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The Propagation Mechanism of Financial Stress in the Context of Global Crises

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Abstract

This study examines the dynamic relationship between the uncertainty indices of seven Asian countries (China, Japan, India, Singapore, South Korea, Malaysia and Taiwan) and the Kansas City Financial Stress Index (KCFSI) of the United States using cross-wavelet transform analysis and Toda-Yamamoto causality test between the period of 2008:01 - 2025:02. Utilizing a dual methodology comprising the cross-wavelet transform (XWT) to capture time-frequency co-movements and the Toda-Yamamoto causality test to establish directional linkages and their statistical significance. The findings reveal significant in-phase coherence, indicating that financial stress in the US often precedes increases in economic uncertainty across Asian economies, particularly during global crises like the 2008 financial crisis and the COVID-19 pandemic. The results highlight the varying degrees of coherence and lead-lag relationships across countries, reflecting differences in economic structures and integration into global markets. These insights emphasize the need for stronger regional financial cooperation, proactive economic policies, and robust risk management strategies to mitigate the impact of external financial shocks. The study concludes with recommendations for future research, including the exploration of additional factors influencing financial stress transmission and the role of emerging financial technologies in global economic stability.

Key words: Cross-wavelet transform, financial crises, Uncertainty index, Early warning, Asian countries

JEL Code: G01, G15, E44

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1. Introduction

History has shown that financial instability in one region can have profound effects globally. For instance, the Asian financial crisis of 1997 had caused widespread currency and financial market volatility in Asian economies such as Thailand, Indonesia, and South Korea, severely undermining regional economic growth (Henderson, 1999; Ho & Yeh, 2014). The mortgage crisis that erupted in the US in 2008 led to a widespread meltdown in global financial markets and had far-reaching effects on economies outside the US (Sapir, 2008; Yeoh, 2010). The problems in the US housing market also deeply affected banks and financial institutions in Europe, setting the stage for the eurozone debt crisis in 2011 (Matthijs, 2013). The eurozone debt crisis, in turn, had widespread negative effects on the global economy, particularly in countries such as Greece, Spain and Italy (Park, 2015), with problems in the public debt and banking sectors (Nelson et al., 2012). These examples clearly illustrate how regional financial crises can spread to the global economy and how economic instability can have a global impact.

Financial crises and market crises are often accompanied by uncertainty. Particularly in Asia (Li & Zhong, 2020), this uncertainty is associated with factors such as political instability, policy changes, market volatility (Alessandri & Mumtaz, 2019) and unexpected global events (Phan et al., 2021; Tsai, 2017; Uddin et al., 2021). High levels of economic and political uncertainty in Asia can lead to business disinvestment, a decline in consumer confidence, and a general economic slowdown (Nilavongse et al., 2020). This suggests that stability is critical for sustainable growth, especially in rapidly developing economies (Bonciani & Ricci, 2020).

Asian countries are a critical concern of uncertainties due to their important role in global trade and economic growth (Wen et al., 2021). These countries such as China, India, Japan, Korea, Malaysia, Singapore and Taiwan are active players in the international markets (Goldstein & Xie, 2011; Hsieh & Nieh, 2010). Financial instability in these countries is associated with various factors such as domestic policy changes, economic reforms, geopolitical tensions and global economic crises (Garrett, 2010; Wang et al., 2021). Therefore, it should be considered that volatility in the financial markets of these economies can cause economic fluctuations worldwide. In this context, continuous monitoring and the adoption of sound risk management strategies are critical to maintaining economic stability.

Adding to the complexity of uncertainties in Asian countries are their diverse economic structures and policy environments (Mohd Thas Thaker et al., 2022). For example, China's exposure to international trade represents a strategic vulnerability in the context of escalating geopolitical tensions. Its deep integration into Western supply chains, especially within high-tech and manufacturing industries, renders it increasingly susceptible to sanctions, export controls and shifts in global trade alliances, while India's economic reforms and growth roadmap present unique challenges and opportunities. Japan, with an advanced economy, is experiencing financial uncertainties influenced by both domestic factors and its interactions with other major economies. The country faces structural vulnerabilities stemming from its aging population, high public debt and persistent

deflationary pressures. These internal challenges are further compounded by Japan's heavy reliance on energy imports and its exposure to external demand, particularly from China and the United States. Despite its technological strengths and robust industrial base, Japan's long-term economic resilience remains constrained by demographic stagnation and fiscal rigidity. Similarly, Korea's technology-based economy is highly sensitive to changes in global demand. Malaysia's resource-based economy is affected by fluctuations in commodity prices and changes in global trade policies. Singapore's position as an international financial center is considered a barometer of global economic fluctuations. Taiwan, with its expertise in high-tech manufacturing, is an important part of regional and global supply chains. These countries, each with its own unique economic profile, face varying degrees of financial uncertainty driven by internal and external forces.

The relationship between these Asian countries and the United States plays an important role in shaping financial uncertainty. The United States is a major trading partner and investor in many of these economies (Frankel et al., 1996; Petri et al., 2017; Shi, 2022). Financial stress originating in the US could have a significant impact on Asia. The interconnectedness of markets means that economic policies, market sentiment, and financial conditions in the US can affect financial stability in these Asian countries (Kim et al., 2015). For example, changes in US interest rates or economic performance can lead to capital flows that affect exchange rates, investment levels and overall financial stability in Asia. In addition, trade policies and geopolitical events involving the US can cause financial volatility in these countries. By examining the correspondence between uncertainty index and the Kansas City Financial Stress Index (KCFSI) in selected Asian countries, this paper highlights the need for an in-depth understanding of how Kansas City Financial Stress Index (KCFSI) affects these Asian countries.

1.1. Research Questions

-What is the dynamic relationship between the Kansas City Financial Stress Index (KCFSI), and uncertainty index in selected Asian countries?

This question explores how KCFSI originating in the US impacts uncertainty index in various Asian countries, emphasizing the lead-lag relationships and the nature of these interactions during different periods.

-How do different Asian countries respond to KCFSI, and what are the patterns of coherence observed during major global crises?

This question addresses the varying responses of each country (China, India, Japan, Korea, Malaysia, Singapore, and Taiwan) to external financial shocks, especially during significant global events like the 2008 financial crisis and the COVID-19 pandemic.

-What factors contribute to differences in financial stress transmission between the US and the selected Asian countries?

This question seeks to identify and explain the factors that cause differences in the lead-lag dynamics between the US and each Asian country, such as economic structure, policy environments, and levels of global market integration.

