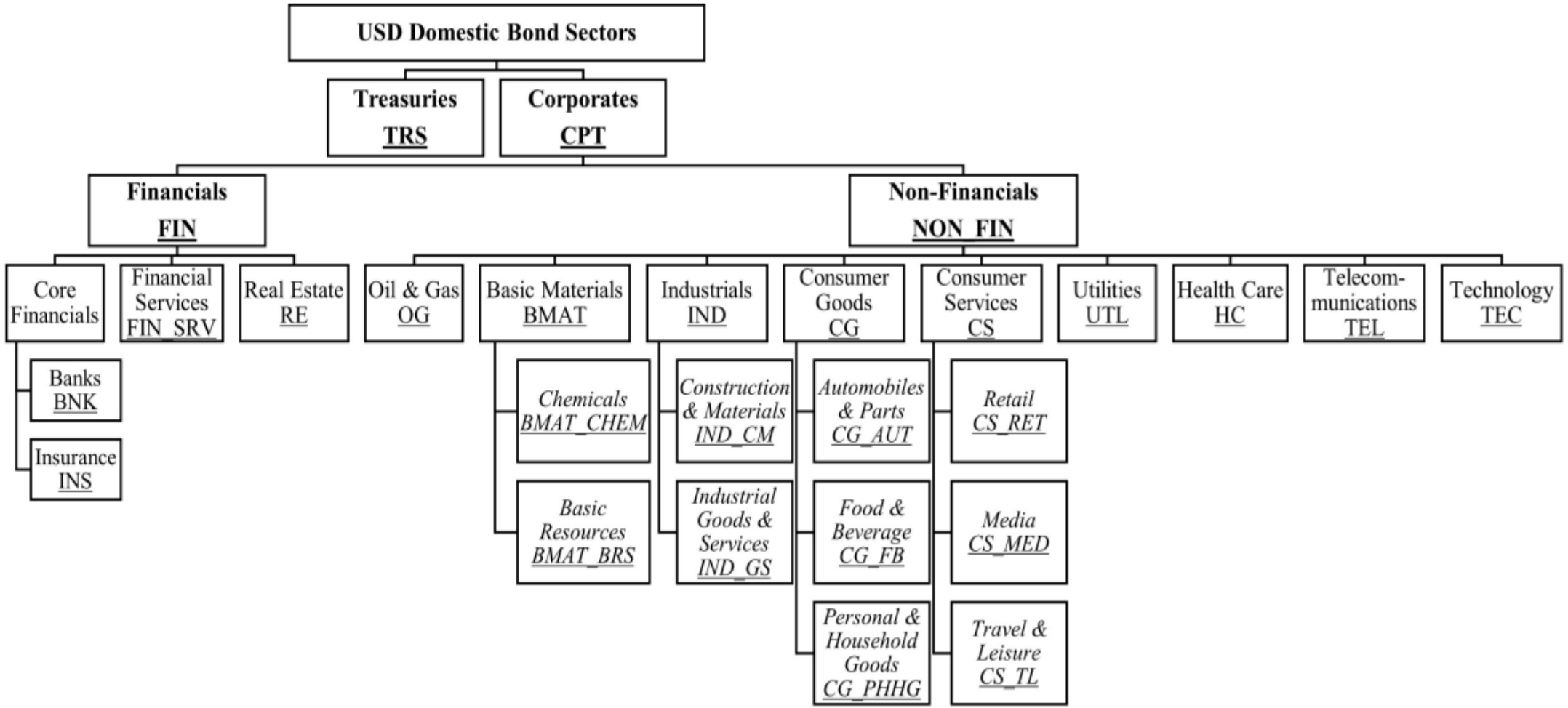


Figure 1: USD Domestic Bonds: Sectoral Indices

Sample; Three Crisis Subsamples

- Our sample covers an extensive period from *January 4, 2000 to October 21, 2021* (**5,688 trading days**), which includes multiple episodes of market turbulence.
- The analysis focuses on two global crises:
- the *2008* financial turmoil and the Covid pandemic
- as well as the European debt crisis, which primarily impacted markets outside the US.

Official Crisis Timelines

- Using the official crisis timelines, we identify three distinct crisis subsamples to investigate the crisis sensitivity of sectoral bond correlations:
- The Global Financial Crisis (*August 9, 2007-March 31,* 2009, per the Federal Reserve Bank of St. Louis timeline),
- The European Debt Crisis (*May 9, 2010-December 31,* 2012, per the European Central Bank timeline), and
- The Covid Crisis (*March 11, 2020- September 30, 2020*, per the World Health Organization timeline).

The Model; The Conditional Mean

Conditional Means

Consider the three-dimensional vectors of returns and errors, denoted by $\mathbf{r}_t = [r_{it}]$ and $\boldsymbol{\epsilon}_t = [\varepsilon_{it}]$ for $i = 1, 2, 3$, respectively. The conditional mean equation is given by:

$$\mathbf{r}_t = \boldsymbol{\phi} + \boldsymbol{\epsilon}_t, \tag{1}$$

where $\boldsymbol{\phi}_t = [\phi_{it}]$ is the vector of drifts.

Conditional Variances: MGARCH Model

MMUFA Framework

- This study employs a vector MGARCH-type process to model conditional variances and their interdependences. The specific framework adopted is the Mixture Multivariate Unrestricted Full Asymmetric (MMUFA) model:
- *Mixture* refers to the integration of EGARCH and APGARCH processes.
- *Multivariate*: Representing the incorporation of multiple GARCH processes.
- *Unrestricted* and *Full*: Indicate that the model allows unrestricted volatility interactions, with the arch and garch parameter matrices being full and at least some of their entries capable of taking both positive and negative values.
- *Asymmetric*: Indicates the inclusion of asymmetric effects in the framework.

