Global Capital Market Interdependence and Spillover Effect of Credit Risk: Evidence from 2007-2009 Global Financial Crisis

William Cheung, Scott Fung, and Shih-Chuan Tsai

Abstract

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Keywords: global financial crisis, market integration, market contagion, credit risk

JEL classification: **C22, F36, G01, G15, O16**

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1. Introduction

The global financial markets are currently experiencing the largest crisis since 1929, which is no simple repetition of the past. The global financial crisis began in 2007 when the subprime mortgage crisis originated in the US spreads rapidly to most financial markets around the globe. As the crisis deepened, stock markets worldwide experienced substantial falling asset prices and entered a period of high volatility. Major banks and financial institutions faced serious liquidity problems, and governments around the world attempted to coordinate efforts to provide financial rescue.

Unlike past crises, such as the 1997 Asian financial crisis, the 1998 Russian crisis, and the 1999 Brazilian crisis, the current crisis originated from the largest and most influential economy, the U.S. market (Eun and Shim, 1989; Jorion and Goetzmann, 1999).[1] The current crisis seems to trigger a prolonged global-wide fear spillover and cause a fundamental change in the correlations among international markets, for both developed and emerging markets. It provides a unique natural experiment for examining the dynamic interrelationships among global stock markets and the contagion effect during a world-wide financial crisis. This paper studies how shocks originated from the dominant U.S. market promptly and pervasively spillover into foreign markets, resulting in intensified interdependence among global stock markets.

The degree of integration among global financial markets tends to change over time. Bekaert and Harvey (2000) show that equity correlations increase after liberalization of capital markets in emerging countries. Chen, Firth, and Rui (2002) document the dynamic interdependence of the major stock markets in Latin America. Goetzmann, Li, and Rouwenhorst (2005) find that the correlation structure of the world equity markets varied considerably over the past 150 years and was high during periods of economic integration. Bekaert, Harvey, Lundblad, and Siegel (2007) show that global market integration is strongest in countries that have liberalized their capital accounts, equity markets, and banking systems. Ozdemira and Cakan (2007) find that while the U.S. stock market leads the other stock markets, the U.K. market can also Granger-causes the U.S. market. Quinn and Voth (2008) argue that stock market correlations are mainly driven by greater freedom to move funds from one country to another, though increasingly correlated economic fundamentals also matter.

Previous studies also suggest that the interdependence among global markets tends to increases during periods marked by financial crises. Tuluca and Zwick (2001) document an enhanced comovement in daily returns from 13 Asian and non-Asian markets after the advent of

[1] Eun and Shim (1989) argue that changes in the US stock market can affect billions in value from stocks in other countries in a single day. Jorion and Goetzmann (1999) show that US equities had the highest real return of all countries during 1921 - 1996, and the high equity premium obtained in the US is at least partly due to the best performing market.

the Asian crisis. Yang, Kolari and Min (2002) find that both long-run cointegration relationships and short-run causal linkages among the U.S., Japanese, and ten Asian emerging stock markets were strengthened during the 1997 Asian financial crisis. Chakrabarti and Roll (2002) show that European and East Asian countries were not susceptible to volatility contagion in the pre-crisis era but the susceptibility increased significantly during the 1997 Asian financial crisis. Yang, Hsiao, Li and Wang (2006) find that both the long-run price relationship and the dynamic price transmission were strengthened among U.S., Germany, and Eastern European emerging stock markets after the 1998 Russian financial crisis. Hon, Strauss, and Yong (2004) show that international stock markets, particularly in Europe, responded more closely to U.S. market shocks in the three to six months after the terrorist attack in the U.S. on September 11, 2001.

Recent studies focus on global market contagion. Different theoretical models are developed in the literature (e.g., Allen and Gale, 2000; Kodres and Pritsker, 2002; Hasman and Samartın, 2008) to explain how a small liquidity shock in one region can spread by contagion throughout other regions. Longin and Solnik (2001) find that equity market correlation is not related to market volatility per se but to the market trend, and equity market correlation increases in bear markets. Campbell, Koedijk and Kofman (2002) find further evidence on increased correlation in international equity returns in bear markets. Van Royen (2002) suggests that the Russian crisis was characterized by both contagion and large aggregate outflows, and that contagion appears to be regional. Forbes and Rigobon (2002) show a high level of market comovement in all periods. Bekaert, Harvey and Ng (2005) identify contagion during crisis periods and find time variation in world and regional market integration. Candelon, Piplack, and Straetmans (2008) suggest that the increases in comovement of stock markets are more of a sudden nature (i.e. contagion) instead of a gradual one (i.e. financial integration).

This paper examines the changing interrelationships among global financial markets before and during the 2007-2009 financial crisis. We use weekly returns to avoid the over-lapping problem and the non-synchronicity problem (e.g., Hung and Cheung, 1995). We first explore the casual relationships between returns and volatilities in S&P500 (SPX) and other global market indices, including U.K. (UKX), Hong Kong (HSI), Japan (NKY), Australia (AS51), Russia (RTSI) and China (SHCOMP), with a standard Vector Autoregressive (VAR) model and the Granger causality test. Since the current financial crisis is be originated from the US housing and credit market, the TED spread, an indicator of perceived credit risk in the general economy is used to test the impact of credit risk on global financial markets. The interrelationships between the TED spread and other global market indices are rarely documented in the existing literature. We are among the first to study the trivariate relationships among the change in the TED spread, returns in SPX, and returns in other global market indices. As in Figure 1, the TED spread spiked up in July 2007, remained volatile for a year, and then spiked even higher in September 2008, reaching a record high of 4.65% on October 10, 2008. To investigate how shocks propagate from one stock market to another and how the impulse-response relations alter during the crisis, we employ the Vector Error Correction model (VECM) in estimating the equilibrium cointegration relationships and impulse response functions among the TED spread, SPX and other indices.

Based on the sample period of January 3rd 2003 to April 3rd 2009, which should provide a fresh and most up-to-date exploration of the interdependence in international stock markets, this paper documents the following findings. First, the overall leadership of the U.S. market enhance during the crisis. The impact of the U.S. market on other global markets, including the U.K. market, the Hong Kong market, the Japan market, the Australia market, and the China market, becomes greater and more significant in the crisis. Second, during the crisis, the TED spread not only Granger causes SPX in the U.S., but also has a spillover effect into other global market indices, such as UKX, NKY, AS51, and RTSI. Third, the equilibrium integration relationships between US and other market indices change dramatically during the crisis. The long-run relationship between U.S. and other stock markets become stronger during the crisis; yet those foreign markets are slow to adjust back to the long-run equilibrium. The cointegration relationships suggest that the TED spread in equilibrium responds fast to fundamental changes in the U.S. and global financial markets, and hence it provides new information about the crisis not only to the U.S. but also to other global stock markets. Fourth, the impulse response analysis indicates that the impacts of orthogonalized shocks from the TED spread on global market indices increase by at least 5 times during the crisis. The impacts of orthogonalized shocks from SPX on global market indices are also larger, at least 2 times larger, during the crisis. Finally, all global markets, both developed and emerging ones, have increasing impacts on the SPX during the financial crisis

Overall, our findings shed light on the existence and dynamics of international stock market linkages. By examining an extreme event such as the 2007-09 financial crisis, we provide new insights into the inner-workings of global financial markets, such as why the higher synchronicity of global market indices are often observed in down-markets. Our findings suggest that the interdependence between international markets strengthens during the crisis, a period of volatile markets, and that the crisis has differential impacts on different markets. Consistent with the "Contagion" hypothesis, we find that the dominant U.S. market has an immediate and significant spillover effect into the global markets. However, we also find a feedback effect as the global markets also affect the U.S. market during the crisis. Most prominently, this paper is among the first to incorporate the TED spread in the analysis and shows that the credit shocks can spillover into stock markets in the U.S. and the global markets. These findings have important implications on global investment diversification and public policy that can alleviate the crisis.

The rest of the paper is organized as follows. Section 2 discusses the empirical framework and data. Section 3 presents the findings of VAR and Granger Causality Tests. Section 4 presents the cointegrating relationships and impulse response functions. Section 5 concludes.

2. Research Frameworks

Our empirical analyses set out to examine how global stock market affects each other, with increasing interdependence during the financial crisis. First, we examine the interrelationships between weekly returns of global market indices. We are interested to examine these interrelationships before the global financial crisis in 2007 and during the global financial crisis from 2007 to present (as of April 3rd, 2009). Second, we examine the informational role of the TED spread, and how the interrelationships between the TED spread and global stock market indices change during the crisis.

2.1. Data and Sample

Our sample contains weekly time-series of major global market indices, which include the following categories: (i) US/S&P500 (SPX) as the 'benchmark' market as the recent financial crisis is believed to be originated from US subprime crisis; (ii) developed financial markets, including UK (UKX), Hong Kong (HSI), Japan (NKY), and Australia (AS51), and (iii) developing and emerging financial markets, including Russia (RTSI), and Shcomp (Shanghai). Our data of market indices is collected from the Bloomberg L.P. The TED spread is usually interpreted as a reliable predictor of financial crisis and calculated as the difference between the three-month T-bill interest rate and the three-month LIBOR. The three-month T-bill interest rate and the three-month LIBOR rate are collected from the websites of Federal Reserve Bank of St. Louis and Britsh Banker's Association respectively.