1.2. Contributions

The motivation for this study stems from the need to address the vulnerabilities revealed by the recent global financial crises. By examining the links between financial stress in the US and financial markets in Asian countries, it aims to provide a comprehensive understanding of how financial stress is transmitted across borders. This understanding is essential for developing resilient financial systems that can withstand external shocks and maintain economic stability. The study aims to provide policymakers with insights into the timing and nature of the transmission of financial stress, enabling them to implement more effective and timely policy responses. It also aims to provide investors with information on potential early warning indicators and risk management strategies that can mitigate the impact of financial turmoil.

The novel contributions of this study are as follows:

-The study aims to contribute to a more stable and resilient global financial system, thereby promoting sustainable economic growth and stability.
-It is the first to apply the cross-wavelet transform (XWT) methodology to examine the linkages between KCFSI and uncertainty indices of seven major Asian economies.
-This study integrates XWT with the Toda-Yamamoto causality test, capturing both time-frequency co-movements and directional relationships.
-It documents heterogeneous lead-lag patterns across countries, revealing how structural differences and varying market integration affect financial stress transmission.
-Furthermore, it provides actionable policy insights for enhancing regional financial stability and mitigating the impact of global financial shocks.

This study is organized into five main sections. The first section introduces the research topic, sets the context, and outlines the objectives of the study. The second section reviews the existing literature and provides a comprehensive overview of the interconnectedness of global financial markets and the methodologies used to study these relationships. The third section discusses the data and methodology used in the study, focusing on cross-wavelet transform analysis to capture time-frequency interactions and Toda-Yamamoto test to explore the directional linkages between the KCFSI and uncertainty indices of selected Asian economies. The fourth section presents the empirical findings, detailing the significant wavelet coherence patterns observed between KCFSI and Asian countries uncertainties across countries and time periods.

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Finally, the fifth section presents recommendations and conclusions based on the findings of the study, providing actionable insights for policymakers and investors, summarizing the main contributions and suggesting areas for future research.

2. Literature Review

The relationship between financial markets across different regions has been extensively studied, especially in the context of financial crises and economic downturns. Numerous studies have demonstrated that financial stress and uncertainties in one region can have profound impacts on other regions, underscoring the global nature of financial markets.

Research using various methodologies, including Granger causality tests, vector autoregressions (VAR), and wavelet analysis, has provided insights into the dynamic interactions between different financial indices. However, there remains a gap in the literature regarding the time-frequency characteristics of these relationships, particularly between major Asian economies and KCFSI. This study aims to fill this gap by employing wavelet coherence analysis to capture the complex and evolving nature of these interactions over time and across frequencies.

A study by Chadwick and Ozturk (2019) created and compared 15 different financial stress indicators across five markets for Turkey using weekly data from 2005 to 2016, finding that a model-averaged indicator effectively identifies periods of financial stress. Sun and Huang (2016) constructed a financial stress index (CNFSI) and a financial conditions index (CNFCI) based on monthly data from China's inter-bank, stock, foreign exchange, and debt markets, showing that the CNFSI performs better in identifying systemic financial stress episodes and proposing leading indicators for monitoring financial instability.

Mansour Ishrakieh et al. (2020) created Lebanon's first Financial Stress Index and emphasized that the dollarization rate is a key indicator, which is significant for other heavily dollarized economies such as Bolivia, Peru, and Uruguay. Çevik et al. (2016) constructed a financial stress index using a dynamic factor model for Indonesia, South Korea, Malaysia, the Philippines, and Thailand, incorporating banking sector risk, security market risk, currency risk, external debt, and sovereign risk, demonstrating that the index effectively tracks recessions and shows that financial stress leads to significant economic slowdowns.

MacDonald et al. (2018) examined cross-covariance and spillover effects among Eurozone economies and financial markets using systemic risk metrics in a multivariate GARCH model, revealing intense stress transmission impacting banking and money markets. Armah et al. (2022) conducted a time-frequency analysis of financial stress and global commodities prices using wavelet-based approaches, providing insights into the dynamic interactions between financial stress and commodity markets. Liu et al. (2017) shows that Economic Policy Uncertainty (EPU) significantly increases future market volatility and that incorporating EPU into volatility models improves forecast performance, with

multifractal volatility models outperforming GARCH class models. A paper investigates volatility spillovers between US economic policy uncertainty and BRIC equity markets, revealing a time-varying and oscillating correlation that underscores the high risk for investors in these markets, especially during periods of global economic instability (Dakhlaoui & Aloui, 2016).

Dagher and Hasanov (2023) investigated oil market shocks and financial instability in Asian countries, highlighting the significant impact of external shocks on financial stability in the region. Fink and Schüler (2015) explored the transmission of U.S. systemic financial stress to emerging market economies, finding that financial stress in the U.S. has substantial spillover effects on these markets. Hippler and Hassan (2015) analyzed the impact of macroeconomic and financial stress on the U.S. financial sector, emphasizing the need for robust risk management strategies to mitigate the effects of financial stress.

Singh and Singh (2017) examined the linkages between U.S. and Indian financial stress indices, demonstrating the interdependencies between these markets and the implications for economic policy. Tiwari et al. (Tiwari et al., 2020) studied the synchronization of policy-related uncertainty, financial stress, and economic activity in the United States, using wavelet coherence to capture the complex interactions between these variables. While the US-China trade conflict has increased global market uncertainty, the US maintains its dominant position in key international markets despite China's growing influence, one study finds, suggesting that concerns about China's rivalry with the US in shaping the global order are less political and political (Zhang et al., 2019). Das & Kumar (2018) expand on the relationship between Economic Policy Uncertainty (EPU) and Stock Prices (SP) using multiple and partial wavelet consistency techniques, finding that SP in developed markets is more significantly affected by the combined effect of domestic policy uncertainty and US EPU. They show that emerging markets are more affected by the combined effect of the US EPU and the SP is more sensitive to domestic policy uncertainty. Ko & Lee (2015), studied the relationship between economic policy uncertainty and stock prices using wavelet analysis. According to the findings, the timing of US policy uncertainty coincides with the policy uncertainty of other countries in the study.

This extensive body of literature highlights the importance of understanding the dynamic relationships between KCFSI and the uncertainty indices across different regions. By focusing on the time-frequency characteristics of these relationships, this study contributes to a deeper understanding of how KCFSI in the US impacts financial uncertainty in selected Asian countries, providing valuable insights for policymakers and investors.