Conditional Covariances

- The conditional covariance matrix given the information set at time $t-1$, $\mathcal{F}_{t-1}$, is denoted as $\mathbf{S}_t = [\sigma_{ij,t}]$, where $\mathbb{C}ov(\varepsilon_{it}\varepsilon_{jt} \mid \mathcal{F}_{t-1}) = \sigma_{ij,t}$.
- The conditional variances appear along the diagonal when $i = j$ and are represented as $\sigma_{ii,t} \triangleq \sigma_{it}$.

Conditional Correlations

- The dynamic conditional correlation (DCC) matrix is denoted as $\mathbf{R}_t = [\rho_{ij,t}]$, where:

$$\rho_{ij,t} = \frac{\sigma_{ij,t}}{\sqrt{\sigma_{it}\sigma_{jt}}}. \tag{2}$$

Devolatilized Errors

Under this notation, the error terms can be expressed as $\varepsilon_{it} = \sqrt{\sigma_{it}}\zeta_{it}$, where the devolatilized errors are defined as $\zeta_{it} = \frac{\varepsilon_{it}}{\sqrt{\sigma_{it}}}$. Consequently, the trivariate vector $\boldsymbol{\zeta}_t = [\zeta_{it}]$ follows a conditional standard normal distribution: $\boldsymbol{\zeta}_t \sim N(\mathbf{0}, \mathbf{R}_t)$.

Conditional Variances

The mixture framework described in eq. (3) suggests that the first conditional variance follows an EGARCH process:

$$ln(\sigma_{1t}) = \omega_1 + (\alpha_{11} + \gamma_{11} s_{1,t-1}) \mid \zeta_{1,t-1} \mid + \sum_{i=2}^{3} (\alpha_{1i} + \gamma_{1i} s_{it})\, \varepsilon_{i,t-1}^{2\delta_i} + \beta_{11} ln(\sigma_{1,t-1}) + \beta_{12} \sigma_{2,t-1}^{\delta_2} + \beta_{13} \sigma_{3,t-1}^{\delta_3}, \qquad (4a)$$

whereas the remaining two conditional variances conform to APGARCH specifications:

$$\sigma_{2t}^{\delta_2} = \omega_2 + (\alpha_{21} + \gamma_{21} s_{1,t-1}) \mid \zeta_{1,t-1} \mid + \sum_{i=2}^{3} (\alpha_{2i} + \gamma_{2i} s_{it})\, \varepsilon_{i,t-1}^{2\delta_i} + \beta_{21} ln(\sigma_{1,t-1}) + \beta_{22} \sigma_{2,t-1}^{\delta_2} + \beta_{23} \sigma_{3,t-1}^{\delta_3}, \qquad (4b)$$

$$\sigma_{3t}^{\delta_3} = \omega_3 + (\alpha_{31} + \gamma_{31} s_{1,t-1}) \mid \zeta_{1,t-1} \mid + \sum_{i=2}^{3} (\alpha_{3i} + \gamma_{3i} s_{it})\, \varepsilon_{i,t-1}^{2\delta_i} + \beta_{31} ln(\sigma_{1,t-1}) + \beta_{32} \sigma_{2,t-1}^{\delta_2} + \beta_{33} \sigma_{3,t-1}^{\delta_3}. \qquad (4c)$$

Conditional Correlations
A New Set of Errors

Conditional Correlations

We define a new set of errors, $\mathbf{e}_t = [e_{it}]$, with a corresponding conditional covariance matrix $\mathbf{Q}_t = [q_{ij,t}]$. This implies that the expectation of $\mathbf{e}_t\mathbf{e}_t'$, conditional on $\mathcal{F}_{t-1}$, is equal to $\mathbf{Q}_t$. By construction, the diagonal elements satisfy $q_{ii,t} \triangleq q_{it}$, and the errors are conditionally normally distributed as $\mathbf{e}_t \mid \mathcal{F}_{t-1} \sim N(\mathbf{0}, \mathbf{Q}_t)$. Furthermore, each error term e_{it} can be expressed as a function of the devolatilized errors: $e_{it} = \sqrt{q}_{it}\zeta_{it}$, implying that:

$$\mathbb{E}(e_{it}e_{jt} \mid \mathcal{F}_{t-1}) = \sqrt{q_{it}}\sqrt{q_{jt}}\mathbb{E}(\zeta_{it}\zeta_{jt} \mid \mathcal{F}_{t-1}) \Rightarrow q_{ij,t} = \sqrt{q_{it}}\sqrt{q_{jt}}\rho_{ij,t} \Rightarrow \rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{it}}\sqrt{q_{jt}}}. \quad (5)$$

The Elements of the Conditional Covariance Matrix

The system above can be expressed in elementwise form as follows:

$$q_{ij,t} = \omega + ae_{i,t-1}e_{j,t-1} + bq_{ij,t-1}. \tag{6c}$$

Equivalently, this can be rewritten as:

$$q_{ij,t} = \omega + aq_{i,t-1}q_{j,t-1}\zeta_{i,t-1}\zeta_{j,t-1} + bq_{ij,t-1}. \tag{6d}$$

Matrix Form
cDCC MGARCH Model

- To estimate the conditional correlations, we first need to estimate the conditional covariance matrix $\boldsymbol{Q_t}$. To achieve this, we employ a trivariate corrected dynamic conditional correlations (cDCC) model, which is a matrix-based MGARCH process designed to capture the dynamics of conditional covariances:

$$\mathbf{Q}_t = \omega + a\mathbf{e}_{t-1}\mathbf{e}'_{t-1} + b\mathbf{Q}_{t-1}. \tag{6a}$$

Alternatively, this can be rewritten as:

$$\mathbf{Q}_t = \omega + a\tilde{\mathbf{Q}}_{t-1}\boldsymbol{\zeta}_{t-1}\boldsymbol{\zeta}'_{t-1}\tilde{\mathbf{Q}}_{t-1} + b\mathbf{Q}_{t-1}, \tag{6b}$$

here, $\tilde{\mathbf{Q}}_t$ represents a modified version of the matrix $\mathbf{Q}_t$, where all off-diagonal elements are set to zero. That is, the term $\mathbf{e}_t$ in eq. (6a) can be replaced with $\tilde{\mathbf{Q}}_t\boldsymbol{\zeta}_t$.

