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COVID-19 and risk spillovers of China’s major financial markets: Evidence from time-varying variance decomposition and wavelet coherence analysis

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ABSTRACT
COVID-19 has influenced financial markets drastically; however, this influence has received little attention, particularly in China. This study investigates risk spillovers across China’s financial and shipping markets through dynamic spillover measures based on time-varying parameter vector autoregression and generalized forecast error variance decompositions. Stock, fund, and futures markets are identified as major risk senders, whereas other markets are identified as major risk receivers. Surprisingly, bonds, gold, and shipping are safe havens that facilitate portfolio optimization. Furthermore, using wavelet coherence analysis, we find that the coherence between dynamic total spillover and COVID-19 varies across time and frequency domains.

1. Introduction
The widespread transmission of a novel coronavirus (COVID-19) led to the declaration of a pandemic on March 11, 2020, which severely affected the economy in multiple ways, including increasing unemployment, investors’ concerns, and risk aversion; decreasing global aviation activities and ship transportation; interrupting the supply chain; and reducing international trade (Amankwah, 2020; Choquet and Lefebvre, 2021; Couch et al., 2020; El Baz and Ruel, 2020; Le et al., 2020; Sun et al., 2021). All of these factors affected financial market stability.

Unemployment reduced income, thereby reducing financial market investments. In particular, the decline in aviation activities triggered a massive decline in energy demand, and the drop in ship transportation caused an inventory squeeze, thereby affecting commodity futures markets. Meanwhile, the banking system has increased credit allocation to revive enterprises hurt by reduced international trade and supply chain disruptions. Thus, banks’ credit risks rose due to the poor performance of companies supported during COVID-19 (Zhu et al., 2021). Moreover, negative sentiment caused by COVID-19 encouraged investors to switch markets (Broadstock et al., 2020).

Recent literature has analyzed the pandemic’s effects on financial markets from multiple perspectives. Some literature describes the pandemic’s impact on one financial asset: risk spillovers and stock market herding (Bouri et al., 2021; Samitas et al., 2022a; Li et al., 2021). Researchers also found a long-term increase in bank defaults and nonperforming loans (Polyzos et al., 2021), overshooting in the Eurobonds market (Sene et al., 2020), and instability in the global and “B&R” initiative forex markets (Wei et al., 2020). Other
studies focused on financial assets. For example, Samitas et al. (2022b) investigated volatility spillover in wine, stocks, bonds, gold, shipping, etc. Furthermore, Samitas et al. (2022c) found that timber and water hedge shipping risk during COVID-19.

However, risk spillovers across China’s financial and shipping markets have received little attention in the literature. Chinese financial markets are rapidly developing and becoming influential in global financial markets (Fang et al., 2021; Cao and Xie, 2022). The shipping market played an irreplaceable role in global supply chains and international trade, thereby affecting financial markets (Gong et al., 2020; Yang et al., 2022). The Chinese economy was affected by the COVID-19 pandemic (Kim et al., 2021) in multiple ways, including an increase in unemployment and risk aversion, the interruption of supply chains, and a reduction in international trade, thereby generating risk spillover across Chinese financial and shipping markets (Dai et al., 2022; Mensi et al., 2021; Si et al., 2021).

This study examines risk spillovers across China’s financial markets and shipping market during COVID-19. It offers three contributions. First, this is the first study to quantitatively analyze risk spillovers across China’s major financial markets during COVID-19. Second, we also consider the shipping market. It supplements the literature that has rarely considered this market. Third, using sentiment indexes reflecting public attention and panic regarding COVID-19 (Fang et al., 2020; Ji et al., 2019), we show that the pandemic has affected the dynamic total spillover across China’s major financial and shipping markets in different frequencies.

The remainder of this study is as follows: Section 2 presents the methodology. Section 3 introduces the data. Section 4 discusses empirical results, and Section 5 concludes.

2. Methodology

This section describes the methodologies employed to study the coherence between COVID-19 and risk spillovers across China’s financial and shipping markets. First, risk spillovers are calculated through dynamic spillover measures based on a time-varying parameter vector autoregression (TVP-VAR) model and generalized forecast error variance decompositions (GFEVD). Second, wavelet coherence analysis verifies the correlation between the pandemic and dynamic total spillover.