The theoretical framework of this study is grounded in the concept of financial contagion and spillover effects, particularly how financial stress in one economy can influence the stability of others. The analysis leverages the theory of economic interconnectedness, which posits that the globalization of financial markets leads to increased vulnerability of national economies to external shocks. Key theoretical components include:

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Financial Contagion Theory: This theory explains how financial crises and stress can spread from one country to others through various channels such as trade, capital flows, and investor behavior. The study examines how US financial stress propagates through Asian economies, highlighting the transmission mechanisms involved.

Wavelet Coherence Analysis: The study utilizes cross-wavelet transform (XWT) analysis to capture the time-frequency interactions between the KCFSI and uncertainty indices of Asian economies. This method allows for identifying periods of significant coherence, demonstrating how KCFSI and uncertainty are linked over time and across different scales.

Economic Integration and Vulnerability: The framework also incorporates theories related to economic integration, which suggest that countries with closer economic ties to the US, such as through trade or financial markets, are more susceptible to external financial shocks. The study explores how varying levels of economic integration affect the degree of coherence and the timing of financial stress transmission.

Policy Response and Economic Resilience: The framework addresses the role of policy responses and the resilience of domestic financial systems in mitigating the effects of external financial shocks. The study evaluates how proactive economic policies, such as monetary and fiscal measures, influence the observed relationships and help stabilize economies.

This theoretical framework underpins the study's approach to understanding the complex and dynamic relationships between KCFSI and uncertainties in selected Asian countries, providing a basis for the empirical analysis and the development of recommendations for policymakers and investors.

3. Methodology

This study employs wavelet coherence analysis to examine the relationship between uncertainty indices from selected Asian countries and the KCFSI. The wavelet coherence method is particularly advantageous for this research as it allows for the analysis of both time and frequency domains, capturing the dynamic and evolving nature of the relationships between these financial indices. Cross-wavelet transformation is a powerful tool for identifying periods of significant coherence, revealing whether the uncertainty indices lead, lag, or move in sync with the KCFSI across different time scales.

The data for this study includes the uncertainty indices from China, India, Japan, Korea, Malaysia, Singapore, and Taiwan, alongside the KCFSI. These indices were selected based on their relevance and the availability of consistent and reliable data. The uncertainty indices reflect various aspects of uncertainty within

each country, while the KCFSI provides a comprehensive measure of financial stress in the US market. The data spans several years, allowing for a thorough analysis of the relationships over different time periods and economic cycles. Additionally, since the variables we used in the study consist of monthly observations, the seasonal effect has been adjusted. The data has been taken from the database of the Federal Reserve Bank of St. Louis and the World Uncertainty Index. In addition, monthly observations for the period of 2008:01- 2025:02 have been used.

The cross-wavelet transform (XWT) is a powerful tool used to analyze the relationships between two-time series in both time and frequency domains. The mathematical formulation of the cross-wavelet transform involves several steps, including the definition of the wavelet transform, the calculation of the cross-wavelet spectrum, and the interpretation of the phase and amplitude information. The significance of coherence is assessed using Monte Carlo simulations, ensuring that the identified relationships are robust and not due to random fluctuations. The results are presented as wavelet coherence plots, with significant regions highlighted, providing a visual representation of the temporal and frequency-specific coherence between the uncertainty indices and the KCFSI. Accordingly, the wavelet coherence of two time series such as x_t and y_t is defined as in Equation 1 (Torrence & Compo, 1998):

$$W_x(a,b) = \int_{-\infty}^{\infty} x_t \psi^* \left(\frac{t-b}{a}\right) dt \qquad (1)$$
$$W_y(a,b) = \int_{-\infty}^{\infty} y_t \psi^* \left(\frac{t-b}{a}\right) dt$$

where $W_x(a,b)$ and $W_y(a,b)$ is the wavelet transform of the time series x_t and y_t, respectively. a is the scale parameter, related to frequency. b is the translation parameter, related to time. ψ^* is the complex conjugate of the mother wavelet $\psi(\cdot)$ (Torrence & Webster, 1999).

$$W_{xy}(a,b) = W_x(a,b)W_y^*(a,b) \qquad (2)$$

where $W_{xy}(a,b)$ represents the cross-wavelet spectrum, providing information on the common power and phase relationships between the two-time series as a function of both time and scale. Cross-wavelet power,

$$\left|W_{xy}(a,b)\right| = \left|W_x(a,b)W_y^*(a,b)\right| \qquad (3)$$

it is calculated as. Phase difference,

$$\phi_{xy}(a,b) = arg\left(W_{xy}(a,b)\right) \qquad (4)$$

where $arg\left(W_{xy}(a,b)\right)$ is the argument (or angle) of the complex number $W_{xy}(a,b)$ (Grinsted et al., 2004). The cross-wavelet transform $W_{xy}(a,b)$ is a complex-valued function that encapsulates the commonalities between two time

series, providing both magnitude (cross-wavelet power) and phase (phase difference) information across time and frequency. This method is particularly useful in analyzing non-stationary time series and uncovering dynamic relationships across different time scales. In addition, Toda-Yamamoto causality test was conducted to bring a different perspective to the findings.

Toda and Yamamoto (1995) developed a method based on the estimation of augmented VAR model ($k+d_{max}$) where k is the optimal time lag on the first VAR model and d_{max} is the maximum integration order on VAR model. VAR model of Toda and Yamamoto causality:

$$y_t = \mu_0 + \left(\sum_{i=1}^{k} \alpha_{1t}\, y_{t-i} + \sum_{i=k+1}^{dmax} \alpha_{2t}\, y_{t-i} \right) + \left(\sum_{i=1}^{k} \beta_{1t}\, x_{t-i} + \sum_{i=k+1}^{dmax} \beta_{2t}\, x_{t-i} \right) + \varepsilon_{1t} \quad (5)$$

$$x_t = \varphi_0 + \left(\sum_{i=1}^{k} \gamma_{1t}\, x_{t-i} + \sum_{i=k+1}^{dmax} \gamma_{2t}\, x_{t-i} \right) + \left(\sum_{i=1}^{k} \delta_{1t}\, y_{t-i} + \sum_{i=k+1}^{dmax} \delta_{2t}\, y_{t-i} \right) + \varepsilon_{2t} \quad (6)$$

4. Findings

This study uncovers significant and complex relationships between the uncertainty indices of selected Asian countries and the KCFSI. Utilizing wavelet coherence analysis, the research identifies key time periods and frequencies where substantial coherence is observed, reflecting strong interactions between these indices. The analysis reveals varied patterns of lead-lag and synchronous relationships, demonstrating the intricate nature of financial interconnectedness between selected Asian countries and the United States. These findings underscore the importance of understanding the temporal and frequency-specific dynamics of financial stress transmission, providing valuable insights for policymakers, investors, and researchers in developing strategies for effective financial risk management and economic stability.