Estimation Steps

Estimation Steps

The dual MGARCH model is estimated in four steps:

Step 1: First, we estimate the MMUFA model using eqs. (1) and (3). This provides estimates for the error terms ($\hat{\boldsymbol{\varepsilon}}_{it}$) and conditional variances ($\hat{\boldsymbol{\sigma}}_{it}$), from which we derive the devolatilized errors ($\hat{\boldsymbol{\zeta}}_{it}$).

Step 2: Using the devolatilized error estimates $\hat{\boldsymbol{\zeta}}_{it}$ from Step 1,we estimate the cDCC model in eq. (6b) to obtain the conditional covariance matrix $\hat{\mathbf{Q}}_t$.

Step 3: Next, using the estimated conditional covariance matrix $\hat{\mathbf{Q}}_t$ from Step 2, we compute the conditional correlations as given in eq. (5), denoted by $\hat{\rho}_{it}$.

Step 4: Finally, we derive the conditional covariances $\hat{\sigma}_{ij,t}$ using $\hat{\boldsymbol{\sigma}}_{it}$ (from Step 1) and $\hat{\rho}_{it}$ (from Step 3) as given in eq. (2).

Bivariate and Trivariate Combinations

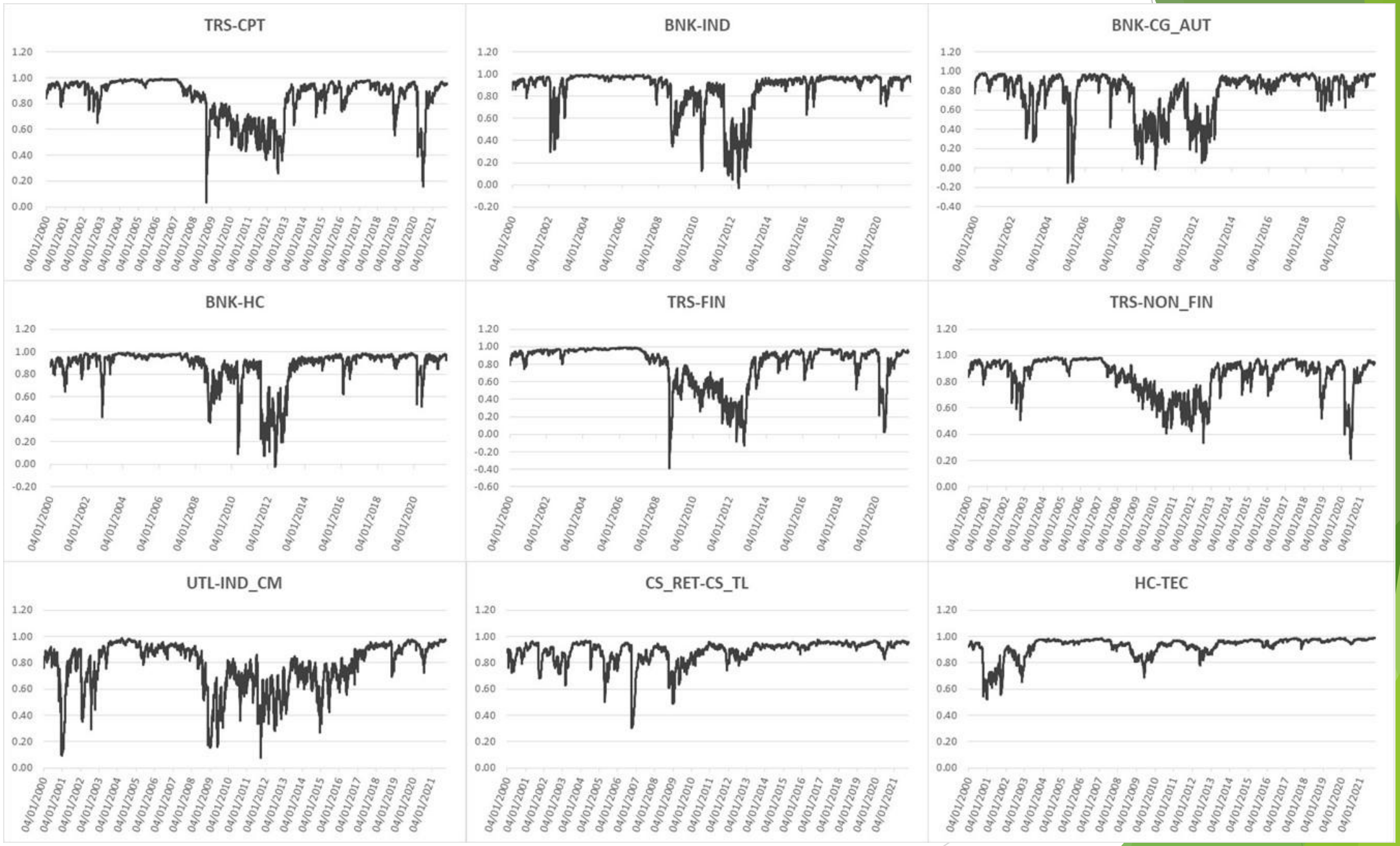
- We apply dual MGARCH models to nineteen bivariate and nine trivariate systems of bond indices.
- The bivariate combinations consist of:
- (a) Treasuries paired with aggregated Corporates, and
- (b) Banks with eighteen financial and non-financial corporate sectors,