2.1. Spillover estimation based on TVP-VAR and GFEVD

Following Antonakakis and Gabauer (2017), we employ a stationary TVP-VAR with time-varying returns:

\[ Y_t = \beta Y_{t-1} + \epsilon_t \quad \epsilon_t \sim N(0, S_t), \]

\[ \beta_t = \beta_{t-1} + \omega_t \quad \omega_t \sim N(0, R_t), \]

\[ Y_t = A_t \epsilon_{t-1} + \epsilon_t, \]

where \( Y_t \), \( \epsilon_t \), and \( \omega_t \) are N X 1 vectors, and \( A_t \), \( S_t \), \( \beta_t \), and \( R_t \) are N X N matrices. According to Diebold and Yilmaz (2012), J. Li et al. (2021), and Li et al. (2022), the h-step error variance in forecasting variable \( i \) due to shocks on variable \( j \) can be written as follows:

\[ \gamma^h_{ij}(t) = \frac{\sum_{i=1}^{N} \psi^h_{ij}(t)}{\sum_{i=1}^{N} \sum_{j=1}^{N} \psi^h_{ij}(t)} \]  

With \( \gamma^h_{ij}(t) \) denotes the h-step ahead GFEVD, \( \gamma^h_{ij}(t) = S_{ij,t}^{-1} \sum_{t} \epsilon_{ij,t} \sum_{t} \epsilon_{ij,t} \) the covariance matrix for the error \( \epsilon_{ij,t} \) and \( \sum_{i=1}^{N} \gamma^h_{ij}(t) = 1 \), \( \sum_{i=1}^{N} \gamma^h_{ij}(t) = N \). The total spillover index of all the markets is defined as follows:

\[ TS^S(h) = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} \gamma^h_{ij}(t)}{\sum_{i=1}^{N} \gamma^h_{ii}(t)} \times 100 \]

The “to,” “from,” and net spillovers indexes are defined as follows, respectively:

\[ NS^S_{j\rightarrow i}(h) = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} \gamma^h_{ij}(t)}{\sum_{i=1}^{N} \gamma^h_{ii}(t)} \times 100 \]  

\[ NS^S_{i\rightarrow j}(h) = \frac{\sum_{j=1}^{N} \sum_{i=1}^{N} \gamma^h_{ij}(t)}{\sum_{i=1}^{N} \gamma^h_{ii}(t)} \times 100 \]  

\[ NS^S_{i\rightarrow j}(h) = NS^S_{j\rightarrow i}(h) - NS^S_{i\rightarrow j}(h) \]

2.2. Wavelet coherence analysis

Following Grinsted et al. (2004), we defined the wavelet coherence of two-time series as follows:
\[ R^2_n(s) = \frac{|S(s^{-1} W^T_m(s))|^2}{S(s^{-1} |W^T_m(s)|^2) \cdot S(s^{-1} |W^T_n(s)|^2)} \] (9)

where \( S \) is a smoothing operator and can be written as:

\[ S(W) = S_{scale}(S_{time}(W_n(s))) \] (10)

where \( S_{scale} \) denotes smoothing along the wavelet scale axis and \( S_{time} \) smoothing in time. The Morlet wavelet is given as follows:

\[ S_{time}(W)_n = \left( W_n(s) \ast c_1^2 \right)^2 \] (11)

\[ S_{scale}(W)_n = \left( W_n(s) \ast c_2 \prod_{0.6s} \right)_n \] (12)

where \( c_1 \) and \( c_2 \) are normalization constants and \( \Pi \) is the rectangle function. The factor of 0.6 is the empirically determined scale decorrelation length for the Morlet wavelet (Grinsted et al., 2004).

3. Data and preliminary analysis

We collect data on China’s major financial and shipping markets from January 20, 2020, to May 26, 2022, from the WIND database. Table 1 lists indices and their descriptions.