As shown in Table 1, the Augmented Dickey-Fuller (ADF) tests were conducted for each variable. Based on the ADF test results, all variables were found to be stationary at levels, except for China Uncertainty Index, which was stationary at first difference.

Table 2 presents the optimal lag length selection based on multiple information criteria. Most of the criteria, including the LR, FPE, AIC and SC, identify lag 4 as the optimal lag length, which is subsequently adopted for the empirical analysis.

Table 1: Augmented Dickey-Fuller (ADF) Unit Root Test

Variable	Constant, with Trend		1% Crit. Val.	Order of Integration
	I(0)	I(1)		
KCFSI	-25.708	-	-25.763	I(0)
CHINA	-0,4078	-146.728	-25.765	I(1)
JAPAN	-57.603	-	-40.037	I(0)
SINGAPUR	-98.411	-	-40.034	I(0)
KOREA	-100.836	-	-40.034	I(0)
INDIA	-52.001	-	-40.037	I(0)
MALAYSIA	-112.791	-	-40.034	I(0)
TAIWAN	-103.673	-	-40.034	I(0)

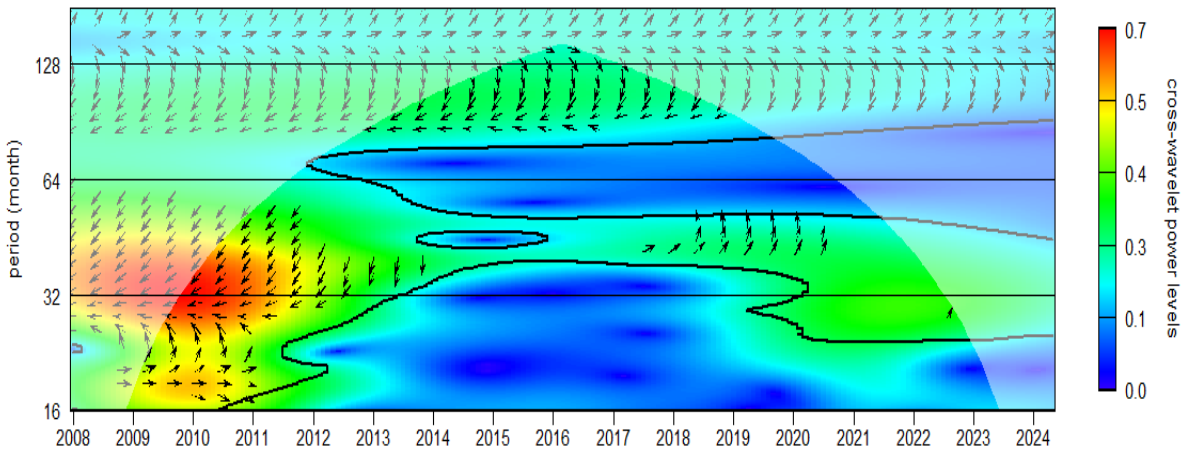
Source: Authors' calculations

Table 2: Lag Length Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-3445.809	NA	116220.3	34.36626	34.49773	34.41946
1	-3065.951	725.6986	5018.352	31.22339	34.79238	31.70220*
2	-2970.736	174.3238	3688.672	30.91280	33.14787	31.81720
3	-2872.416	172.1822	2640.299	30.57131	33.85818	31.90132
4	-2796.598	126.7417*	2379.586*	30.45371*	32.40667*	32.20932
5	-2744.315	83.23586	2734.522	30.57030	35.96077	32.75152

Note: *indicates lag order selected by the criterion

Fig. 1 Cross Wavelet Transform, China Uncertainty Index over KCFSI



In Fig. 1, the phase arrows between the China uncertainty index and the KCFSI in the XWT analysis mainly point to the right and upward, indicating an in-phase relationship in which the KCFSI and the China uncertainty index move together. In this case, financial stress in the US appears to slightly lead China's

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uncertainty, indicating that financial shocks in the US are rapidly transmitted to China. This is particularly evident during the global financial crisis and the COVID-19 pandemic. The upward slope of the arrows during these periods means that the KCFSI tends to lead when the two indices are in phase, meaning that increases in financial stress in the US are followed by increased uncertainty in China. This lead-lag relationship reflects China's deep economic integration with global markets, where financial stress in major economies such as the US rapidly affects China's economic policy conditions. On the other hand, according to the results of the Toda-Yamamoto causality analysis, no causal relationship was found between KCFSI and China Uncertainty Index.

Table 3: Results of Toda-Yamamoto Causality Test between KCFSI and China Uncertainty Index

Variables	Chi-sq	df	P-values
$KCFSI \times CHINA$	5.029683	4	0.2843
$CHINA \times KCFSI$	0.658722	4	0.9563