Our sample period is January 3rd, 2003 to April 3rd, 2009. To report the most up-to-date data of global financial crisis, we collect the date up to April 3rd, 2009. We pick January 3rd, 2003 as beginning date to avoid the effect of internet bubbles during late 90s' to early 00s' (Ofek and Richardson, 2003). We use July 2007 as the starting point of global financial crisis, because this is the time when the subprime crisis get serious during summer 2007 and AAA CDS got downgraded. For example, the TED spread, an indicator of perceived credit risk in the general economy, spiked up in July 2007, remained volatile for a year, then spiked even higher in September 2008. However, alternative benchmark of starting of the crisis does not alter our main results and conclusions (robustness tests are not reported here).[2]

We use weekly series of these variables to avoid over-lapping problem and non-synchronicity problem where global financial markets do not trade with the same exact trading hours and different opening or closing times between interacting global financial markets can lead to spurious causal relationships (see, e.g. Hung and Cheung (1995) on the problem of using daily data and the justification of using weekly data). Our focus will be the comparisons of the changing interrelationships among global financial markets before and during the global financial crisis. Our analyses will use SPX (US) as the 'benchmark' case because of the leadership of the U.S. market (Eun and Shim, 1989; Jorion and Goetzmann, 1999) and the recent financial crisis is originated from the US.

Table 1 reports the weekly returns (change in log prices) of global market indices and the TED spread before the financial crisis (January 2003 to June 2007) and during the financial crisis (July 2007 to April 2009). Again, using alternative date (such as February 2007) to identify the starting time of global financial crisis does not change our findings and conclusions.

Panel A of Table 1 reports the summary statistics of the weekly returns of global market indices and TED spread, with the comparison of the returns before and during the financial crisis. All global market index returns have dropped significantly since the financial crisis in July 2007, as all global markets have their average weekly positive returns turn into negative returns during the crisis. RTSI (Russia) experienced the largest decline in returns, while UKX (UK) experienced the least.

Panel B of Table 1 reports the pair-wise correlations between the returns of SPX (US) and the returns of other global market indices before the financial and during the financial crisis. Except for SHCOMP (China), there are dramatic increases in correlations between the returns of SPX and the returns of other global market indices since the financial crisis. This finding suggests that the financial crisis has increase the stock market synchronicity dramatically, with SPX and UKX have the strongest positive correlations.

Panel C of Table 1 reports the pair-wise correlations between TED spread and global market indices before and during the financial crisis. Before the financial crisis in July 2007, the correlation between the TED spread and SPX is negative and insignificant. Also, the correlations

[2] Brunnermeier (2008) uses February 2007 as the starting date of the subprime mortgage default crisis, indicated by the drop of the ABX index (of CDS) backed by A, BBBB & BBB subprime mortgage.

between the TED spread and other global market indices are positive and insignificant before the crisis. During the financial crisis, there are negative and significant correlations between TED spread and all global market indices except SHCOMP (China)[3].This finding is consistent with the interpretation of the TED spread as perceived credit risk and its linkage to global stock market returns could be strengthened during the financial crisis.

2.2. Empirical Frameworks

Our empirical analyses are organized as follows. First, the unit root tests are performed on all variables used in the analyses, including: log of global market indices (including US/S&P500 Index (SPX), UK/ FTSE100 Index (UKX), Hong Kong/ Hang Seng Index (HSI), Japan/ Nikkei225 Index (NKY), Australia/ ASX 200 Index (AS51), Russia/ Russian RTS Index (RTSI), and China/ Shanghai SE Composite Index (Shcomp)), and the TED spread. We apply the Augmented Dickey-Fuller test to test the null hypothesis that the process follows a random walk with or without a time trend. The results show that all time-series are subject to unit root problem, and the first-differences of these variables are stationary.

Second, we take the first-difference of the global market indices (which are subject to unit root problem) and estimate the VAR systems for the relationships between change in the log of S&P500 and change in the log of other global market indices. Moreover, we estimate the trivariate relationships between the change in TED spread, the returns of SPX and the returns of other global market indices.

Third, from the VAR systems estimated above, we perform the Granger causality tests, to investigate the causal relationships among the returns of global market indices and the relationships between the change in TED spread, the returns of SPX and the returns of other global market indices.

Fourth, we estimate the cointegrating Vector Error-Correction Model (VECM) for the unit root processes of log of global market indices and the TED spread (which are all integrated of order (1)). We apply the Johansen test to identify the equilibrium relationships between the log of SPX and the log of other global market indices, and the equilibrium relationships between the TED spread, the log of SPX, and the log of other global market indices.

Finally, we report the impulse-response functions estimated from the cointegrating VECM to show how shocks originated from one financial market can affect other global financial markets, and how the impulse-response relationships change during the financial crisis.

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[3] The negative correlations is smallest between TED spread and UKX (-19.77%) and highest between TED spread and RTSI (-33.38%).

3. Empirical Findings

3.1. Unit Root Tests

In order to check whether or not the time series is stationary, we apply the augmented Dickey-Fuller test by estimating the following model.

$$\Delta y_t = \alpha + \beta y_{t-1} + \delta_t + \sum_{i=1}^{k} \gamma_i \Delta y_{t-i} + \varepsilon_t \tag{1}$$

The null hypothesis is that y_t follows a random walk without drift and Equation (1) is fitted without the constant term α and the time trend δ_t. Testing $\beta = 0$ is equivalent to testing that y_t follows a unit root process. We test the process under null hypothesis with restriction $\alpha = 0$ and $\delta = 0$.

The results (not reported here) show that the time series of (the log of) stock market indices, including USA (SPX), UK (UKX), Hong Kong (HSI), Japan (NKY), Australia (AS51), and Russia (RTSI), and the TED spread are all subject to unit root problem.[4] Since there is an upward trend in some of these variables over time, we also test the null hypothesis that y_t follows a unit root with α unrestricted and a time trend included in the regression, and find same conclusion. We take the first-differences of these variables, and find that they are all stationary processes. As such, we take the first-order differences of those processes in estimating VAR system and use the level of these processes (which are non-stationary and integrated of order (1)) for cointegrating VECM.

3.2. Vector Autoregressive Models

We examine the pair relationships between returns in SPX and other global market indices before and during the 2007 crisis in the VAR model. The analyses focus on the link between the U.S. market and other global markets because the current crisis is originated from the U.S. and spillovers into other countries. We also estimate the VAR system for the relationships between the volatility of SPX and the volatilities of other global indices. The general form of a two-variable autoregressive model can be expressed as follows.

$$\Psi_t = \mathrm{B}_0 + \mathrm{B}_1 \Psi_{t-1} + \mathrm{B}_2 \Psi_{t-2} + \varepsilon_t, \tag{2}$$

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[4] We also compute the squares of all global market returns as proxy for volatility (see Section 3.3), and find that these processes are also subject to unit root problems.

where

$$\Psi_t = \begin{bmatrix} X_t \\ Y_t \end{bmatrix};\ \mathrm{B}_0 = \begin{bmatrix} \beta_{10} \\ \beta_{20} \end{bmatrix};\ \mathrm{B}_1 = \begin{bmatrix} \beta_{11} & \beta_{13} \\ \beta_{21} & \beta_{23} \end{bmatrix};\ \mathrm{B}_2 = \begin{bmatrix} \beta_{12} & \beta_{14} \\ \beta_{22} & \beta_{24} \end{bmatrix};\ \varepsilon_t = \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

Table 2 reports the VAR relationships between SPX returns and other global market returns, as well as those between SPX return volatility and return volatilities in other global markets. Consistent with Ozdemira and Cakan (2007), Panel A shows that the impact of SPX returns on UKX returns is positive and significantly greater during the crisis, suggesting a increasing spillover effect from the U.S. market to the U.K. market during the crisis. We also find a possible feedback effect from the U.K. market to the U.S. market during the crisis since the impact of UKX returns on SPX returns is negative and more significant during the crisis. The result from the right column exhibits a similar spillover and feedback effect in return volatilities. Panel B reports a significant spillover effect from the U.S. market to the Hong Kong market in terms of index returns and volatilities during the crisis. The Hong Kong market does not seem to have a feedback effect to the U.S. market either before or during the crisis.

Panel C shows that the spillover effect from the U.S. market to the Japan market greatly intensifies during the crisis as the impact of SPX returns/volatility on NKY returns/volatility becomes significantly larger. Whilst the impact of NKY returns/volatility on SPX returns/volatility is significant before the crisis, the feedback effect from the Japan market to the U.S. market during the crisis is insignificant. Similar to the Japan market, the Australia market, in Panel D, has a significant impact on the U.S. market before the crisis but the feedback effect from the Australia market to the U.S. market is not significant. The impact of SPX returns/volatility on AS51 returns/volatility substantially increases during the crisis, indicating an enhanced spillover effect.

Panel E suggests a weaker link between the U.S. market and the Russia market, even in the crisis. Both the spillover effect and the feedback effect are not significant before and during the crisis. The lagged impact of RTSI returns on SPX returns is significant during the crisis. Panel F indicates that, although the interdependence between the two markets is weak before the crisis, the spillover effect from the U.S. market to the China market increases during the crisis in terms of index returns and volatilities. The feedback effect from the China market to the U.S. market during the crisis remains insignificant.

3.3. Causal relationships between S&P500 and Global Market Indices

We examine the lead-lag relationships between the U.S. market and other global markets with the Granger causality test (the Wald statistics). Panel A of Table 3 shows that, although no specific causal relationship can be identified before the crisis, both the U.K. and Russia markets exhibit two-way causal relationships with respect to the U.S. market during the crisis. The U.S. market leads the Hong Kong and Australia markets before and during the crisis, with strengthened causal relationship in the crisis. With weak causal relationship with the China market before the crisis, the U.S. market Granger-causes the China market during the crisis. Interestingly, whilst the Japan market lead the U.S. market to a certain extent (the Wald statistics is significant at 10% level) before the crisis, the U.S. market switches places in the causal relationship with enhanced leadership during the crisis.