Trivariate Models

- The trivariate models involve the following combinations:
- three major groups: Treasuries with aggregated Financials and Non-Financials
- three financial industries excluding Banks (Insurance-Financial Services-Real Estate)
- Banks with the two Basic Materials subsectors (Chemicals and Basic Resources).
- Banks with the two Industrial subsectors (Construction & Materials and Industrial Goods & Services)
- three Consumer Goods subsectors (Automobiles & Parts-Food & Beverage-Personal & Household Goods)
- three Consumer Services subsectors (Retail-Media-Travel & Leisure)
- Oil & Gas with the two Basic Materials subsectors
- Utilities with the two Industrial subsectors
- Health Care with the two most high-tech-related sectors (Telecommunications and Technology)

Fourty four Correlations

- The nineteen bivariate model generate nineteen correlation timeseries.
- The nine trivariate systems generate twenty-seven pairwise correlations, including two duplicates.
- Therefore, our correlation statistical analysis will be based on twenty-five correlations from the trivariate specifications.
- The investigation of forty-four correlations in total provides a unique framework to scrutinize a wide variety of sectoral interdependences with particular focus on:
- sovereign with corporate bond markets, the major financial industry of Banks with all other corporate sectors, the financial subsectors, the consumer goods and services subsectors, heavy industries with utilities, and medical with technological sectors.


TRS-CPT
BNK-IND
BNK-CG_AUT
BNK-HC
TRS-FIN
TRS-NON_FIN
UTL-IND_CM
CS_RET-CS_TL
HC-TEC

Procyclical Behavior

- The graphical analysis provides strong evidence supporting the cyclical nature of correlations.
- Specifically, correlation timeseries decrease sharply in periods of market turbulence, whereas they remain high in tranquil times.
- This pattern highlights the inherently procyclical behavior of sectoral interdependences and decoupling in bond markets.
- These findings contrast with the well-documented countercyclical sectoral interlinkages and contagion observed in equities, credit default swaps (CDS), and other financial instruments.
- The near-unity correlations observed across all sectors during normal market conditions provide compelling evidence of a high degree of bond market integration.
- This level of cohesion is not typically seen in other asset classes, such as equities, commodities, or credit derivatives.

Sectoral Bond Interdependencies

- To the best of our knowledge, this is the first study to provide such conclusions on financial interdependences.
- Bond sectors have been largely overlooked by the existing literature and the procyclical pattern is mostly diagnosed for safe havens in the cross-asset nexus (e.g., sovereign bonds-stocks, precious metals-stocks).
- Our findings can further feed into real-world practices of policymakers and investment industry experts.
- Policymakers should consider the bonds' resilience in times of crisis, which can reduce systemic risk and promote financial stability.
- Portfolio and risk managers must incorporate sectoral bond combinations in their investment and risk strategies to take advantage of the diversification benefits due to decreased correlations in periods of market turbulence.

Policymakers and Risk Managers

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- Policymakers should consider the bonds' resilience in times of crisis, which can reduce systemic risk and promote financial stability.
- **Portfolio and risk managers** must incorporate sectoral bond combinations in their investment and risk strategies to take advantage of the diversification benefits due to decreased correlations in periods of market turbulence.

Divirsifiers

- The summary statistics for the entire period confirm high maximum values close to one for all correlations, with mean values around 0.80 and 0.90.
- Beyond certifying the *high market integration*, the overall positive (but below unity) correlations on average demonstrate that all sectors act as diversifiers (Baur and Lucey, 2010), supporting H1a.

Crisis Analysis

- After reviewing the summary statistics, we investigate how correlations behave in response to **crisis shocks**.
- Their vulnerability to crises is assessed through mean difference tests, including the Satterthwaite-Welch t-test and Welch F-test, to determine the interdependence patterns under *the second hypothesis (H2)*.

Global Crisis: Decoupling

- In the context of the Global Crisis, correlations predominantly exhibit a significant decline while maintaining a positive in-crisis average.
- This finding provides strong empirical support for decoupling (H2c) and **procyclicality (H3a)** as correlation decreases coincide with the economic downturn.
- The decoupling phenomenon has been primarily documented in the stock-bond nexus during flight-to-quality episodes and among safe-haven assets.

	Global crisis
TRS-CPT	Decoupling (↓)
BNK-INS	Decoupling (↓)
BNK-FIN_SRV	Decoupling (↓)
BNK-RE	Decoupling (↓)
BNK-OG	Decoupling (↓)
BNK-BMAT	Decoupling (↓)
BNK-IND	Decoupling (↓)
BNK-CG	Decoupling (↓)
BNK-CG_AUT	Decoupling (↓)
BNK-CG_FB	Decoupling (↓)
BNK-CG_PHHG	Decoupling (↓)
BNK-CS	Decoupling (↓)
BNK-CS_RET	Decoupling (↓)
BNK-CS_MED	Decoupling (↓)
BNK-CS_TL	Decoupling (↓)
BNK-UTL	Decoupling (↓)
BNK-HC	Decoupling (↓)
BNK-TEL	Decoupling (↓)
BNK-TEC	Decoupling (↓)

Model	Combinations	Global crisis
(i)	TRS-FIN	Decoupling (↓)
	TRS-NON_FIN	Decoupling (↓)
	FIN-NON_FIN	Decoupling (↓)
(ii)	INS-FIN_SRV	Decoupling (↓)
	INS-RE	Decoupling (↓)
	FIN_SRV-RE	Decoupling (↓)
(iii)	BNK-BMAT_CHEM	Decoupling (↓)
	BNK-BMAT_BRS	Decoupling (↓)
	BMAT_CHEM-BRS	Decoupling (↓)
(iv)	BNK-IND_CM	Decoupling (↓)
	BNK-IND_GS	Decoupling (↓)
	IND_CM-IND_GS	Decoupling (↓)
(v)	CG_AUT-CG_FB	Decoupling (↓)
	CG_AUT-CG_PHHG	Decoupling (↓)
	CG_FB-CG_PHHG	Decoupling (↓)
(vi)	CS_RET-CS_MED	Decoupling (↓)
	CS_RET-CS_TL	Contagion
	CS_MED-CS_TL	Contagion
(vii)	OG-BMAT_CHEM	Decoupling (↓)
	OG-BMAT_BRS	Decoupling (↓)
(viii)	UTL-IND_CM	Decoupling (↓)
	UTL-IND_GS	Decoupling (↓)
(ix)	HC-TEL	Decoupling (↓)
	HC-TEC	Decoupling (↓)
	TEL-TEC	Decoupling (↓)