Source: Authors' calculations

Fig. 2 Cross wavelet transform India Uncertainty Index over KCFSI

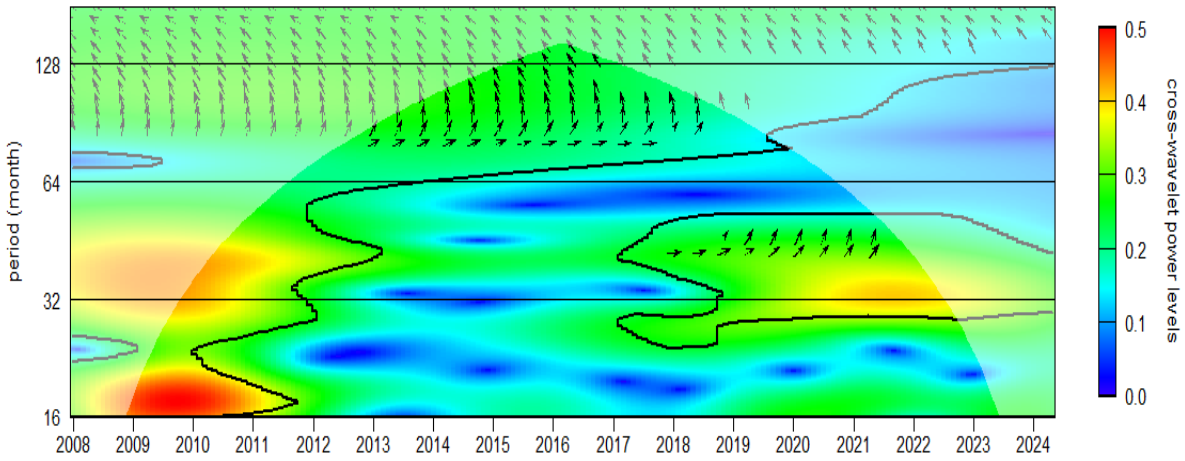

Fig 2 shows the phase arrows in the India-KCFSI analysis showing various directions. During the global financial crisis, the arrows were generally pointing to the right, indicating an in-phase relationship, with some arrows pointing slightly upwards. This suggests that the KCFSI led uncertainty in India, meaning that KCFSI preceded increases in India's uncertainty. However, during the COVID-19 pandemic, there are instances where the phase arrows pointed downward or to the left, indicating a shift towards a lead-lag relationship, where India's uncertainty could lead the KCFSI or exhibit out-of-phase behavior. This complex pattern can be attributed to India's unique economic circumstances, including the challenges of

managing a large, informal economy during a global pandemic, which could cause India's uncertainty to deviate from or even lead global financial stress indicators. In addition, according to the results of the Toda-Yamamoto causality analysis, causality was found from KCFSI to India Uncertainty Index at 5% significance level.

Table 4: Results of Toda-Yamamoto Causality Test between KCFSI and India Uncertainty Index

Variables	Chi-sq	df	P-values
$KCFSI \nrightarrow INDIA$	14.65498	4	0.0055
$INDIA \times KCFSI$	7.043678	4	0.1336

Source: Authors' calculations

Fig. 3 Cross wavelet transform Japan Uncertainty Index over KCFSI

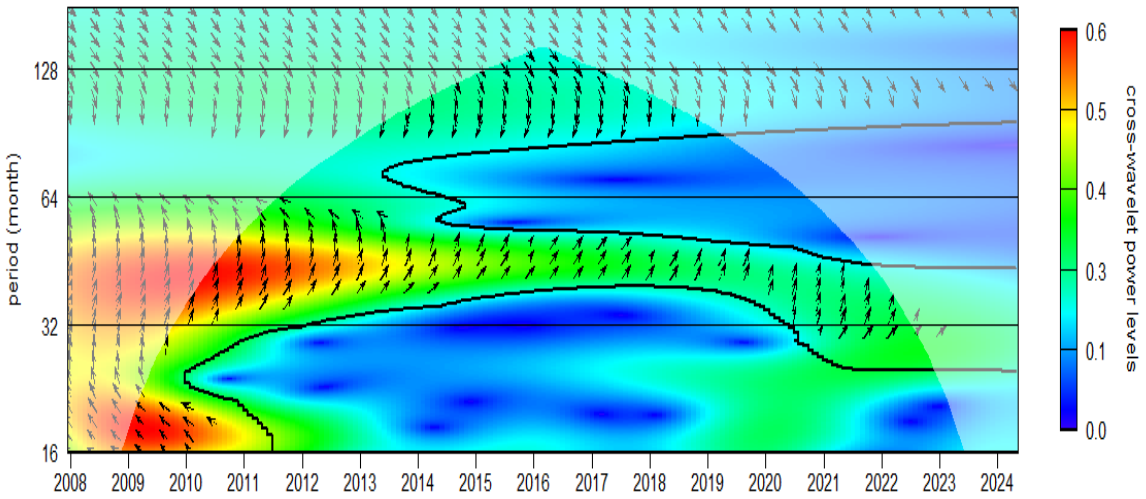

Fig. 3, which shows the Japan-KCFSI, XWT analysis findings, the phase arrows mostly point to the right and show slight upward or downward slopes, indicating an in-phase relationship in which the KCFSI often leads. This suggests that financial stress in the United States precedes increases in uncertainty in Japan. This relationship is particularly strong during the global financial crisis and 2011 tsunami, where the arrows indicate that financial stress index in the United States preceded increased uncertainty in Japan. During the tsunami and Fukushima nuclear disaster, the directions of the arrows suggest that although domestic factors largely influenced Japan's uncertainty, ongoing global financial stress also played a significant role. The upward slope during these periods suggests that Japan's uncertainty generally followed financial stress in the United States, reflecting Japan's dependence on global markets and the impact of external financial conditions on its economic and political stability. On the other hand, according to the results of the Toda-Yamamoto causality analysis, causality was found from KCFSI to Japan Uncertainty Index at 5% significance level.

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Table 5: Results of Toda-Yamamoto Causality Test between KCFSI and Japan Uncertainty Index

Variables	Chi-sq	df	P-values
$KCFSI \nrightarrow JAPAN$	16.10664	4	0.0029
$JAPAN \times KCFSI$	3.477479	4	0.4813