Overall, these findings suggest that the relationships between the U.S. market and other global stock markets have experienced a dramatic change during the current crisis. As the crisis originated from the U.S., the U.S. market plays a more important leading role in unfolding the uncertainty and transmitting relevant information. Further explorations using index volatilities and trading volume (results not reported here) drive to the same conclusion. Together, these support existing literature on increasing global market interdependence during financial crises (Tuluca and Zwick , 2001; Yang, Kolari and Min, 2002; Chakrabarti and Roll, 2002; Hon, Strauss, and Yong, 2004; Yang, Hsiao, Li and Wang, 2006).

3.4. Causal relationships Between TED spread, S&P500, and Global Market Indices

To examine the role of the TED spread, an indicator of perceived credit risks, in the current crisis, Panel B of Table 3 reports the trivariate causal relationships between changes in the TED spread, SPX returns, and other global index returns. While the TED spread has no significant causal relationship with respect to any of the stock market indices before the crisis, it becomes an important leading indicator during the crisis. The TED spread has a greater predictive power and leads the U.S. market, the U.K. market, and the Australia market during the crisis. The TED spread exhibits two-way causality relationship with the Japan market during the crisis. Interestingly, the TED spread switches places in causal relationship with the Russia market and leads RTSI returns during the crisis. Overall, the TED spread not only affects the U.S. market, but also has a spillover effect into other global markets, including U.K. market, Australia Japan, and Russia. This finding complements existing findings on contagion effect during financial crisis (Longin and Solnik, 2001; Campbell, Koedijk and Kofman, 2002; Van Royen, 2002; Bekaert, Harvey and Ng, 2005; Candelon, Piplack, and Straetmans, 2008).

4. Cointegrating Relationships between US and Global Market Indices

As discussed above, the time-series of the log of global market indices and the TED spread are subject to unit root problem. Since the first-differences of the variables are covariance stationary, a simple regression related to the changes in these variables appears to be a viable alternative. However, if these variables are cointegrated, the simple regression of changes in the variables could be misspecified. According to Granger (1981), it is not possible for the dependent variable to be a random walk while the independent variable and the residual are covariance stationary. In order to avoid the problem of misspecification and imbalance, we estimate the cointegrating VECM for the relationships between SPX (US) and other global market indices and the relationships between the TED spread, SPX, and other global indices. The VECM takes the form as in the following equation.

$$\Delta y_t = v + \Pi\, y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i\, \Delta y_{t-i} + \varepsilon_t \qquad (3)$$

where $\Pi = \sum_{j=1}^{j=p} Aj - I_k$ and $\Gamma_i = -\sum_{j=i+1}^{j=p} Aj$.

y_t is a $K\times 1$ vector of variables, v is a $K\times 1$ vector of parameters, and ε_t is a $K\times 1$ vector of disturbances with mean 0 and covariance matrix Σ. Using the above cointegrating equation, we estimate the parameters of the cointegrating VECM for the time-series of the log of SPX and log of global market indices (which are all shown to have unit root and integrated with the same order). The parameters of cointegrating VECMs for the interrelationships include: (i) the parameters in the cointegrating equations β; (ii) the adjustment coefficient α; these parameters have useful interpretations on the relationships between SPX and other global indices. Results are reported in Table 4.

To examine the credit risk spillover, we also estimate the parameters of the trivariate cointegrating VECM for the time-series of the TED spread, the log of SPX and the log of other global market indices (which are all shown to have unit root and integrated with the same order). We report the estimation results in Table 5.

4.1. Equilibrium Relationships

Johansen (1995) shows that if there are r cointegrating equations, there are at least r^2 restrictions on identifying the free parameters in β. Johansen's identification scheme is

$$\beta' = (I_r, \beta^{\wedge\prime})$$

where I_r is the r time r identity matrix and β^'is an $(K - r)$ times r matrix of identified parameters. We estimate the VECM with two cointegrating equations and two lags on all three series. For robustness test, we include additional lags in the cointegrating equations and find identical conclusion. With the normalization, we can interpret the estimates of the parameters in each cointegrating equations as indicating the equilibrium relationship between various global financial markets.

4.2. Equilibrium Relationships between S&P500 and Other Global Market Indices

Table 4 reports the cointegrating VECM between the log of SPX, and the log of other global market indices. Our focus here is to identify the cointegrating relationships between the U.S. and other global financial markets, and how the equilibrium relationships might change before and during the recent global financial crisis in 2007. We summarize our results as follows.

(i) Cointegrating relationships of SPX vis-à-vis UKX, RTSI, NKY, and HSI: before the financial crisis, the cointegrating rank test (the Johansen test) for cointegration suggests that there exists (pairwise) equilibrium relationships of SPX vis-à-vis UKX, RTSI, NKY, and HSI. In the equilibrium relationships, all four cointegrating coefficients (β) of SPX on UKX, RTSI, NKY, and HSI increase during the crisis and are statistically significant before and during the crisis. Note that the adjustment parameter (α) are insignificant for UKX, RTSI, NKY, and HSI.

(ii) Cointegrating relationships of SPX vis-à-vis AS51: the cointegrating rank test (the Johansen test) for cointegration suggests that there exists equilibrium relationship between SPX and AS51 before and during the crisis. The cointegrating coefficient β on AS51 change from -0.507 to 1.045, both are statistically significant. Also, before the crisis, the adjustment parameter (α) of AS51 before the crisis is significant and have a value of 0.042, suggesting that this market is the main adjusting force in the equilibrium relationship. When SPX is increasing (decreasing), AS51 will quickly increase (decrease) toward the level of SPX in the equilibrium relationships. During the financial crisis, the cointegrating coefficient (β = -1.045) on AS51 is drastically larger in absolute magnitude and statistically significant, although the adjustment parameter (α) is not.

(iii) Cointegrating relationships of SPX vis-à-vis Shcomp: the cointegrating coefficient (β) on Shcomp is statistically insignificant before the financial crisis. During the financial crisis from July 2007, the cointegrating coefficient (β = -0.522) on Shcomp becomes statistically significant. This suggests the existence of equilibrium relationship between SPX and Shcomp during the crisis.

Overall, these findings suggest that the equilibrium relationships between US and global market indices change dramatically before and during the financial crisis. During the financial crisis, the strength of the long-run relationship between US and other global financial markets increases, yet these markets are slow to adjust back to the long-run equilibrium during the financial crisis. Together with the findings in Sections 3.2 and 3.3, the findings here provide new contribution to existing literature on intensifying interdependence among global markets during periods of financial crises (Tuluca and Zwick , 2001; Yang, Kolari and Min, 2002; Chakrabarti and Roll, 2002; Hon, Strauss, and Yong, 2004; Yang, Hsiao, Li and Wang, 2006).

4.3. Equilibrium Relationships between TED spread, S&P500 and Other Global Market Indices

Table 5 reports the cointegrating VECM between the TED spread, the log of SPX, and the log of other global market indices. Our focus here is to identify the cointegrating relationships between the TED spread, S&P500 and other global market indices, and examine how the relationships change during the financial crisis.[5] We interpret the results of the first of two trivariate cointegrating equations as indicating the existence of equilibrium relationship between TED spread and global indices and the second equation as the existence of equilibrium relationship between SPX and global indices (which are rarely documented in the existing literature). For robustness test, we include additional lags in the cointegrating VECM and find very similar results and identical conclusion.

Panel A of Table 5 suggests that, before the financial crisis, the cointegrating relationships between TED spread and global indices are all negative significant except for AS51. During the financial crisis, the adjustment parameter (α) on TED spread is statistically significant on all global market indices. This result implies that the TED spread is the equilibrium adjusting force during the crisis.[6]

Panel B of Table 5 suggests that, after the financial crisis, the cointegrating relationships between SPX and other global indices are all negative significant except for AS51. The sign of cointegrating parameter β for AS51(Australia) is significant and positive before, and during the crisis.

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[5] The Johansen identification scheme has placed 4 constraints on the parameters in β: coefficient of TED spread = 1, coefficient of SPX = 0, coefficient of UKX = 0, and coefficient of SPX = 1.

[6] For example, during the financial crisis from July 2007, the cointegrating rank test (the Johansen test) for cointegration suggests that there exist two equilibrium relationships between TED spread, SPX and Shcomp. The significant cointegrating coefficients on Shcomp are 0.971 and -0.473 in the equilibrium relationship between TED spread and Shcomp and the equilibrium relationship between SPX and Shcomp respectively. The TED spread, SPX, and Shcomp are all significant adjustment parameter (α). The fact that $|-0.814|>|-0.355|>|-0.217|$ indicates that the TED spread is the main adjusting force in the equilibrium relationship.

Overall, these findings suggest that there are cointegrating VECM connections identified for the interrelationships between TED spread, SPX in the US, and other global market indices. We observe stronger integrating relationships between the US and other global markets during the financial crisis. Most importantly, we find the equilibrium relationship between the TED spread (an indicator of perceived credit risk in the general economy) and other global market indices; this relationship is rarely documented in the existing literature. The TED spread in cointegrating relationship has the largest adjustment coefficient, suggesting that the TED spread in equilibrium responds to fundamental changes in the US and global financial markets, and the TED spread provide new information (about financial crisis) not only to the US but other global financial markets. During the financial crisis, the TED spread not only affects SPX in the US, but also has spillover effects into other global markets. For robustness test, we include additional lags in the cointegrating VECM, and find very similar results and identical conclusion. Based on our results from VAR, Granger causality test, and cointegration (in Sections 3.2, 3.4 and 4.3), we conclude that the TED spread have a greater predictive power during the 2007-2009 financial crisis.