Two cases of Contagion

- Within the trivariate models, only two correlations in the Consumer Services sector—specifically, Travel & Leisure with Retail and Travel & Leisure with Media—demonstrate a significant increase during the Global Crisis, maintaining a positive in-crisis level.
- These two instances represent the only observed cases of contagion (H2a) and countercyclicality (H3b) within the broader decoupling environment that characterized the US bond market during the 2008 global financial crisis.
- This case of contagion suggests that the Consumer Services industry is less resilient than other sovereign and corporate sectors, which tend to decouple during crises.
- Unlike these sectors, which provide diversification opportunities and contribute to overall financial stability, the Consumer Services sector appears more susceptible to market turbulence.

Model	Combinations	European crisis
(i)	TRS-FIN	Decoupling (↓)
	TRS-NON_FIN	Decoupling (↓)
	FIN-NON_FIN	Decoupling (↓)
(ii)	INS-FIN_SRV	Contagion
	INS-RE	Contagion
	FIN_SRV-RE	Contagion
(iii)	BNK-BMAT_CHEM	Decoupling (↓)
	BNK-BMAT_BRS	Decoupling (↓)
	BMAT_CHEM-BRS	Contagion
(iv)	BNK-IND_CM	Decoupling (↓)
	BNK-IND_GS	Decoupling (↓)
	IND_CM-IND_GS	Lower interdependence
(v)	CG_AUT-CG_FB	Contagion
	CG_AUT-CG_PHHG	Contagion
	CG_FB-CG_PHHG	Contagion
(vi)	CS_RET-CS_MED	Contagion
	CS_RET-CS_TL	Contagion
	CS_MED-CS_TL	Contagion
(vii)	OG-BMAT_CHEM	Contagion
	OG-BMAT_BRS	Contagion
(viii)	UTL-IND_CM	Lower interdependence
	UTL-IND_GS	Contagion
(ix)	HC-TEL	Decoupling (↓)
	HC-TEC	Contagion
	TEL-TEC	Contagion

European Crisis
Banks (Bivariate Models): Decoupling

- Turning to the European crisis, we find that the US bond market was not entirely unaffected. Decoupling (H2) is the predominant interdependence type in Treasuries with Corporates and Banks with other corporate sectors.
- There are two cases of an insignificant correlation decrease among financial subsectors (Banks with Insurance and Banks with Financial Services), which leads to the conclusion of lower interdependence.
- The sole exception of increasing correlations is observed in the pair of Banks with a Consumer Goods subsector (Automobiles & Parts).

Trivariate Systems: Mixed Results Contagion, Countercyclicality

- The trivariate models yield mixed results.
- The majority of pairwise correlations exhibit contagion (H2a) and countercyclicality (H3b), reflecting their response to the European business cycle downturn.
- A significant correlation increase during the European debt market turmoil is estimated for various corporate sectoral pairs: the Financial, the Basic Materials, the Consumer Goods and Services subsectors,
- Oil & Gas (with Basic Materials), Utilities with Industrial Goods and Services, Health Care with Telecommunications and with the two technological sectors.

Decoupling, Procyclicality

- In line with the bivariate results, decoupling (H2c) and procyclicality (H3a) is still the case for the following combinations:
- (i) sovereign, financial, and non-financial industries,
- (ii) Banks with Basic Materials and with Industrial subsectors,
- and (iii) Health Care with Telecommunications.
- Additionally, two instances of lower interdependence, characterized by insignificant correlation decreases, are identified in the Industrial subsectors pair and between Utilities and Industrial Construction & Materials.

	Covid crisis
TRS-CPT	Decoupling (↓)
BNK-INS	Decoupling (↓)
BNK-FIN_SRV	Decoupling (↓)
BNK-RE	Decoupling (↓)
BNK-OG	Decoupling (↓)
BNK-BMAT	Decoupling (↓)
BNK-IND	Decoupling (↓)
BNK-CG	Decoupling (↓)
BNK-CG_AUT	Decoupling (↓)
BNK-CG_FB	Decoupling (↓)
BNK-CG_PHHG	Decoupling (↓)
BNK-CS	Decoupling (↓)
BNK-CS_RET	Decoupling (↓)
BNK-CS_MED	Decoupling (↓)
BNK-CS_TL	Decoupling (↓)
BNK-UTL	Decoupling (↓)
BNK-HC	Decoupling (↓)
BNK-TEL	Decoupling (↓)
BNK-TEC	Decoupling (↓)

Model	Combinations	Covid crisis
(i)	TRS-FIN	Decoupling (↓)
	TRS-NON_FIN	Decoupling (↓)
	FIN-NON_FIN	Decoupling (↓)
(ii)	INS-FIN_SRV	Decoupling (↓)
	INS-RE	Decoupling (↓)
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	BNK-IND_GS	Decoupling (↓)
	IND_CM-IND_GS	Decoupling (↓)
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	CG_AUT-CG_PHHG	Decoupling (↓)
	CG_FB-CG_PHHG	Decoupling (↓)
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(ix)	HC-TEL	Decoupling (↓)
	HC-TEC	Decoupling (↓)
	TEL-TEC	Decoupling (↓)

Covid Crisis: Decoupling

- Moving to the Covid crisis, we observe a decoupling environment similar to that of the 2008 global financial crisis, in stark contrast to the mixed outcomes of the regional crisis in the European economy.
- The pandemic-induced economic shock had a widespread impact on global markets, resembling the effects of the US subprime crisis.
- Covid correlations decrease significantly with the *economic* slowdown (H3a) with bond markets exhibiting broad-based decoupling (H2c) across all sectors.
- Nevertheless, the health crisis shock has been less potent than the 2008 turmoil. It has not driven correlations close to the negative territory for any short crisis times.