Source: Authors' calculations

Fig. 4 Cross wavelet transform Korea Uncertainty Index over KCFSI

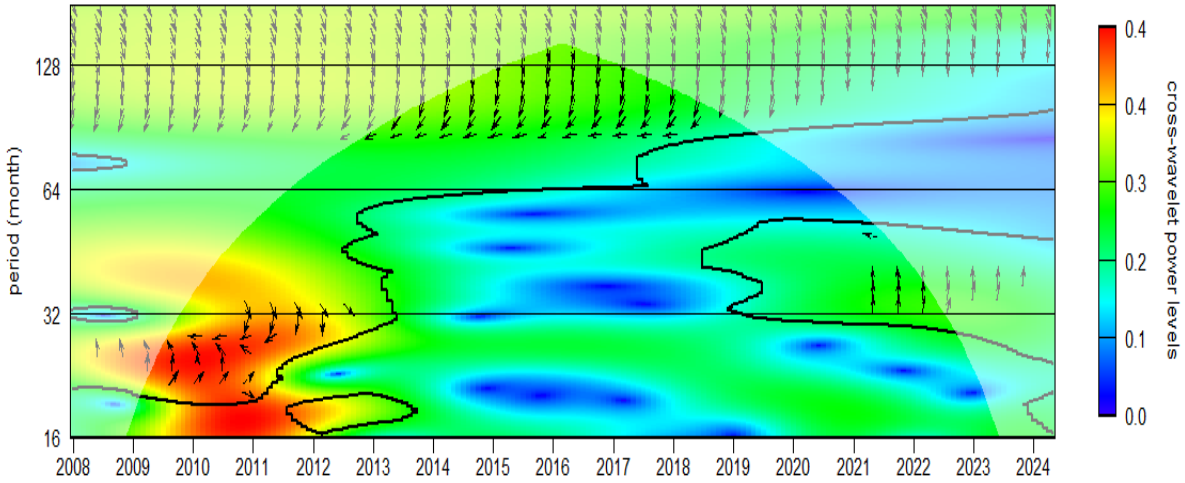

Fig. 4, which contains the findings for Korea, shows that during the global financial crisis and the COVID-19 pandemic, the phase arrows point predominantly to the right and slightly upward, indicating an intra-phase relationship where the KCFSI tends to lead Korea's uncertainty index. This suggests that KCFSI often precedes increases in uncertainty in Korea, reflecting Korea's sensitivity to global financial conditions due to its export-oriented economy. However, during certain periods, the phase arrows point to the left or downward, indicating potential out-of-phase movements or periods when Korea's uncertainty may lead or deviate from the KCFSI. This may be due to proactive fiscal and monetary policy responses that may temporarily cushion Korea's economy from sudden global financial shocks and cause a delay in the transmission of stress from the US. In addition, according to the results of the Toda-Yamamoto causality analysis, causality was found from KCFSI to Korean Uncertainty Index at 5% significance level.

Table 6: Results of Toda-Yamamoto Causality Test between KCFSI and Korea Uncertainty Index

Variables	Chi-sq	df	P-values
$KCFSI \nrightarrow KOREA$	14.08640	4	0.0070
$KOREA \times KCFSI$	3.100298	4	0.5412

Source: Authors' calculations

Fig. 5 Cross wavelet transform Malaysia Uncertainty Index over KCFSI

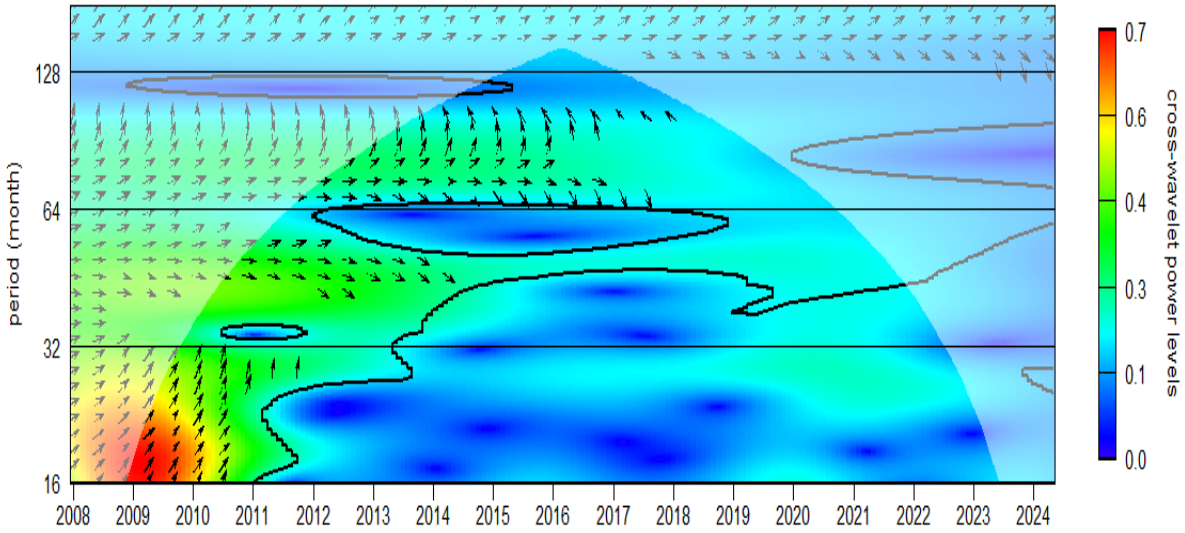

Fig. 5, which contains the findings for Malaysia, shows that during the global financial crisis and the COVID-19 pandemic, the phase arrows point predominantly to the right and slightly upward, indicating an intra-phase relationship where the KCFSI tends to lead Malaysia's uncertainty index. This is particularly evident during the global financial crisis and pandemic; the upward slope of the arrows suggests that US financial stress generally precedes increases in uncertainty in Malaysia. The consistent leadership of the KCFSI highlights Malaysia's vulnerability to external financial conditions, given its open economy and dependence on global trade. During periods of significant global financial turmoil, such as the global financial crisis and the COVID-19 pandemic, Malaysia's uncertainty closely follows the trajectory of US financial stress, reflecting its deep integration into the global economy. In addition, according to the results of the Toda-Yamamoto causality analysis, KCFSI is the cause of the Malaysia Uncertainty Index at 5% significance level.

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Table 7: Results of Toda-Yamamoto Causality Test between KCFSI and Malaysia Uncertainty Index

Variables	Chi-sq	df	P-values
$KCFSI \nrightarrow MALAYSIA$	11.82744	4	0.0187
$MALAYSIA \times KCFSI$	1.319024	4	0.8581