4.4. Impulse-Response Analysis for TED spread, S&P500 and Global indices

We examine the impulse-response functions for the VECMs in Section 4.4. Table 6 presents the impulse-response functions for the trivariate relationships between the TED spread, the log of SPX, and the log of other global market indices. Table 6 reports the 4-week and 12-week ahead impulse-response parameters for each pair-wise relationship. For further analysis, we also examine the plots of impulse-response functions over time (results not reported here).[7]

Panel A of Table 6 reports the 4-week ahead (*short-term*) impulse-response parameters for each pair-wise relationship. First, Column (3) (and the first row of Column (5)) of Panel A summarizes the impulse from TED spread to all global market indices. The 4-week ahead impulse-response functions from cointegrating VECM show that the *short-term* impacts of orthogonalized shocks from the TED spread (the perceived credit risk) on global market indices become negative and the absolute magnitude of the impulse-response functions increases significantly during the financial crisis. This finding suggests that orthogonalized shocks from the TED spread have large and negative impacts on various global market indices during the crisis. For example, the absolute size of the 4-week ahead impulse-response from the TED spread to SPX increases from -0.127 to -2.253 during the financial crisis. Before the financial crisis, the

[7] Further examination suggests that the impulse-response functions from cointegrating VECM do not always die out – the I(1) variables modeled in a cointegrating VECM are not mean-reverting, and the unit root model in the companion matrix imply that the effect of some shocks maybe permanent.

impact of orthogonalized shocks from TED spread (the perceived credit risk) on global market indices is much smaller.

Second, Column (4) (and the second row of Column (5)) of Panel A summarizes the impulse-response functions of orthogonalized shocks from SPX to each of the global market indices. The *short-term* impacts of orthogonalized shocks from SPX on global market indices are much larger (at least 2 times larger) during the financial crisis. For example, the impact from SPX to SHCOMP (China) increases from 4.277 to 22.16 during the crisis. This finding suggests that orthogonalized shocks from SPX have larger short-term impacts on various global market indices during the crisis.

Third, Column (5) (except row 1) of Panel B summarizes the impulse-response functions of orthogonalized shocks from each of the global market indices on SPX. Interestingly, the orthogonalized shocks from all global indices have larger impacts on the SPX during the financial crisis. The results in Column (5) indicate that the *short-term* impacts of orthogonalized shocks from other global market indices on SPX are much larger (at least four times larger) during the financial crisis.

Panel B of Table 6 reports the 12-week ahead (*long-term*) impulse-response parameters for each pair-wise relationships.

First, Column (3) (and the first row of Column (5)) of Table 6 Panel B summarizes the impulse-response functions of orthogonalized shocks from the TED spread to each of the global market indices. Similar to the results in Panel A, the 12-week ahead impacts of orthogonalized shocks from the TED spread on global market indices increase by at least five times during the financial crisis. For example, the absolute size of the 12-week ahead impulse-response parameter from TED spread to SPX increases from -0.063 to -2.404 during the financial crisis. This finding suggests that orthogonalized shocks from the TED spread have long-term permanent impacts on various global market indices. Before the financial crisis, the *long-term* impacts of orthogonalized shocks from TED spread on global market indices are much weaker.

Second, Column (4) (and the second row of Column (5)) of Table 6 Panel B summarizes the impulse-response functions of orthogonalized shocks from SPX to each of the global market indices. The *long-term* impacts of orthogonalized shocks from the TED spread on global market indices are much larger (at least two times larger) during the financial crisis. For example, the absolute size of the 12-week ahead impulse-response parameter from SPX to UKX increases from 1.102 to 3.212 during the financial crisis.

Third, Column (5) (except row 1) of Table 6 Panel B summarizes the impulse-response functions of orthogonalized shocks from each global market indices on SPX. Similar to the results in Column (4), the results in Column (5) indicate that the *long-term* impacts of orthogonalized shocks from other global market indices on SPX are much larger (at least three times larger) during the financial crisis. Interestingly, all global indices (including emerging markets) are having larger impacts on the SPX during the financial crisis.

Together with the findings in Sections 3.2, 3.4 and 4.3, these findings demonstrate that the interrelationships between TED spread, SPX, and other global indices have been dramatically strengthened during the 2007-2009 financial crisis. These findings are consistent with the presence of contagion effect and the hypothesis that global financial markets are more integrated during the crisis. Most prominently, the overall findings contribute to existing literature on understanding how a shocks originated from one region can create contagion effect during financial crises (Longin and Solnik, 2001; Campbell, Koedijk and Kofman, 2002; Van Royen, 2002; Bekaert, Harvey and Ng, 2005; Candelon, Piplack, and Straetmans, 2008).

5. Conclusion

As Stiglitz (1999, p.1509) points out, "financial and currency crises have hit with increasing frequency, at high budgetary costs to the governments that inevitably try to resurrect their economies. But the cost is high; for years after the crisis, growth is slower and unemployment higher. By one reckoning, 80 to 100 countries have faced a crisis since the mid-1970s". Examining the dynamic interrelationship among global markets during crises is therefore increasingly important in understanding market efficiency, information flows, and global integration. The current crisis stemmed from the influential U.S. market has pervasive effects on global markets. Such an "extreme" event presents a unique experimental setting to gather new insights into the changing global market interdependence and the spillover effect of credit risk.

Based on the most up-to-date sample from January 3rd, 2003 to April 3rd, 2009, we document a significant spillover effect from the U.S. market to other global financial markets in U.K., Hong Kong, Japan, Australia, and China. The linkage between the U.S. market and other global markets, both the short-term causal relationship and long-term cointegrating equilibrium, strengthens during the current crisis. We also find that during the crisis, the TED spread adjusts to new information rapidly and serves as a leading 'fear' indicator, not only for the U.S. market but also for other global markets. While the impact of orthogonalized shocks from the U.S. market on other global markets increases by at least 2 times during the crisis, the impact of orthogonalized shocks from the TED spread on global market indices increases by at least 5 times.

Although the current crisis may be far from over and it is premature to reach any final verdict, our findings shed light on the dynamic interrelationships among international markets and the contagion effect in a catastrophe. They also provide important implications for portfolio managers and policy makers. As the crisis causes system-wide shocks in both developed and emerging markets and undermines the effect of global diversification, portfolio managers need to take the increasing international linkage into account when constructing their portfolio. Policy makers also need to understand the spillover effect when coordinating their efforts to alleviate the current crisis. For future research, it is important to better understand factors that may affect the dynamics of global interdependence, such as market imperfection, investors' sentiment, and information efficiency.

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Table 1 Summary Statistics

This table reports the weekly returns (change in log prices) of global market indices and the TED spread before the financial crisis (January 2003 to June 2007) and during the financial crisis (July 2007 to April 2009). Panel A reports the summary statistics of the returns of global market indices before and during the financial crisis. The last column of Table A reports the t-test of mean difference between the returns before the crisis and the returns during the financial crisis. Panel B reports the pair-wise correlations between the returns of SPX (US) and the returns of other global market indices before and during the financial crisis. Panel C reports the pair-wise correlations between the TED spread and the returns of global market indices before and during the financial crisis. Using alternative date (such as February 2007) to identify the starting time of global financial crisis does not change the main findings and conclusions.

Panel A. Summary statistics of global market indices and TED spread before and during the crisis

	Before financial crisis (January 2003 to June 2007)	During the financial crisis (July 2007 to April 2009)	Difference (During Crisis – Before Crisis)
SPX returns	Mean = 0.0022 Median = 0.0023 Std deviation = 0.0157	Mean = -0.0065 Median = -0.0040 Std deviation = 0.0433	-0.0087***
UKX returns	Mean = 0.0021 Median = 0.0027 Std deviation = 0.0163	Mean = -0.0055 Median = -0.0028 Std deviation = 0.0446	-0.0077**
HSI returns	Mean = 0.0036 Median = 0.0053 Std deviation = 0.0207	Mean = -0.0048 Median = -0.0030 Std deviation = 0.0514	-0.0084**
NKY returns	Mean = 0.0032 Median = 0.0062 Std deviation = 0.0228	Mean = -0.0080 Median = -0.0025 Std deviation = 0.0493	-0.0112***
AS51 returns	Mean = 0.0031 Median = 0.0044 Std deviation = 0.0129	Mean = -0.0058 Median = -0.0052 Std deviation = 0.0382	-0.0089***
RTSI returns	Mean = 0.0073 Median = 0.0104 Std deviation = 0.0395	Mean = -0.0100 Median = -0.0071 Std deviation = 0.0832	-0.0174***
SHCOMP returns	Mean = 0.0048 Median = 0.0031 Std deviation = 0.0310	Mean = -0.0054 Median = -0.0111 Std deviation = 0.0537	-0.0102**
TED spread	Mean = 0.3616 Median = 0.34 Std deviation = 0.1456	Mean = 1.4612 Median = 1.3 Std deviation = 0.6770	1.0995***

Note: ***, **, * denote 1%, 5%, 10% significance of t-test of mean difference.

Panel B. Pair-wise correlations between SPX and other global market indices before and during the crisis

Pair-wise correlation: SPX returns vis-à-vis other market returns	Before financial crisis (January 2003 to June 2007)	During the financial crisis (July 2007 to April 2009)
SPX returns vis-à-vis UKX returns	0.7513***	0.8831***
SPX returns vis-à-vis HSI returns	0.4341***	0.6566***
SPX returns vis-à-vis NKY returns	0.4571***	0.7818***
SPX returns vis-à-vis AS51 returns	0.4859***	0.7193***
SPX returns vis-à-vis RTSI returns	0.2799***	0.5284***
SPX returns vis-à-vis SHCOMP returns	0.0787	-0.2070*

Note: ***, **, * denote 1%, 5%, 10% significance of the pair-wise correlations.

