Keywords
Implied volatility indexes; Uncertainty transmission; Bounds testing approach; Generalized impulse responses and variance decompositions

Overview
With the acceleration of global market integration and rapid development of information trading systems, traders are no longer limited to one single market, but tend to adopt cross-market investment portfolio strategies to reduce market risk. Moreover, the liberalization of capital inflows and the financialization of commodity markets have increased integration between commodity markets and financial markets so that commodity prices, exchange rates and stock indexes tend to change simultaneously in response to the same shock, such as the 2008 financial crisis. Though the price transimission between the major commodity markets (e.g. crude oil and gold) and the financial markets (e.g. exchange rates and stocks) have been widely validated, the research on the cross-market transmission of uncertainty is very limited. Affected by the unstable economic situation, commodity markets as well as financial markets tend to present increasing volatility recently. Therefore, understanding the transmission mechanism of cross-market volatility information is important for guiding the traders to learn the volatility linkages among markets and to timely adjust the investment portfolios.
The Volatility Indexes, which measure market expectations of near-term volatility and reflect the forward-looking uncertainty, have been paid much attention to after the global financial crisis. The relationships between the S&P 500 Volatility Index (VIX) and the new asset volatility indexes (Crude oil, Gold and EuroCurrency Volatility Indexes) which were newly introduced by the Chicago Board Options Exchange (CBOE) during the 2008 financial crisis will be researched in this study. From the perspective of implied volatility, some new findings on cross-market volatility linkages are provided and the researches for the cross-market transmission mechanism of volatility information are extended.

Methods
The conventional Johansen-Juselius cointegration test as well as the bounds testing approach based on the Autoregressive Distributed Lag (ARDL) are firstly utilized to test the long-term equilibrium relationships among the four volatility indexes. Then the generalized forecast error variance decompositions and the generalized impulse response functions are employed to understand the impacts and responses to market shocks. Compared to the conventional orthogonal methods, the generalized methods can provide more robust results which are not affected by the orders of variables.

Results
The cointegration test results suggest that there is no long-term equilibrium relationship among the VIX and the newly introduced Crude oil, Gold and EuroCurrency volatility indexes. That is, the uncertainty of each market is mainly dominated by its own factors. The Granger causality test results that the VIX Granger causes other markets indicate that the uncertainty changes on the stock markt are transmitted to exchange, gold and crude oil markets. In addition, the results that Eurocurrency volatility index

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The Uncertainty Analysis of Cross-market Transmission among Oil, Gold, Stock and Exchange Markets: Evidence from Implied Volatility Indexes of CBOE

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Granger causes the gold and crude oil volatility index indicate the uncertainty changes from exchange market will influence the future volatility expectations of gold and crude oil which are both priced in dollars in the international markets. The results of the generalized forecast error variance decompositions show that the spillover effects among volatility indexes are significant. The volatility shock of the stock market has strong impacts on the expectations of the near-term volatility of the other three markets. The percentage contribution of VIX to eurocurrency, gold and crude oil volatility indexes is 16%, 17.6% and 24.8% respectively in the long run (after 40 days). The impulse response function results reveal that each volatility index initially responds positively and significantly to shocks from own and others. However, the response tends to weak after three horizons due to market overreaction in response to new volatility information and "readjust" the expectation of the future volatility. As robustness test, the whole sample is further divided into two sub-sample, the financial crisis spread period (2008/6/3-2009/12/31) and the recovery period (2010/1/4-2011/9/13). Then the relationships of the four market volatility indexes are re-examined during the two sub-samples respectively. The uncertainty of the stock market are significantly transmitted to the other markets during the crisis spread period, while the impact weakens during the recovery period. It means when the own market mechanism start to recover, the changes in the expectation of the future volatility are mainly impacted by their own matket factors. The generalized variance decompositions and impulse response functions also confirm that the uncertainty transmitted from the stock market to other three markets weakens during the second period.

Conclusions

This study examines the cross-market volatility linkages among the stock, exchange rate, gold and crude oil markets when the market conditions became unstable and more uncertain using the implied volatility indexes published by CBOE. The results show that the uncertainty is transmitted from the stock markt to the other three markets which became vulnerable to external conditions during the crisis spread period. That is, the stock market volatility index is expected to guide the future volatility expectation of other markets as a benchmark after the global financial crisis broke out. The uncertainty of the exchange market is also transmitted to the gold and crude oil markets. Specifically, the crude oil market is the most vulnerable to the volatility shocks in the other markets after the oil price fell sharply during the crisis. The generalized variance decompositions and impulse respond functions also reveal that there are significant volatility spillovers from the financial markets to the commodity markets verifying the financialization of gold and crude oil markets.

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