Source: Authors' calculations

Fig. 6 Cross wavelet transform Singapore Uncertainty Index over KCFSI

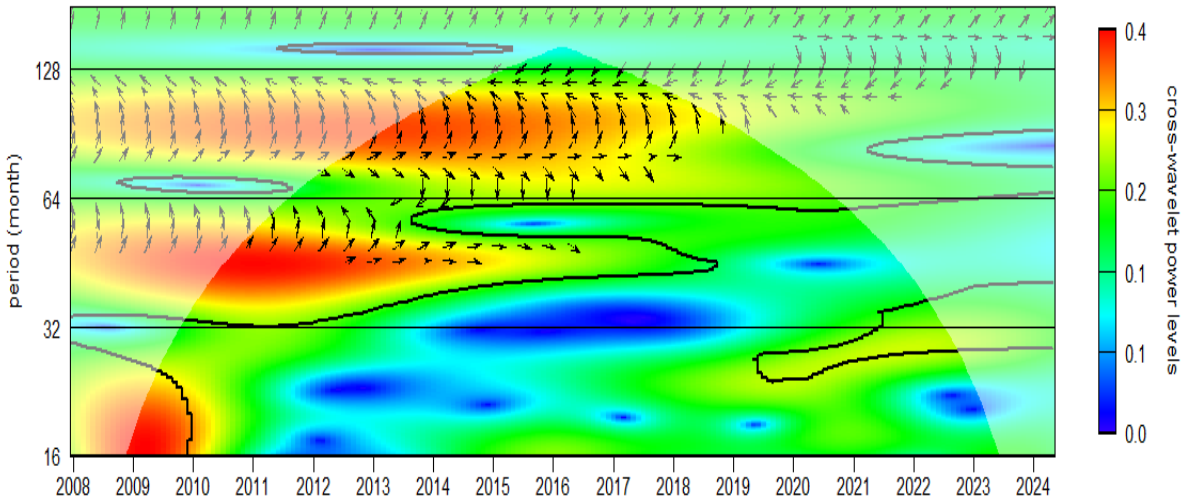


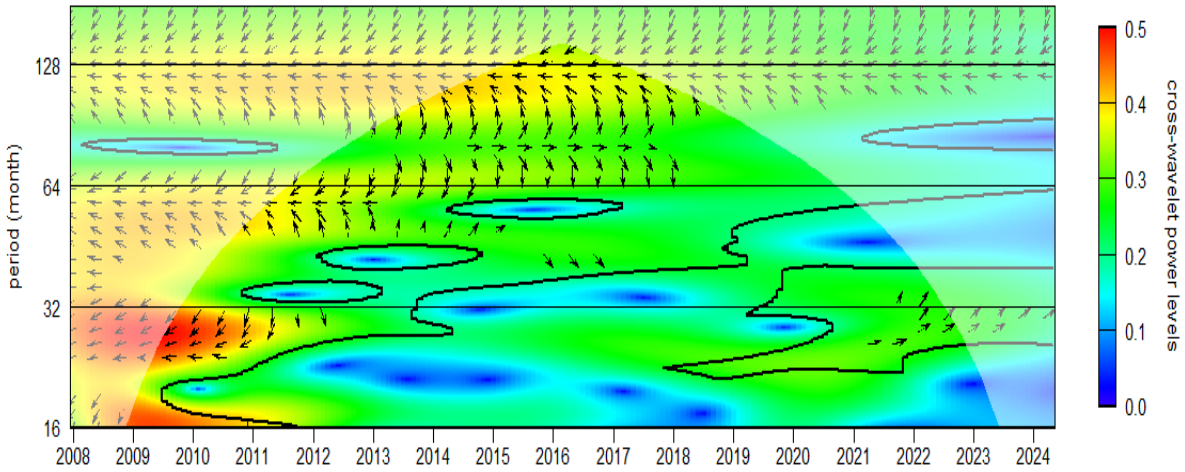
Fig 6 showing the Singapore-KCFSI analysis results, the phase arrows generally point to the right with a slight upward slope, indicating an in-phase relationship driven by the KCFSI. This suggests that financial stress in the US precedes increases in uncertainty in Singapore, reflecting Singapore's role as a global financial center that is highly sensitive to external financial conditions. The upward slope during periods of significant coherence, such as the global financial crisis and pandemic, suggests that the transmission of financial stress from the US to Singapore is relatively rapid, and that Singapore's uncertainty closely mirrors fluctuations in US financial markets. The strong and consistent in-phase relationship across time scales highlights Singapore's vulnerability to global financial shocks, given its reliance on international trade and finance. In addition, according to the results of the Toda-Yamamoto causality analysis, causality was found from KCFSI to Singapore Uncertainty Index. KCFSI is the cause of the Singapore Uncertainty Index at 5% significance level.

Table 8: Results of Toda-Yamamoto Causality Test between KCFSI and Singapore Uncertainty Index

Variables	Chi-sq	df	P-values
$KCFSI \nrightarrow SINGAPORE$	9.783093	4	0.0442
$SINGAPORE \times KCFSI$	3.563393	4	0.4683

Source: Authors' calculations

Fig. 7 Cross wavelet transform Taiwan Uncertainty Index over KCFSI



In Fig. 7, where the findings for Taiwan are shown, the phase arrows in the XWT analysis generally point to the right with a slight upward slope, indicating that the KCFSI leads Taiwan's uncertainty. This is particularly evident during the global financial crisis, where the in-phase relationship suggests that increases in financial stress in the US are followed by increased uncertainty in Taiwan. The upward slope suggests that the KCFSI's lead is evident, and that the Taiwan's uncertainty responds to financial stress in the US after a short lag. This relationship is consistent with Taiwan's economic structure, which is heavily dependent on exports, especially in the technology sector, making it highly sensitive to global financial conditions. During the pandemic, the pattern remains similar, and the phase arrows reflect that financial stress in the US continues to lead increases in Taiwan's uncertainty, ongoing global supply chain disruptions, and their impacts on Taiwan's export-oriented economy. On the other hand, according to the results of the Toda-Yamamoto causality analysis, no causal relationship was found between the KCFSI and Taiwan Uncertainty Index.

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Table 9: Results of Toda-Yamamoto Causality Test between KCFSI and Taiwan Uncertainty Index

Variables	Chi-sq	df	P-values
$KCFSI \times TAIWAN$	3.499519	4	0.4780
$TAIWAN \times KCFSI$	1.738393	4	0.7837

Source: Authors' calculations

The direction of the phase arrows in the cross-wavelet coherence analysis provides critical insights into the lead-lag relationships between the KCFSI and the uncertainty indices of selected Asian countries. In most cases, the KCFSI tends to be a leader, suggesting that financial stress in the US precedes increases in uncertainty in these countries. This lead-lag relationship is particularly pronounced during major global crises such as the global financial crisis, the COVID-19 pandemic, and the 2011 tsunami in Japan. The upward slope of the phase arrows in many analyses suggests that although the economic uncertainty of these countries is affected by financial stress in the US, the transmission of this stress may involve a short lag, reflecting the time required for global financial conditions to affect economies of Asian countries. This analysis highlights the significant impact of US financial conditions on global uncertainty, especially in Asia, where economies are deeply integrated into global markets and highly sensitive to external shocks. The findings of the Toda-Yamamoto causality test support the results of wavelet coherence analysis.

5. Recommendations and Implications

Enhanced Regional Financial Cooperation:

Recommendation: Asian countries should strengthen regional financial cooperation frameworks, such as the ASEAN+3 Macroeconomic Research Office (AMRO) and the Chiang Mai Initiative, to better coordinate responses to external financial shocks.

Rationale: The XWT analysis indicates that KCFSI often leads to increased uncertainty in Asian countries. Enhanced cooperation could help mitigate the spillover effects of such external shocks, allowing for more effective regional responses that stabilize economies.

Diversification of Economic Ties:

Recommendation: Asian economies should seek to diversify their economic and trade relationships beyond the US to reduce dependence on a single major economy.