Panel C. Pair-wise correlations between TED spread and global market indices before and during the crisis

Pair-wise correlation: TED spread and SPX	Before financial crisis (January 2003 to June 2007)	During the financial crisis (July 2007 to April 2009)
TED spread vis-à-vis SPX returns	-0.0338	-0.2492**
TED spread vis-à-vis UKX returns	0.0107	-0.1977*
TED spread vis-à-vis HSI returns	0.0416	-0.2233**
TED spread vis-à-vis NKY returns	0.0297	-0.3209***
TED spread vis-à-vis AS51 returns	0.0168	-0.2554**
TED spread vis-à-vis RTSI returns	0.0201	-0.3338***
TED spread vis-à-vis SHCOMP returns	0.1033	0.0148

Note: ***, **, * denote 1%, 5%, 10% significance of the pair-wise correlations.

Table 2 VAR models for returns and volatilities in global market indices

This table reports the results of the following two-variable autoregressive model:

$$\Psi_t = \mathrm{B}_0 + \mathrm{B}_1 \Psi_{t-1} + \mathrm{B}_2 \Psi_{t-2} + \varepsilon_t , \qquad (2)$$

where

$$\Psi_t = \begin{bmatrix} X_t \\ Y_t \end{bmatrix} ; \; \mathrm{B}_0 = \begin{bmatrix} \beta_{10} \\ \beta_{20} \end{bmatrix} ; \; \mathrm{B}_1 = \begin{bmatrix} \beta_{11} & \beta_{13} \\ \beta_{21} & \beta_{23} \end{bmatrix} ; \; \mathrm{B}_2 = \begin{bmatrix} \beta_{12} & \beta_{14} \\ \beta_{22} & \beta_{24} \end{bmatrix} ; \; \varepsilon_t = \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

Panel A Relation between SPX and UKX

			Index Return					Index Volatility	
Before Crisis									
$R(SPX)_t$			Coefficient	Z value	$Vol(SPX)_t$			Coefficient	Z value
	β_{11}	$R(SPX)_{t-1}$	-0.0749	-0.75		β_{11}	$Vol(SPX)_{t-1}$	0.8762	8.86***
	β_{12}	$R(SPX)_{t-2}$	0.4121	0.42		β_{12}	$Vol(SPX)_{t-2}$	0.0902	0.92
	β_{13}	$R(UKX)_{t-1}$	-0.0779	-0.82		β_{13}	$Vol(UKX)_{t-1}$	-0.0321	-0.41
	β_{14}	$R(UKX)_{t-2}$	-0.0492	-0.52		β_{14}	$Vol(UKX)_{t-2}$	0.0536	0.69
	β_{10}	Constant	0.0025	2.52***		β_{10}	Constant	0.1598	0.43
$R(UKX)_t$			Coefficient	Z value	$Vol(UKX)_t$			Coefficient	Z value
	β_{21}	$R(SPX)_{t-1}$	0.0316	0.31		β_{20}	$Vol(SPX)_{t-1}$	0.0024	0.02
	β_{22}	$R(SPX)_{t-2}$	0.0753	0.75		β_{20}	$Vol(SPX)_{t-2}$	0.0098	0.08
	β_{23}	$R(UKX)_{t-1}$	-0.1336	-1.35		β_{20}	$Vol(UKX)_{t-1}$	0.8965	9.02***
	β_{24}	$R(UKX)_{t-2}$	-0.1451	-1.50		β_{20}	$Vol(UKX)_{t-2}$	0.0935	0.94
	β_{20}	Constant	0.0028	2.58***		β_{20}	Constant	0.1592	0.34
During Crisis									
$R(SPX)_t$			Coefficient	Z value	$Vol(SPX)_t$			Coefficient	Z value
	β_{11}	$R(SPX)_{t-1}$	0.5584	2.55***		β_{11}	$Vol(SPX)_{t-1}$	1.4375	6.49***
	β_{12}	$R(SPX)_{t-2}$	0.4323	1.79*		β_{12}	$Vol(SPX)_{t-2}$	-0.4155	-1.86*
	β_{13}	$R(UKX)_{t-1}$	-0.7124	-3.21***		β_{13}	$Vol(UKX)_{t-1}$	-0.4565	-2.51***
	β_{14}	$R(UKX)_{t-2}$	-0.2985	-1.29		β_{14}	$Vol(UKX)_{t-2}$	0.4241	2.34**
	β_{10}	Constant	-0.0055	-1.25		β_{10}	Constant	1.1847	0.33
$R(UKX)_t$			Coefficient	Z value	$Vol(UKX)_t$			Coefficient	Z value
	β_{21}	$R(SPX)_{t-1}$	0.9316	4.41***		β_{20}	$Vol(SPX)_{t-1}$	1.0671	4.08***
	β_{22}	$R(SPX)_{t-2}$	0.5145	2.21**		β_{20}	$Vol(SPX)_{t-2}$	-0.8416	-3.20***
	β_{23}	$R(UKX)_{t-1}$	-1.0355	-4.82***		β_{20}	$Vol(UKX)_{t-1}$	0.0311	0.14
	β_{24}	$R(UKX)_{t-2}$	-0.3232	-1.44		β_{20}	$Vol(UKX)_{t-2}$	0.7175	3.35***
	β_{20}	Constant	-0.0034	-0.81		β_{20}	Constant	7.1032	1.69*

Panel B Relation between SPX and HSI

			Index Return					Index Volatility	
Before Crisis									
$R(SPX)_t$			Coefficient	Z value	$Vol(SPX)_t$			Coefficient	Z value
	β_{11}	$R(SPX)_{t-1}$	-0.1456	-2.00**		β_{11}	$Vol(SPX)_{t-1}$	0.8228	11.22***
	β_{12}	$R(SPX)_{t-2}$	-0.0428	-0.58		β_{12}	$Vol(SPX)_{t-2}$	0.1133	0.53
	β_{13}	$R(HSI)_{t-1}$	0.1732	0.31		β_{13}	$Vol(HSI)_{t-1}$	0.0191	0.46
	β_{14}	$R(HSI)_{t-2}$	0.0584	1.25		β_{14}	$Vol(HSI)_{t-2}$	0.0083	0.20
	β_{10}	Constant	0.0024	2.25		β_{10}	Constant	0.7337	1.53
$R(HSI)_t$			Coefficient	Z value	$Vol(HSI)_t$			Coefficient	Z value
	β_{21}	$R(SPX)_{t-1}$	0.2525	2.72***		β_{20}	$Vol(SPX)_{t-1}$	0.3877	2.97***
	β_{22}	$R(SPX)_{t-2}$	0.0582	0.7		β_{20}	$Vol(SPX)_{t-2}$	-0.2591	-1.96**
	β_{23}	$R(HSI)_{t-1}$	-0.1532	-2.21**		β_{20}	$Vol(HSI)_{t-1}$	0.8086	11.01***
	β_{24}	$R(HSI)_{t-2}$	0.0294	0.41		β_{20}	$Vol(HSI)_{t-2}$	0.1357	1.88*
	β_{20}	Constant	0.0034	2.18**		β_{20}	Constant	-1.2793	-1.50
During Crisis									
$R(SPX)_t$			Coefficient	Z value	$Vol(SPX)_t$			Coefficient	Z value
	β_{11}	$R(SPX)_{t-1}$	0.0118	0.08		β_{11}	$Vol(SPX)_{t-1}$	0.9207	6.51***
	β_{12}	$R(SPX)_{t-2}$	0.2057	1.45		β_{12}	$Vol(SPX)_{t-2}$	-0.0108	-0.08
	β_{13}	$R(HSI)_{t-1}$	-0.0932	-0.78		β_{13}	$Vol(HSI)_{t-1}$	0.0024	0.03
	β_{14}	$R(HSI)_{t-2}$	-0.1039	-0.89		β_{14}	$Vol(HSI)_{t-2}$	0.0487	0.59
	β_{10}	Constant	-0.0050	-1.31		β_{10}	Constant	-0.5953	-0.49
$R(HSI)_t$			Coefficient	Z value	$Vol(HSI)_t$			Coefficient	Z value
	β_{21}	$R(SPX)_{t-1}$	0.3524	2.22**		β_{20}	$Vol(SPX)_{t-1}$	0.4301	1.96**
	β_{22}	$R(SPX)_{t-2}$	0.4519	2.84***		β_{20}	$Vol(SPX)_{t-2}$	-0.3069	-1.32
	β_{23}	$R(HSI)_{t-1}$	-0.2299	-1.71*		β_{20}	$Vol(HSI)_{t-1}$	0.8279	5.87***
	β_{24}	$R(HSI)_{t-2}$	-0.1049	-0.79		β_{20}	$Vol(HSI)_{t-2}$	0.0907	0.66
	β_{20}	Constant	-0.0008	-0.16		β_{20}	Constant	1.7464	0.86

Note: *, **, and *** indicate significance at the 10, 5, 1 percent levels, respectively.