Fig. 1 displays all market returns. During the sample period, all market returns are volatile. Therefore, stock, interbank, and forex markets have negative mean returns under COVID-19, whereas other markets have positive ones (Table 2). Meanwhile, the interbank
market is the most volatile, with a standard deviation of 5.113. All markets have different skewness and high kurtosis (>3), thereby indicating high-peak and fat-tail phenomena. The Augmented Dickey–Fuller (ADF) test proves that the data are stationary.

4. Empirical results

4.1. Spillover across the markets

First, we discuss the dynamic total spillover of China’s major financial and shipping markets. Fig. 2 shows that after human-to-human transmission was confirmed on January 20, 2020, dynamic total spillover increased and peaked (peak value = 53.832) on February 10, 2020. With anti-epidemic measures in place, risk spillover gradually decreased, even lower than pre-pandemic levels (Dai et al., 2022; Dai and Zhu, 2022). From February 24, 2022, the dynamic total spillover increased again and peaked at 30.64 on March 17, 2022. This is likely because the Federal Reserve rate hike raised concerns about increased market volatility and decreased market liquidity. Furthermore, it is partly attributed to the Russia–Ukraine war, which induced turbulence in the international energy market, raised uncertainties in global financial markets, and increased risk spillovers in China’s markets.

According to Fig. 3 and Table 3, the stock, fund, and futures markets are the senders of net risk spillovers, whereas other markets are receivers. Huge transaction scale and high leverage in stock, fund, and futures markets amplify senders’ shock risks (El-Alaoui et al., 2018). Meanwhile, receivers benefit from the positive returns of bond, gold, and shipping markets, which are considered safe-haven assets to some extent.

The bond market is characterized as fixed income, and its price fluctuation is weakly or negatively correlated with the economic cycle, stock market, and other major assets during COVID-19, thereby allowing risk diversification. Combined with lasting negative net risk spillovers (Fig. 3), its role as a safe-haven asset is stable (Choudhury et al., 2022).

Investors buy gold to hedge against high inflation caused by massive currency issuance during the pandemic. However, Fig. 3 shows that net risk spillovers received by gold decreased from March 11, 2020, to March 24, 2020, and February 11, 2022, to March 11, 2022, respectively.
thereby indicating that gold’s role as a safe haven has diminished due to the gold spot market being largely affected by oil shocks (Salisu et al., 2020; Wang et al., 2020). The former reduction of net risk spillover is attributed to the decreased demand for oil during COVID-19 and a failed oil production deal between Organization of the Petroleum Exporting Countries and Russia, whereas the latter arises from energy market uncertainty caused by the Russia–Ukraine war. Even though gold is considered a safe-haven asset (Bouri et al., 2021; Das et al., 2020), its hedge effect is not permanent.

Similarly, the shipping market’s role has changed from receiver to sender after February 2021, thereby indicating that its role as a safe haven has diminished. The rapid recovery of US import demand and lack of resources and information in the supply chain have accumulated shipping market risk in China and spillover to other financial markets. Therefore, investors should carefully evaluate whether to use it as a safe-haven asset.

Additionally, stock and fund markets have the largest “to” spillovers (39.06 and 37.95, respectively), thereby indicating their close association during the crisis (Table 3).

The main reason is probably that the stock position rose to approximately 80% in stock funds after the revised version of Measures for the Administration of the Operations of Publicly Offered Securities Investment Funds issued by China Securities Regulatory Commission on August 8th, 2015, in China (Wang and Wang, 2018), thereby causing information spillover (Kim et al., 2016).
Furthermore, the biggest risk spillover (9.63) to the forex market comes from the stock market (Li et al., 2021). China’s leadership in stabilizing the pandemic and economic recovery increased investor confidence, caused a surge in foreign capital in China, and boosted demand for RMB in the forex market. This study could be beneficial for policymakers and investors. Policymakers must notice strong dynamic interactions between two markets, such as, stock–futures pair. For investors, we evidenced that bond, gold, and shipping markets are safe-haven assets, but their roles differ. In the dynamic term, the bond market remains a stable safe haven. However, gold and shipping markets have a strong hedge effect at the beginning of the pandemic, but it diminishes afterward.