Regression Analysis

- Next, we identify macro indicators that drive the cyclical dynamics of conditional correlations through regression analysis.
- The correlation time series are Fisher-transformed (ρ_t) and used as dependent variables in an OLS regression where we add the macro and news proxies as explanatory variables of the correlation trajectory.
- As explained earlier, we incorporate six macro effects:
- *economic policy* and *financial uncertainty*, *disease news*, *credit conditions*,
- *news sentiment*, *economic activity*,
- each of which is tested separately in the following regression model:

$$\rho_t = \kappa_0 + \kappa_1 \rho_{t-1} + \kappa_2 X_{t-1} + u_t, \qquad (7)$$

Table 6. Sectoral bond correlations: macro regression results

Panel A. Regressions on macro and news variables						
	EPU	FU	ID	CR	NS	EC
TRS-CPT	-0.0016^{*}	-0.0453^{*}	-0.0034	-0.2075^{*}	0.0318^{*}	0.0201°
	(-1.99)	(-2.24)	(-1.20)	(-2.05)	(2.01)	(1.69)

Procyclicality

- Our findings show that we can clearly accept the **procyclicality** hypothesis (H3a) for the entire sample in the decoupling sectoral combinations where decoupling and lower interdependence are the predominant patterns across the whole sample (at least for two out of three crises).
- *Uncertainties*, *disease news*, and *credit conditions* are estimated with a negative sign, while *news sentiment* and *economic activity* get a positive sign
- Weak fundamentals drive correlations at lower levels.

Impact of Economic Uncertainty

- We measure EPU's indirect effect on correlations by adding the EPU interaction terms into our specification as follows:

$$\rho_t = \kappa_0 + \kappa_1 \rho_{t-1} + \kappa_2 EPU_{t-1} + (\kappa_3 + \kappa_3^{EPU} EPU_{t-1}) X_{t-1} + u_t,$$

Panel B. The policy uncertainty impact on macro regressors

$EPU\times$	FU	ID	CR	NS	EC
TRS-CPT	-0.0057^{*}	-0.0014	-0.0296^{*}	0.0109°	0.0075°
	(-2.12)	(-1.01)	(-2.11)	(1.86)	(1.73)

Procyclicality

- The *indirect economic uncertainty* effect shows similar results with the uncertainty channel exacerbating the macro effects on correlations.
- The EPU interaction terms partly explain the impact of each regressor on bond connectedness dynamics and are estimated with the same sign as the macro impact for the procyclical cases.

The Crisis Impact

- Next, we enrich our macro sensitivity exercise by estimating the macro effects for each crisis period.
- We add slope dummy variables to the macro regressors to isolate each macro impact during the two global crises, the financial (GF) and the health (GH) crises:

$$\rho_t = \kappa_0 + \kappa_1 \rho_{t-1} + (\kappa_2 + \kappa_2^C Dum_{C,t-1}) X_{t-1} + u_t, \qquad (9)$$

The Crisis Impact

- Finally, we explore the crisis shock on the indirect EPU effect by adding slope dummies to the EPU interaction terms as follows:

$$\rho_t = \kappa_0 + \kappa_1 \rho_{t-1} + \kappa_2 EPU_{t-1} + (\kappa_3 + \kappa_3^{C\text{-}EPU} Dum_{C,t-1} EPU_{t-1}) X_{t-1} + u_t, \qquad (10)$$

Panel C. The crisis impact on macro regressors

$Dum_{GF}\times$	EPU	FU	ID	CR	NS	EC
TRS-CPT	-0.0011^{*}	-0.0039^{*}	-0.0028	-0.0767^{*}	0.0288^{**}	0.0029°
	(-2.10)	(-2.24)	(-0.50)	(-2.05)	(2.48)	(1.68)

Panel C. The policy uncertainty impact on macro regressors during the Global crisis

$Dum_{GF}EPU\times$	FU	ID	CR	NS	EC
TRS-CPT	-0.0019^{*}	-0.0017	-0.0307^{**}	0.0109^{*}	0.0015°
	(-2.37)	(-1.29)	(-2.47)	(2.00)	(1.70)

Procyclicality

- Finally, the crisis influence on correlation drivers and the indirect EPU impact further strengthen our conclusions on the macro relevance of bonds co-movement.
- The effects of the macro environment are intensified by the crisis shock as estimated by the slope dummies.
- The regressors retain the same sign, in line with the procyclicality hypothesis, but their effect is amplified by the crisis shock.

Table 6. Sectoral bond correlations: macro regression results

Panel A. Regressions on macro and news variables						
	EPU	*FU*	*ID*	*CR*	*NS*	*EC*
CS_RET-CS_TL	−0.0006	−0.0078	0.0004	−0.0365*	0.0216*	0.0014
	(−0.97)	(−1.46)	(0.28)	(−2.41)	(2.15)	(0.72)
CS_MED-CS_TL	−0.0010	−0.0073	0.0004	−0.0423**	0.0195°	0.0016
	(−1.37)	(−1.42)	(0.25)	(−2.46)	(1.70)	(0.70)

Consumer Services: Mixed Results

- For combinations that are characterized by contagion in more than one crisis, the signs are mixed, preventing us from confirming any of the cyclicality hypotheses in the initial macro regression.
- In particular, for the two Consumer Services pairs with contagion across the Global and European turmoils:
- Uncertainty, disease, and activity coefficients are insignificant with mixed signs,
- while credit and news sentiment effects are significant with signs fitting to the procyclicality case.