Panel C Relation between SPX and NKY

			Index Return					Index Volatility	
Before Crisis									
R(SPX)$_t$			Coefficient	Z value	Vol(SPX)$_t$			Coefficient	Z value
	β_{11}	R(SPX)$_{t-1}$	-0.1040	-1.42		β_{11}	Vol(SPX)$_{t-1}$	0.9367	12.95***
	β_{12}	R(SPX)$_{t-2}$	0.0560	0.94		β_{12}	Vol(SPX)$_{t-2}$	0.0627	0.86
	β_{13}	R(NKY)$_{t-1}$	-0.0950	-1.93**		β_{13}	Vol(NKY)$_{t-1}$	-0.0850	-2.27**
	β_{14}	R(NKY)$_{t-2}$	-0.0551	-1.13		β_{14}	Vol(NKY)$_{t-2}$	0.0830	2.25**
	β_{10}	Constant	0.0031	3.01***		β_{10}	Constant	0.2518	0.64
R(NKY)$_t$			Coefficient	Z value	Vol(NKY)$_t$			Coefficient	Z value
	β_{21}	R(SPX)$_{t-1}$	0.1925	1.74*		β_{20}	Vol(SPX)$_{t-1}$	0.2521	1.77*
	β_{22}	R(SPX)$_{t-2}$	0.0592	0.54		β_{20}	Vol(SPX)$_{t-2}$	-0.1627	-1.13
	β_{23}	R(NKY)$_{t-1}$	-0.1251	-1.57*		β_{20}	Vol(NKY)$_{t-1}$	0.8552	11.60***
	β_{24}	R(NKY)$_{t-2}$	-0.0052	-0.08		β_{20}	Vol(NKY)$_{t-2}$	0.1039	1.43
	β_{20}	Constant	0.0030	1.95**		β_{20}	Constant	-0.7696	-0.99
During Crisis									
R(SPX)$_t$			Coefficient	Z value	Vol(SPX)$_t$			Coefficient	Z value
	β_{11}	R(SPX)$_{t-1}$	0.1453	0.87		β_{11}	Vol(SPX)$_{t-1}$	1.0236	5.98***
	β_{12}	R(SPX)$_{t-2}$	0.0530	0.31		β_{12}	Vol(SPX)$_{t-2}$	-0.1955	-1.14
	β_{13}	R(NKY)$_{t-1}$	-0.2139	-1.44		β_{13}	Vol(NKY)$_{t-1}$	-0.0930	-0.83
	β_{14}	R(NKY)$_{t-2}$	0.0940	0.53		β_{14}	Vol(NKY)$_{t-2}$	0.1959	1.77*
	β_{10}	Constant	-0.0051	-1.33		β_{10}	Constant	-0.5654	-0.50
R(NKY)$_t$			Coefficient	Z value	Vol(NKY)$_t$			Coefficient	Z value
	β_{21}	R(SPX)$_{t-1}$	0.4524	2.47***		β_{20}	Vol(SPX)$_{t-1}$	0.5251	2.03**
	β_{22}	R(SPX)$_{t-2}$	0.3403	1.94**		β_{20}	Vol(SPX)$_{t-2}$	-0.5195	-2.01**
	β_{23}	R(NKY)$_{t-1}$	-0.4160	-2.57***		β_{20}	Vol(NKY)$_{t-1}$	0.6359	3.74***
	β_{24}	R(NKY)$_{t-2}$	-0.0230	-0.14		β_{20}	Vol(NKY)$_{t-2}$	0.3387	2.02**
	β_{20}	Constant	-0.0051	-1.21		β_{20}	Constant	1.8138	1.05

Panel D Relation between SPX and AS51

			Index Return					Index Volatility	
Before Crisis									
R(SPX)$_t$			Coefficient	Z value	Vol(SPX)$_t$			Coefficient	Z value
	β_{11}	R(SPX)$_{t-1}$	-0.0517	-0.58		β_{11}	Vol(SPX)$_{t-1}$	0.9121	12.20***
	β_{12}	R(SPX)$_{t-2}$	0.0243	0.32		β_{12}	Vol(SPX)$_{t-2}$	0.0704	0.95
	β_{13}	R(AS51)$_{t-1}$	-0.1891	-2.04**		β_{13}	Vol(AS51)$_{t-1}$	-0.1329	-1.72*
	β_{14}	R(AS51)$_{t-2}$	0.0343	0.38		β_{14}	Vol(AS51)$_{t-2}$	0.1410	1.86*
	β_{10}	Constant	0.0028	2.52***		β_{10}	Constant	0.3505	0.74
R(AS51)$_t$			Coefficient	Z value	Vol(AS51)$_t$			Coefficient	Z value
	β_{21}	R(SPX)$_{t-1}$	0.2185	3.52***		β_{20}	Vol(SPX)$_{t-1}$	0.2449	3.38***
	β_{22}	R(SPX)$_{t-2}$	0.0581	1.10		β_{20}	Vol(SPX)$_{t-2}$	-0.1955	-2.72***
	β_{23}	R(AS51)$_{t-1}$	-0.1454	-1.93		β_{20}	Vol(AS51)$_{t-1}$	0.8437	11.29***
	β_{24}	R(AS51)$_{t-2}$	0.0803	1.09		β_{20}	Vol(AS51)$_{t-2}$	0.1357	1.85*
	β_{20}	Constant	0.0027	3.15***		β_{20}	Constant	-0.9851	-2.14**
During Crisis									
R(SPX)$_t$			Coefficient	Z value	Vol(SPX)$_t$			Coefficient	Z value
	β_{11}	R(SPX)$_{t-1}$	0.0999	0.54		β_{11}	Vol(SPX)$_{t-1}$	0.9444	6.09***
	β_{12}	R(SPX)$_{t-2}$	0.3815	2.35**		β_{12}	Vol(SPX)$_{t-2}$	-0.0408	-0.26
	β_{13}	R(AS51)$_{t-1}$	-0.2506	-1.42		β_{13}	Vol(AS51)$_{t-1}$	-0.0202	-0.14
	β_{14}	R(AS51)$_{t-2}$	-0.3533	-2.03**		β_{14}	Vol(AS51)$_{t-2}$	0.0954	0.66
	β_{10}	Constant	-0.0060	-1.55		β_{10}	Constant	-0.7036	-0.46
R(AS51)$_t$			Coefficient	Z value	Vol(AS51)$_t$			Coefficient	Z value
	β_{21}	R(SPX)$_{t-1}$	0.5005	3.88***		β_{20}	Vol(SPX)$_{t-1}$	0.4712	2.95***
	β_{22}	R(SPX)$_{t-2}$	0.4230	3.15***		β_{20}	Vol(SPX)$_{t-2}$	-0.4147	-2.52***
	β_{23}	R(AS51)$_{t-1}$	-0.5372	-3.54***		β_{20}	Vol(AS51)$_{t-1}$	0.6480	4.30***
	β_{24}	R(AS51)$_{t-2}$	-0.3558	-2.47***		β_{20}	Vol(AS51)$_{t-2}$	0.2946	1.99**
	β_{20}	Constant	-0.0049	-1.31		β_{20}	Constant	1.2395	0.79

Note: *, **, and *** indicate significance at the 10, 5, 1 percent levels, respectively.

Panel E Relation between SPX and RTSI

		Index Return				Index Volatility	
Before Crisis							
$R(SPX)_t$		Coefficient	Z value	$Vol(SPX)_t$		Coefficient	Z value
β_{11}	$R(SPX)_{t-1}$	-0.1501	-2.23**	β_{11}	$Vol(SPX)_{t-1}$	0.8536	12.41***
β_{12}	$R(SPX)_{t-2}$	-0.1179	-0.03	β_{12}	$Vol(SPX)_{t-2}$	0.1195	1.73*
β_{13}	$R(RTSI)_{t-1}$	0.0031	0.11	β_{13}	$Vol(RTSI)_{t-1}$	0.0033	0.12
β_{14}	$R(RTSI)_{t-2}$	0.0027	0.09	β_{14}	$Vol(RTSI)_{t-2}$	0.0032	0.11
β_{10}	Constant	0.0030	2.71	β_{10}	Constant	1.0888	1.5
$R(RTSI)_t$		Coefficient	Z value	$Vol(RTSI)_t$		Coefficient	Z value
β_{21}	$R(SPX)_{t-1}$	-0.1387	-0.81	β_{20}	$Vol(SPX)_{t-1}$	-0.0095	-0.06
β_{22}	$R(SPX)_{t-2}$	-0.0264	-0.15	β_{20}	$Vol(SPX)_{t-2}$	0.0419	0.25
β_{23}	$R(RTSI)_{t-1}$	0.2385	3.26***	β_{20}	$Vol(RTSI)_{t-1}$	1.1186	16.14***
β_{24}	$R(RTSI)_{t-2}$	-0.1328	-1.78*	β_{20}	$Vol(RTSI)_{t-2}$	-0.1296	-1.86*
β_{20}	Constant	0.0066	2.36***	β_{20}	Constant	-1.0313	-0.58
During Crisis							
$R(SPX)_t$		Coefficient	Z value	$Vol(SPX)_t$		Coefficient	Z value
β_{11}	$R(SPX)_{t-1}$	-0.0809	-0.67	β_{11}	$Vol(SPX)_{t-1}$	0.8013	6.12***
β_{12}	$R(SPX)_{t-2}$	0.1788	1.43	β_{12}	$Vol(SPX)_{t-2}$	0.0918	0.71
β_{13}	$R(RTSI)_{t-1}$	-0.0440	-0.67	β_{13}	$Vol(RTSI)_{t-1}$	0.1023	1.50
β_{14}	$R(RTSI)_{t-2}$	-0.1577	-2.74***	β_{14}	$Vol(RTSI)_{t-2}$	-0.0594	-0.87
β_{10}	Constant	-0.0003	-0.07	β_{10}	Constant	3.0394	1.60
$R(RTSI)_t$		Coefficient	Z value	$Vol(RTSI)_t$		Coefficient	Z value
β_{21}	$R(SPX)_{t-1}$	0.1671	0.66	β_{20}	$Vol(SPX)_{t-1}$	0.3129	1.28
β_{22}	$R(SPX)_{t-2}$	0.1952	0.81	β_{20}	$Vol(SPX)_{t-2}$	-0.2730	-1.12
β_{23}	$R(RTSI)_{t-1}$	-0.3164	-2.52***	β_{20}	$Vol(RTSI)_{t-1}$	1.0014	7.86***
β_{24}	$R(RTSI)_{t-2}$	-0.2092	-1.89**	β_{20}	$Vol(RTSI)_{t-2}$	-0.0307	-0.24
β_{20}	Constant	0.0011	0.13	β_{20}	Constant	-0.5318	-0.15