4.2. Relationship between the COVID-19 pandemic and dynamic total spillover

Using wavelet coherence analysis (Gulerce and Unal, 2016) in time and frequency domains, we examine the relationship between dynamic total spillover across markets and COVID-19 represented by “XG” and “YQ” (Baidu indexes of “Xinguan” and “Yiqing”), which reflect public attention and panic regarding the pandemic, respectively.

Fig. 4 shows the estimated wavelet coherence for dynamic total spillover and XG (YQ), thereby demonstrating that the pandemic affects all markets’ dynamic total spillover. Table 4 summarizes the periods when dynamic total spillover and COVID-19 are highly correlated based on Fig. 4.

For the XG test, strong comovements for dynamic total spillover and XG appeared four times with different frequency cycles (Table 4). The first strong comovement indicated that the sudden outbreak of the pandemic increased panic, which induced risk dependency among financial markets in the short term (9–16 days), until the pandemic stabilized in early April 2020 due to anti-pandemic measures. The second and third strong coherences are attributed to the slowdown of global economic trends, continued rate hikes, and geopolitical conflict (Tables 4 and A.1), which caused long-term turbulence across all markets (32–48 and 37–90 days, respectively). The fourth strong comovement is due to the large-scale pandemic outbreak in Xi’an, Jilin, and Shanghai (China’s financial center). It caused market concerns and short-term risk spillovers across all markets (3–16 days). YQ yields similar results.
Investors should note that the frequency cycle (short or long term) varies with strong comovement between the outbreak of COVID-19 and dynamic total spillover. Our results suggest that the early COVID-19 outbreak and recent large, localized epidemic had short-term coherence. Meanwhile, the slowdown of global economic trends, continued rate hikes, and political conflicts induce high dependency in the long run.

5. Conclusion

This study examines risk spillovers between China’s financial and shipping markets during COVID-19. We found net risk spillovers from stock, fund, and futures markets due to significant transaction scales and high leverage. During the pandemic, bond, gold, and shipping markets are still considered safe havens. However, gold and shipping markets’ role as safe-haven assets weakened and disappeared afterward, thereby suggesting that investors should not pursue them blindly. Moreover, we examine the coherence between dynamic total spillover and COVID-19 in frequency and time domains. The early COVID-19 outbreak and recent large, localized epidemic have short-term magnitude coherence. Meanwhile, the long-term correlation is caused by global economic slowdown, rate hikes, and political conflicts. Our results could help with portfolio optimization, policymaking, and risk management.

CRediT authorship contribution statement

Qiwei Xie: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Funding acquisition, Resources. Lu Cheng: Writing – review & editing, Data curation, Formal analysis, Investigation. Ranran Liu: Methodology, Data curation, Formal analysis, Writing – original draft. Xiaolong Zheng: Data curation, Software, Visualization, Validation, Resources. Jingyu Li: Methodology, Supervision, Writing – review & editing, Validation, Funding acquisition, Project administration, Resources.

Declarations of Competing Interest

None

Data availability

Data will be made available on request.

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Appendix

Table A.1

| No. | Time         | Major event                                                                                                                                 |
|-----|--------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | 1/23/2020    | Wuhan lockdown                                                                                                                              |
| 2   | 3/12/2020    | China’s National Health Commission declared that the epidemic had passed an inflection point                                              |
| 3   | 3/15/2020    | The Federal Reserve cut interest rates to zero                                                                                              |
| 4   | 4/20/2020    | WTI crude futures plunged into negative territory                                                                                         |
| 5   | 12/31/2020   | In 2020, the global economic trend slowed to –3.3%, which is the lowest since World War II                                                  |
| 6   | 9/22/2021    | Increase in Fed rate hike expectations                                                                                                       |
| 7   | 12/23/2021   | Xi’an lockdown                                                                                                                              |
| 8   | 2/24/2022    | Russia-Ukraine war                                                                                                                         |
| 9   | 3/14/2022    | Jilin lockdown                                                                                                                              |
| 10  | 3/17/2022    | The Fed raised rates by 25 basis points                                                                                                     |
| 11  | 3/28/2022    | Shanghai lockdown                                                                                                                          |

Table A.1: List of major pandemic events.
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