Panel B. The policy uncertainty impact on macro regressors					
$EPU\times$	FU	ID	CR	NS	EC
CS_RET-CS_TL	−0.0006	0.0000	−0.0081*	0.0076°	0.0004
	(−1.12)	(0.28)	(−2.02)	(1.74)	(0.59)
CS_MED-CS_TL	−0.0009	0.0001	−0.0099**	0.0062	0.0005
	(−1.35)	(0.06)	(−2.48)	(1.45)	(0.59)

Consumer Services: Mixed Results

- The same applies to the indirect EPU effect on these correlations mixed signs and insignificant parameters.

Panel C. The crisis impact on macro regressors

$Dum_{GF}\times$	EPU	FU	ID	CR	NS	EC
CS_RET-CS_TL	0.0005*	0.0070°	0.0001	0.0472°	−0.0203*	−0.0003°
	(2.11)	(1.69)	(0.36)	(1.89)	(−1.99)	(−1.82)
CS_MED-CS_TL	0.0007*	0.0076°	0.0002	0.0623*	−0.0328°	−0.0010°
	(2.30)	(1.72)	(0.43)	(2.31)	(−1.83)	(−1.66)

Panel C. The policy uncertainty impact on macro regressors during the Global crisis

$Dum_{GF}EPU\times$	FU	ID	CR	NS	EC
CS_RET-CS_TL	0.0013°	0.0000	0.0315*	−0.0118*	−0.0001°
	(1.72)	(0.42)	(1.97)	(−2.06)	(−1.68)
CS_MED-CS_TL	0.0026°	0.0001	0.0502*	−0.0159°	−0.0003°
	(1.83)	(0.69)	(2.33)	(−1.84)	(−1.65)

Countercyclicality

- The addition of the crisis shock, however, allows us to clearly accept the countercyclicality hypothesis for the Global *crisis period*, where *contagion* is diagnosed.
- *Weak fundamentals* of the financial turmoil increase countercyclical correlations by adding an increment to the macro drivers and the indirect EPU impact:
- uncertainties and credit effects become more positive, while news and activity turn more negative.
- The disease news slope dummy is insignificant since the disease effect is more profound in the pandemic times.

Implications and Discussion

- Our findings on the **sectoral bonds n**exus demonstrate the predominant decoupling phenomenon in turbulent times.
- Such a conclusion has important implications for portfolio and risk managers.
- While, for most assets, correlations sharply escalate after a crisis shock, the bond market exhibits resilience with looser interdependences, given the downward sectoral correlation trajectory during turmoils.
- Investment portfolios and effective risk strategies should exploit this unique opportunity for hedging and diversification in times when most correlations of risky assets explode.
- Against this backdrop, we discuss the implications of the proposed econometric specification and our novel results on sectoral bond markets.

Hedge Bond Portfolios

- Let us denote the portfolio p and the first and second indices as asset i and j, respectively.
- The daily payoff of the bond portfolio is computed as follows:
- $r_{pt} = r_{it} - b_{ij,t} r_{jt}$. Type equation here.
- The weight of the hedge instrument (j) is the **dynamic beta** $(b_{ij,t})$ of the portfolio.
- This is our time-varying optimal hedge ratio or hedging cost, estimated on a daily basis to minimize portfolio risk.
- Our one-dollar purchase of index i is covered by the beta dollars sale of index j. This optimization exercise calculates the daily beta as follows:
- $b_{ij,t} = \frac{\sigma_{ij,t}}{\sigma_{jt}}$,
- where $\sigma_{ij,t}$ represents the covariance between the two indices, and σ_{jt} denotes the variance of the hedge position j.

Hedging cost decreases

- Since the hedging cost is tightly related to the covariance structure, we expect that its pattern highly depends on the correlation dynamics and exhibits cyclicality sensitive to macro fundamentals and crisis episodes.
- Tables 7 and 8 report the dynamic beta estimations for each crisis subsample. We present the in-crisis average levels and changes compared to the pre-crisis periods across all sectoral pairs under scope.
- For most portfolios, the hedging cost decreases during turbulent times in line with the decoupling phenomenon observed in correlation dynamics.

Table 7. Optimal hedge ratios (dynamic betas) of sectoral bond portfolios (bivariate systems).

	Global crisis			European crisis			Covid crisis		
	pre-crisis	in-crisis	mean diff.	pre-crisis	in-crisis	mean diff.	pre-crisis	in-crisis	mean diff.
TRS-CPT	0.960	0.962	+0.002	0.862	0.670	−0.192	1.072	0.429	−0.643
BNK-INS	0.726	0.651	−0.074	0.599	0.699	+0.100	0.587	0.487	−0.100
BNK-FIN_SRV	0.951	0.860	−0.091	0.896	0.909	+0.013	0.938	0.989	+0.051
BNK-RE	0.905	0.525	−0.380	0.455	0.500	+0.045	0.815	0.648	−0.167
BNK-OG	0.635	0.577	−0.058	0.600	0.457	−0.144	0.614	0.561	−0.052
BNK-BMAT	0.764	0.686	−0.078	0.704	0.596	−0.107	0.680	0.474	−0.205
BNK-IND	0.821	0.790	−0.030	0.743	0.453	−0.290	0.600	0.434	−0.166
BNK-CG	0.890	0.813	−0.077	0.754	0.511	−0.243	0.731	0.556	−0.175
BNK-CG_AUT	0.977	0.723	−0.254	0.432	0.542	+0.110	1.003	0.588	−0.415
BNK-CG_FB	0.813	0.721	−0.092	0.661	0.473	−0.188	0.615	0.471	−0.144
BNK-CG_PHHG	0.860	0.723	−0.137	0.632	0.478	−0.154	0.633	0.526	−0.107
BNK-CS	0.785	0.763	−0.022	0.677	0.442	−0.235	0.617	0.442	−0.175
BNK-CS_RET	0.837	0.755	−0.081	0.629	0.390	−0.238	0.607	0.445	−0.162
BNK-CS_MED	0.686	0.696	+0.010	0.617	0.444	−0.173	0.582	0.413	−0.169
BNK-CS_TL	0.886	0.625	−0.262	0.465	0.354	−0.111	0.687	0.532	−0.154
BNK-UTL	0.721	0.641	−0.080	0.576	0.322	−0.254	0.456	0.325	−0.130
BNK-HC	0.691	0.669	−0.022	0.595	0.402	−0.193	0.619	0.499	−0.121
BNK-TEL	0.712	0.707	−0.005	0.650	0.521	−0.129	0.535	0.380	−0.155
BNK-TEC	0.813	0.783	−0.030	0.694	0.520	−0.174	0.699	0.522	−0.177