Panel F Relation between SPX and SHCOMP

		Index Return				Index Volatility	
Before Crisis							
$R(SPX)_t$		Coefficient	Z value	$Vol(SPX)_t$		Coefficient	Z value
β_{11}	$R(SPX)_{t-1}$	-0.1563	-2.12**	β_{11}	$Vol(SPX)_{t-1}$	0.8247	11.72***
β_{12}	$R(SPX)_{t-2}$	-0.0522	-0.69	β_{12}	$Vol(SPX)_{t-2}$	0.1694	2.41***
β_{13}	$R(SHCOMP)_{t-1}$	-0.0350	-0.96	β_{13}	$Vol(SHCOMP)_{t-1}$	-0.0386	-1.15
β_{14}	$R(SHCOMP)_{t-2}$	-0.0047	-0.13	β_{14}	$Vol(SHCOMP)_{t-2}$	0.0426	1.26
β_{10}	Constant	0.0033	2.82***	β_{10}	Constant	0.1277	0.32
$R(SHCOMP)_t$		Coefficient	Z value	$Vol(SHCOMP)_t$		Coefficient	Z value
β_{21}	$R(SPX)_{t-1}$	0.1543	1.05	β_{20}	$Vol(SPX)_{t-1}$	0.1843	1.23
β_{22}	$R(SPX)_{t-2}$	0.1789	0.12	β_{20}	$Vol(SPX)_{t-2}$	-0.1454	-0.98
β_{23}	$R(SHCOMP)_{t-1}$	0.0490	0.68	β_{20}	$Vol(SHCOMP)_{t-1}$	1.0186	14.32***
β_{24}	$R(SHCOMP)_{t-2}$	0.1178	1.57	β_{20}	$Vol(SHCOMP)_{t-2}$	-0.0130	-0.18
β_{20}	Constant	0.0035	1.47	β_{20}	Constant	-2.1919	2.57***
During Crisis							
$R(SPX)_t$		Coefficient	Z value	$Vol(SPX)_t$		Coefficient	Z value
β_{11}	$R(SPX)_{t-1}$	-0.1485	-1.37	β_{11}	$Vol(SPX)_{t-1}$	0.7823	7.33***
β_{12}	$R(SPX)_{t-2}$	0.1472	1.26	β_{12}	$Vol(SPX)_{t-2}$	0.1680	1.56
β_{13}	$R(SHCOMP)_{t-1}$	-0.1134	-1.44	β_{13}	$Vol(SHCOMP)_{t-1}$	-0.0824	-1.27
β_{14}	$R(SHCOMP)_{t-2}$	0.1062	1.40	β_{14}	$Vol(SHCOMP)_{t-2}$	0.1074	1.63
β_{10}	Constant	-0.0022	-0.55	β_{10}	Constant	0.8006	0.88
$R(SHCOMP)_t$		Coefficient	Z value	$Vol(SHCOMP)_t$		Coefficient	Z value
β_{21}	$R(SPX)_{t-1}$	0.5474	3.46***	β_{20}	$Vol(SPX)_{t-1}$	0.5765	3.26***
β_{22}	$R(SPX)_{t-2}$	0.1150	0.68	β_{20}	$Vol(SPX)_{t-2}$	-0.5606	-3.15***
β_{23}	$R(SHCOMP)_{t-1}$	0.0875	0.76	β_{20}	$Vol(SHCOMP)_{t-1}$	1.1152	10.41***
β_{24}	$R(SHCOMP)_{t-2}$	0.1099	0.99	β_{20}	$Vol(SHCOMP)_{t-2}$	-0.1323	-1.21
β_{20}	Constant	-0.0003	-0.05	β_{20}	Constant	0.2700	0.18

Note: *, **, and *** indicate significance at the 10, 5, 1 percent levels, respectively.

<u>Table 3</u> Causal relation for returns and volatilities in between TED spread, US and global market indices

This table reports the Granger causality tests on the relationships between TED spreads, U.S. market returns, and global market returns. The Wald statistics are computed to test whether the hypothesis (that *x* does not Granger-cause *y*) can be rejected. Panel A reports the pair relationship between returns in the U.S. market index (SPX) and the global stock market indices. Panel B reports the trivariate relationship between TED spreads and returns in the U.S. market index (SPX) and the global stock market indices.

<u>Panel A</u> Causal relation between SPX and global stock indices

Before Crisis		During Crisis	
	Wald Test (Chi^2)		Wald Test (Chi^2)
U.S. vs. U.K.			
R(SPX) Granger causes R(UKX)	0.6243	R(SPX) Granger causes R(UKX)	20.627***
R(UKX) Granger causes R(SPX)	0.9082	R(UKX) Granger causes R(SPX)	10.299***
U.S. vs. Hong Kong			
R(SPX) Granger causes R(HSI)	7.3955**	R(SPX) Granger causes R(HSI)	11.186***
R(HSI) Granger causes R(SPX)	1.5665	R(HSI) Granger causes R(SPX)	1.2939
U.S. vs. Japan			
R(SPX) Granger causes R(NKY)	3.2213	R(SPX) Granger causes R(NKY)	8.3995***
R(NKY) Granger causes R(SPX)	4.8322*	R(NKY) Granger causes R(SPX)	2.8346
U.S. vs. Australia			
R(SPX) Granger causes R(AS51)	12.543***	R(SPX) Granger causes R(AS51)	18.972***
R(AS51) Granger causes R(SPX)	4.3681	R(AS51) Granger causes R(SPX)	4.8832*
U.S. vs. Russia			
R(SPX) Granger causes R(RTSI)	0.0852	R(SPX) Granger causes R(RTSI)	9.1676***
R(RTSI) Granger causes R(SPX)	0.3343	R(RTSI) Granger causes R(SPX)	5.9311**
U.S. vs. China			
R(SPX) Granger causes R(SHCOMP)	1.3680	R(SPX) Granger causes R(SHCOMP)	9.9830***
R(SHCOMP) Granger causes R(SPX)	2.7866	R(SHCOMP) Granger causes R(SPX)	2.8548

Note: *, **, and *** indicate significance at the 10, 5, 1 percent levels, respectively.

Panel B Trivariate relation between TED spread, US and global market indices

Before Crisis	Wald Test (Chi^2)	During Crisis	Wald Test (Chi^2)
TED spread vs. U.S. vs. U.K.			
TED spread Granger causes R(SPX)	2.5182	TED spread Granger causes R(SPX)	9.3567***
TED spread Granger causes R(UKX)	0.6790	TED spread Granger causes R(UKX)	15.471***
R(SPX) Granger causes TED spread	3.0964	R(SPX) Granger causes TED spread	2.9008
R(UKX) Granger causes TED spread	3.1027	R(UKX) Granger causes TED spread	3.1610
TED spread vs. U.S. vs. Hong Kong			
TED spread Granger causes R(SPX)	1.9657	TED spread Granger causes R(SPX)	4.0038
TED spread Granger causes R(HSI)	0.7064	TED spread Granger causes R(HSI)	0.9049
R(SPX) Granger causes TED spread	3.3939	R(SPX) Granger causes TED spread	3.3929
R(HSI) Granger causes TED spread	4.6475*	R(HSI) Granger causes TED spread	0.7132
TED spread vs. U.S. vs. Japan			
TED spread Granger causes R(SPX)	2.6189	TED spread Granger causes R(SPX)	5.8962**
TED spread Granger causes R(NKY)	1.0402	TED spread Granger causes R(NKY)	10.588***
R(SPX) Granger causes TED spread	2.0838	R(SPX) Granger causes TED spread	2.1616
R(NKY) Granger causes TED spread	4.0263	R(NKY) Granger causes TED spread	7.0993**
TED spread vs. U.S. vs. Australia			
TED spread Granger causes R(SPX)	2.4177	TED spread Granger causes R(SPX)	4.652*
TED spread Granger causes R(AS51)	0.3185	TED spread Granger causes R(AS51)	7.4749***
R(SPX) Granger causes TED spread	2.3597	R(SPX) Granger causes TED spread	5.2032*
R(AS51) Granger causes TED spread	3.8185	R(AS51) Granger causes TED spread	1.0523
TED spread vs. U.S. vs. Russia			
TED spread Granger causes R(SPX)	3.2943	TED spread Granger causes R(SPX)	4.7862*
TED spread Granger causes R(RTSI)	2.878	TED spread Granger causes R(RTSI)	17.799***
R(SPX) Granger causes TED spread	1.7617	R(SPX) Granger causes TED spread	2.6165
R(RTSI) Granger causes TED spread	7.8491**	R(RTSI) Granger causes TED spread	0.0873
TED spread vs. U.S. vs. China			
TED spread Granger causes R(SPX)	3.6244	TED spread Granger causes R(SPX)	0.9934
TED spread Granger causes R(SHCOMP)	0.1690	TED spread Granger causes R(SHCOMP)	2.0717
R(SPX) Granger causes TED spread	2.0965	R(SPX) Granger causes TED spread	4.7006
R(SHCOMP) Granger causes TED spread	0.4280	R(SHCOMP) Granger causes TED spread	3.5015

Note: *, **, and *** indicate significance at the 10, 5, 1 percent levels, respectively.