Rationale: The strong in-phase coherence during the global financial crisis and the COVID-19 pandemic highlights the vulnerability of these economies to US financial stress. Diversifying trade and investment partners could help reduce the transmission of financial stress from the US and stabilize domestic economic conditions.

Development of Domestic Financial Markets:

Recommendation: Policymakers in Asian countries should focus on developing deep, liquid, and resilient domestic financial markets to reduce reliance on external financing.

Rationale: The analysis shows that US financial stress significantly impacts Asian economies, often increasing uncertainty. Strengthening domestic financial markets can provide a buffer against external shocks and reduce the transmission of financial stress from global markets.

Crisis Management Frameworks:

Recommendation: Establish robust crisis management frameworks that include early warning systems and contingency plans to address the impacts of global financial stress.

Rationale: The lead-lag relationships identified in the XWT analysis suggest that there is often a lag between the onset of financial stress in the US and its impact on Asian economies. Early warning systems and pre-established crisis management protocols could allow for timely interventions to mitigate the effects of such stress.

Promotion of Economic Resilience:

Recommendation: Asian countries should implement policies that enhance economic resilience, such as building foreign exchange reserves, promoting economic diversification, and investing in infrastructure.

Rationale: Given the observed strong coherence during periods of global economic turmoil, enhancing economic resilience can help Asian countries better withstand external shocks and reduce the severity of economic uncertainty.

Integration of Risk Management in Corporate Strategies:

Recommendation: Corporations in Asia should integrate comprehensive risk management strategies into their operations to better manage the risks associated with global financial instability.

Rationale: The frequent lead of the KCFSI suggests that financial stress in the US can rapidly affect corporate performance in Asia. Proactive risk management can help companies navigate these challenges and maintain stability during periods of global financial stress.

Policy Synchronization with Global Financial Trends:

Recommendation: Policymakers should closely monitor global financial trends, particularly in the US, and align domestic monetary and fiscal policies accordingly.

Rationale: The XWT analysis indicates that KCFSI often leads to Asian uncertainty indices. By synchronizing policies with global financial conditions, Asian countries can better manage the spillover effects of external financial stress and reduce domestic economic volatility.

5.1. Implications

Global Financial Connectedness

The strong lead-lag relationship between the KCFSI and the uncertainty indices of Asian countries highlights the interconnectedness of global financial markets. This connectivity means that financial instability in major economies, particularly the US, can quickly spread to other regions and increase global economic uncertainty.

Sensitivity to External Shocks

Asian economies, particularly those heavily dependent on exports and external financing, are vulnerable to external financial shocks. This vulnerability is highlighted by the significant consistency observed during major global crises, indicating that these economies are heavily influenced by financial conditions in the US.

The Importance of Regional Coordination

The findings suggest that regional coordination among Asian countries is crucial in managing the spillover effects of global financial stress. By working together, these countries can better prepare for and respond to external shocks, reducing the impact on their economies.

Need for Proactive Economic Policies

The delay in the transmission of financial stress from the United States to Asian countries provides an opportunity for proactive economic policies. Policymakers can use this delay to implement measures that stabilize domestic economies before the full impact of external shocks is felt.

Potential for Structural Reforms

The findings highlight the need for structural reforms in Asian economies to reduce their dependence on external markets and enhance domestic economic stability. Such reforms could include diversifying economic activities, improving financial regulation, and increasing the resilience of financial institutions.

Increased Focus on Risk Management

The significant impact of financial stress in the United States on Asian economies suggests that both the public and private sectors in these countries should place greater emphasis on risk management. This includes developing strategies to mitigate the effects of global financial instability and ensuring that businesses and financial institutions are prepared for potential shocks.

Long-Term Economic Planning

The consistent post-pandemic and post-crisis effects suggest that the effects of global financial stress may have long-term implications for Asian economies. This highlights the importance of long-term economic planning that considers the potential for recurring global financial instability.

Crisis Response Mechanisms

The observed phase relationships suggest that timely and effective crisis response mechanisms are essential to mitigate the impact of global financial stress on Asian economies. This includes both immediate responses to financial shocks and long-term strategies for economic recovery and resilience.

6. Conclusion

In this study, we have analyzed the dynamic relationship between the uncertainty indices of various Asian countries and the Kansas City Financial Stress Index (KCFSI) of the United States using XWT analysis. The results reveal significant in-phase coherence, indicating that financial stress in the US tends to lead to increases in uncertainty across Asia, especially during periods of global crises such as the 2008 financial crisis and the COVID-19 pandemic. This finding underscores the profound impact that US financial conditions have on the economic

stability of Asian countries, highlighting the interconnected nature of global financial markets.

This study makes a novel contribution to the literature by being the first to apply the XWT methodology to examine the dynamic linkages between the Kansas City Financial Stress Index (KCFSI) and major Asian financial markets. The XWT analysis further shows that the transmission of financial stress from the US to Asian countries is not uniform across all nations, with varying degrees of coherence and lead-lag relationships observed. For instance, while China, Japan, and Korea exhibit a strong and consistent in-phase relationship, other countries like India and Malaysia demonstrate more complex patterns, with occasional out-of-phase behavior. These differences may be attributed to each country's unique economic structure, policy responses, and level of integration into the global economy. The analysis also highlights the influence of major events such as the 2011 tsunami in Japan, which caused significant disruptions and altered the typical lead-lag relationships between US financial stress and Japanese economic uncertainty.

The implications of these findings are significant for policymakers and financial institutions in Asia. The strong influence of US financial stress on Asian economies necessitates the development of robust regional cooperation mechanisms, proactive economic policies, and effective risk management strategies. By enhancing financial market resilience, diversifying economic ties, and establishing early warning systems, Asian countries can better mitigate the impact of external financial shocks. Furthermore, understanding the lead-lag dynamics identified in this study can inform more timely and targeted policy interventions, helping to stabilize economies in the face of global financial turbulence.

Future research should build on these findings by exploring the role of additional factors that may influence the transmission of financial stress, such as political events, trade relations, and domestic policy measures. Moreover, expanding the scope of analysis to include other regions, such as Europe or Latin America, could provide a more comprehensive understanding of global financial interconnections. Studies could also employ more advanced econometric techniques or high-frequency financial data to capture short-term dynamics in financial stress transmission and more granular details of the lead-lag relationships identified in this study. Additionally, exploring the impact of emerging financial technologies and digital currencies, such as cryptocurrency volatility or fintech adoption, these dynamics could offer valuable insights into how global financial stress is transmitted in an increasingly digital economy.

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