Decline Betas⟶Decoupling

- In hedge portfolios derived from bond pairs of the bivariate systems (Table7), we have two cases (Treasuries-Corporates and Banks-Media) of a minor increase in the dynamic beta during the Global crisis in contrast to the falling in-crisis correlations.
- In the European crisis, four bond portfolios exhibit a hedging cost increase. For the pair of *Banks with Automobiles & Parts*, the optimal hedge ratio change is in line with the contagion we have diagnosed for this interdependence combination.
- For the other three pairs, the change is small, while correlations decrease.
- In the Covid crisis, all average betas decrease in line with the overall decoupling, except for one case of a portfolio with two financial subsectors(Banks-Financial Services).

Table 8. Optimal hedge ratios (dynamic betas) of sectoral bond portfolios (trivariate systems).

Model	Pairs	Global crisis			European crisis			Covid crisis		
		pre-crisis	in-crisis	mean diff.	pre-crisis	in-crisis	mean diff.	pre-crisis	in-crisis	mean diff.
(i)	TRS-FIN	1.108	0.882	−0.227	0.747	0.513	−0.235	1.385	0.470	−0.914
	TRS-NON_FIN	0.865	0.994	+0.129	0.787	0.606	−0.180	0.955	0.388	−0.567
	FIN-NON_FIN	0.772	0.754	−0.018	0.801	0.549	−0.253	0.682	0.601	−0.081
(ii)	INS-FIN_SRV	1.331	0.965	−0.367	1.050	1.012	−0.037	1.561	1.481	−0.080
	INS-RE	1.248	0.658	−0.591	0.636	0.755	+0.119	1.340	1.155	−0.185
	FIN_SRV-RE	0.908	0.490	−0.418	0.531	0.638	+0.108	0.849	0.678	−0.171
(iii)	BNK-BMAT_CHEM	0.836	0.711	−0.125	0.614	0.567	−0.046	0.629	0.384	−0.245
	BNK-BMAT_BRS	0.696	0.615	−0.082	0.633	0.559	−0.074	0.649	0.482	−0.167
	BMAT_CHEM-BRS	0.791	0.685	−0.106	0.757	0.716	−0.042	1.014	1.248	+0.234
(iv)	BNK-IND_CM	0.827	0.520	−0.307	0.377	0.405	+0.029	0.553	0.392	−0.161
	BNK-IND_GS	0.793	0.779	−0.015	0.707	0.420	−0.287	0.638	0.458	−0.180
	IND_CM-IND_GS	0.876	0.792	−0.085	0.729	0.510	−0.219	1.108	0.862	−0.246
(v)	CG_AUT-CG_FB	0.702	0.586	−0.116	0.354	0.594	+0.240	0.530	0.620	+0.090
	CG_AUT-CG_PHHG	0.774	0.597	−0.176	0.305	0.589	+0.283	0.525	0.791	+0.266
	CG_FB-CG_PHHG	1.069	0.884	−0.186	0.780	0.922	+0.143	0.957	1.193	+0.235
(vi)	CS_RET-CS_MED	0.836	0.871	+0.036	0.835	0.870	+0.035	0.936	0.784	−0.153
	CS_RET-CS_TL	1.099	0.799	−0.300	0.726	0.905	+0.179	1.074	0.974	−0.101
	CS_MED-CS_TL	1.196	0.828	−0.368	0.691	0.846	+0.154	1.072	1.153	+0.081
(vii)	OG-BMAT_CHEM	1.085	0.919	−0.166	0.849	0.975	+0.125	0.985	0.790	−0.195
	OG-BMAT_BRS	0.982	0.848	−0.133	0.829	0.872	+0.043	0.994	0.692	−0.302
(viii)	UTL-IND_CM	1.036	0.705	−0.332	0.620	0.862	+0.242	1.121	0.949	−0.172
	UTL-IND_GS	1.079	1.044	−0.035	1.074	1.178	+0.104	1.278	1.049	−0.229
(ix)	HC-TEL	0.985	0.905	−0.080	0.903	0.882	−0.020	0.861	0.704	−0.156
	HC-TEC	1.183	1.061	−0.122	1.020	1.136	+0.115	1.078	1.013	−0.065
	TEL-TEC	1.157	1.020	−0.137	0.983	1.061	+0.077	1.168	1.268	+0.100

Trivariate Systems

- For sectoral pairs of the trivariate systems (Table 8), during the two global crises, we estimate once again lower hedging costs for most cases, following the lower interdependences for most portfolios.
- In the European crisis, where there are many contagion phenomena, the optimal hedge ratios are rising for the majority of contagious bond sectors. Similarly, for *most decouplers*, the *betas fa*ll.

Summary

- In summary, it is evident that market practitioners should consider the predominant pattern of sectoral bond correlations, that is, decoupling, which offers dramatically *reduced hedging costs* and *diversification benefits*.
- The procyclical nature of bond connectedness for most sectors can protect the financial system with a precious safeguard of resilience.
- Macro-prudential policies should take into account that bonds, a widely utilized asset class, *contribute to financial stability* even in difficult times of a market or *global turmoil*.
- Holding bond positions in a variety of different sovereign and corporate sectors guarantee a secure payoff for market players.
- **Regulatory frameworks** should encourage individual and, most importantly, **institutional investors** to delve into this sectoral range in order to avoid big losses or bankruptcy dominos during crises.