Table 4 Cointegrating relation of US and global market indices

This table reports the VECM takes the form as the following equation.

$$\Delta y_t = v + \Pi\, y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i\, \Delta y_{t-i} + \varepsilon_t \qquad \text{where} \qquad \Pi = \sum_{j=1}^{j=p} Aj - I_k \ \text{ and } \ \Gamma_i = -\sum_{j=i+1}^{j=p} Aj \qquad (3)$$

y_t is a $K\times 1$ vector of variables, v is a $K\times 1$ vector of parameters, and ε_t is a $K\times 1$ vector of disturbances with mean 0 and covariance matrix Σ. Engle and Granger (1987) show that if the variables y_t are $I(1)$ the matrix Π has rank $0 \le r \le K$, where r is the number of cointegrating vectors. If the variables cointegrate, $0 \le r \le K$ and Equation (4) shows that a VAR in the first-difference is misspecified because it omits the lagged level term Πy_{t-1}. Assume that Π has a reduced rank $0 < r < K$ so that it can be expressed as $\Pi = \alpha\beta'$, where α and β are both K times r matrices of rank r. Using the above cointegrating equation, the parameters of the cointegrating VECM are estimated for the time-series of the log of S&P500 index of USA and log of global market indices (which are all shown to have unit root and integrated with the same order). The parameters of cointegrating VECMs for the interrelationships between log of S&P500 index of USA and log of global market indices include: (i) the parameters in the cointegrating equations β; (ii) the adjustment coefficient.

	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
SPX	-0.034	1.19	1	.	0.035	0.28	1	.
UKX	0.010	0.32	-0.812***	8.38	0.192	1.60	-1.314***	19.68
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
SPX	-0.061	0.038	1	.	-0.093	1.29	1	.
HSI	0.098	0.050	-0.584***	17.51	0.086	1..02	-0.859***	10.92
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
SPX	0.002	0.09	1	.	-0.144	1.51	1	.
NKY	0.070*	2.28	-0.582***	7.20	0.045	0.41	-0.894***	16.06
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
SPX	-0.016	0.71	1	.	-0.091	0.87	1	.
AS51	0.042*	2.24	-0.507***	8.34	0.051	0.57	1.045***	11.37
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
SPX	-0.035*	1.82	1	.	0.119*	1.77	1	.
RTSI	0.032	0.66	-0.263***	5.61	0.026	0.20	-0.433***	7.71
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
SPX	-0.001	0.07	1	.	-0.101	2.78	1	.
SHCOMP	0.371**	2.72	0.099	0.55	-0.007	0.15	-0.622***	5.01

Note: *, **, and *** indicate significance at the 10, 5, 1 percent levels, respectively.

Table 5 Trivariate cointegrating relation of US Ted Spread, US and global market indices

This table reports the VECM takes the form as the following equation.

$$\Delta y_t = v + \Pi\, y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i\, \Delta y_{t-i} + \varepsilon_t \quad \text{where} \quad \Pi = \sum_{j=1}^{j=p} Aj - I_k \quad \text{and} \quad \Gamma_i = -\sum_{j=i+1}^{j=p} Aj \qquad (3)$$

y_t is a $K\times1$ vector of variables, v is a $K\times1$ vector of parameters, and ε_t is a $K\times1$ vector of disturbances with mean 0 and covariance matrix Σ. Engle and Granger (1987) show that if the variables y_t are $I(1)$ the matrix Π has rank $0 \le r \le K$, where r is the number of cointegrating vectors. If the variables cointegrate, $0 \le r \le K$ and Equation (4) shows that a VAR in the first-difference is mis-specified because it omits the lagged level term Πy_{t-1}. Assume that Π has a reduced rank $0 < r < K$ so that it can be expressed as $\Pi = \alpha\beta'$, where α and β are both K times r matrices of rank r. Using the above cointegrating equation, the parameters of the trivariate cointegrating VECM are estimated for the time-series of the TED spread, log of SPX(US) index of USA and log of global market indices (which are all shown to have unit root and integrated with the same order). The parameters of cointegrating VECMs for the interrelationships between log of S&P index of USA and log of global market indices include: (i) the parameters in the cointegrating equations β; (ii) the adjustment coefficient. Panel A reports the cointegrating relation of US TED spread and the log of global market indices. Panel B reports the cointegrating relation of the log of SPX (US) and the log of global market indices.

Panel A	**Before Crisis**				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	-0.163***	-4.53	1	.	-0.196***	-3.88	1	.
SPX	0.002	0.17	.	.	-0.011	-1.47	.	.
UKX	0.016	1.24	-0.716***	-6.37	-0.007	-0.90	-0.230	-0.27
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	-0.131***	-4.05	1	.	0.144***	-3.29	1	.
SPX	0.005	0.45	.	.	-0.009	-1.28	.	.
HSI	0.035*	2.41	-0.469***	-5.24	-0.007	-0.88	-0.281	-0.41
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	-0.136***	-4.11	1	.	-0.134**	-2.61	1	.
SPX	0.010	0.91	.	.	-0.007	-0.88	.	.
NKY	0.023	1.39	-0.494***	-5.23	-0.018*	-2.09	-0.146	-0.24
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	-0.175***	-4.84	1	.	-0.129**	-3.03	1	.
SPX	0.002	0.18	.	.	-0.010	-1.46	.	.
AS51	0.001	0.05	0.531***	-7.32	-0.004	-0.62	-0.374	-0.47
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	-0.153***	-4.32	1	.	-0.150***	-3.38	1	.
SPX	0.006	0.51	.	.	-0.007	-1.12	.	.
RTSI	0.030	1.51	-0.228***	5.15	-0.003	-0.44	-0.074	0.21
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	-0.161***	-3.73	1	.	-0.814***	-5.44	1	.

SPX	0.022	0.70	.	.	-0.217***	-4.13	.	.
SHCOMP	0.026	0.36	-18.170*	-2.38	-0.355***	-3.93	0.971***	4.76

Note: *, **, and *** indicate significance at the 10, 5, 1 percent levels, respectively.

Panel B	**Before Crisis**				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	-0.025	-0.30	.	.	1.606*	1.65	.	.
SPX	-0.031	-1.07	1	.	0.149	1.01	1	.
UKX	0.017	0.56	-0.181***	-8.30	0.269*	1.92	-1.276***	-20.36
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	0.158	1.41	.	.	0.709	1.52	.	.
SPX	0.057	-1.47	1	.	-0.071	-0.98	1	.
HSI	0.087*	1.74	-0.585***	-18.66	0.102	1.18	0.854***	-10.98
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	0.098	1.57	.	.	0.109	0.16	.	.
SPX	0.001	0.06	1	.	-0.124	-1.21	1	.
NKY	0.060*	1.93	-0.588***	-7.31	0.118	1.04	-0.915***	-16.77
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	-0.022	-0.33	.	.	0.599	0.90	.	.
SPX	-0.015	-0.63	1	.	-0.094	-0.87	1	.
AS51	0.042*	2.20	0.509***	-8.25	0.056	0.60	1.009***	-12.75
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	0.085	1.48	.	.	-0.639	1.48	.	.
SPX	0.034*	1.75	1	.	-0.106	1.59	1	.
RTSI	0.021	0.42	-0.265***	5.59	0.098	0.81	-0.452***	7.35
	Before Crisis				**During Crisis**			
Variables	Adjustment (α)	Z value	Cointegrating (β)	Z value	Adjustment (α)	Z value	Cointegrating (β)	Z value
Ted Spread	0.145***	3.75	.	.	-0.426	-0.59	.	.
SPX	0.019	-0.67	1	.	-1.127***	-4.45	1	.
SHCOMP	-0.021	-0.32	-20.295*	-2.39	-0.027	-0.06	-0.473***	-11.55

Note: *, **, and *** indicate significance at the 10, 5, 1 percent levels, respectively.

Table 6 Impulse Response Analysis of US Ted Spread, US and global market indices

This table reports the impulse response function of a particular market due to price shocks from (i) TED spread to global market indices (ii) SPX(US) to global market indices, and (iii) global market indices to SPX(US) for 4-week ahead (Panel A) and 12-week ahead (Panel B) horizons.

Panel A: 4-week ahead impulse response

(1) Market	(2) Period	(3) TED Spread [Impulse from (3) Response to (1)]	(4) SPX [Impulse from (4) Response to (1)]	(5) SPX [Impulse from (1) Response to (5)]
TED Spread				
	Pre-crisis	---	---	-0.127
	During-crisis	---	---	-2.253
UKX				
	Pre-crisis	0.157	1.116	-0.059
	During-crisis	-2.054	3.202	-1.150
HSI				
	Pre-crisis	0.215	1.101	-0.018
	During-crisis	-2.746	3.630	-3.126
NKY				
	Pre-crisis	0.333	1.170	-0.201
	During-crisis	-3.293	3.353	-0.808
AS51				
	Pre-crisis	-0.106	0.819	-0.158
	During-crisis	-2.007	2.765	-0.656
RTSI				
	Pre-crisis	0.649	1.283	-0.001
	During-crisis	-5.582	5.538	0.530
SHCOMP				
	Pre-crisis	1.970	4.277	0.090
	During-crisis	-4.301	22.16	5.118

Panel B: 12-week ahead impulse response

(1) Market	(2) Period	(3) TED Spread [Impulse from (3) Response to (1)]	(4) SPX [Impulse from (3) Response to (1)]	(5) SPX [Impulse from (1) Response to (3)]
TED Spread				
	Pre-crisis	---	---	-0.063
	During-crisis	---	---	-2.404
UKX				
	Pre-crisis	0.319	1.102	-0.076
	During-crisis	-1.684	3.212	-1.221
HSI				
	Pre-crisis	0.689	1.098	-0.036
	During-crisis	-2.900	3.646	-0.148
NKY				
	Pre-crisis	0.541	1.142	-0.215
	During-crisis	-3.156	3.327	-0.684
AS51				
	Pre-crisis	-0.128	0.820	-0.175
	During-crisis	-1.892	2.761	-0.636
RTSI				
	Pre-crisis	1.142	1.230	-0.016
	During-crisis	-5.795	5.584	0.570
SHCOMP				
	Pre-crisis	2.568	3.519	-0.109
	During-crisis	-3.997	20.37	5.318

Figure 1. Time Series of weekly Ted Spread, S&P500 index of USA and global market Indices from 3rd January 2003 to 3rd April 2009