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The impact of the subprime financial crisis on stock index returns for high- and low-risk countries via CDS indices

Abstract

This study surveys the contagion effects extended by Longstaff (2010) and variance decomposition from the ABX index represented by the prices of the securitized CDOs to the CDS index in North America (referred to as the CDX-US index), and from the CDX-US index to stock indices in high-risk and low-risk countries during the pre-crisis and crisis periods. The empirical findings indicate that the variance decomposition and contagion effects from the lower-rated ABX index to the CDX-US indices is larger than those from the higher-rated ABX index to the CDX-US indices. The results of a causation test show that the CDX-US index spreads separately to stock markets in high-risk and low-risk countries, conforming to the view that CDS markets lead stock markets, as addressed by Norden and Weber (2004). Since the development period, there is a larger degree of components of the variance from the CDX-US indices to the stock indices in high-risk countries than in low-risk countries. Since the initial stage of the crisis, there are significant contagion effects between the CDX-US indices and stock markets where there are more significant contagion effects from the CDX-US indices to stock indices in high-risk countries than in low-risk countries. This study concludes that financial contagion spreads from stock markets in high-risk countries to those in low-risk ones. These results conform to the view that there is a major increase in shocks caused by financial crises in high-risk countries, as described by Radelet and Sachs (1998) and Kaminsky (2003).

Keywords: subprime crisis, ABX index, contagion effects, variance decomposition, causation, country risk.
JEL Classification: C22, C58, F21, G11, G15, G32, G38.

Introduction

Starting in late 2000, the Federal Reserve Board (hereinafter Fed) initiated a series of interest rate cuts. This action, along with a loose monetary policy, led to a booming housing market, but at the same time suppressed the profits of financial institutions. The more relaxed credit-checking policy and loan approval process eventually had a negative impact on the property market, resulting in a bubble in the housing market[1]. The Fed initiated a wave of interest rate increases begins in June 2004[2]. Thus, real property prices responded with dramatic drops, which left many of the subprime borrowers who took out loans to buy their previously-expensive houses incapable of making their repayments, leading to a large number of defaults and foreclosures[3]. Subprime loans and other indices were then packaged into derivatives such as collateralized debt obligations (CDOs), which were sold to markets all over the world. When defaults occurred along with falling realty prices, all investments relative to subprime loans and their derivatives were distressed, and the tremendous losses precipitated a global financial disaster. On February 7, 2007, the Europe's biggest bank, HSBC Holdings, blamed soured US subprime loans for its first-ever profit warning[4]. On March 16, 2008, the Fed came to the rescue of Bear Stearns, the fifth largest US bank, which required an infusion of emergency funds by JPMorgan Chase to make up for its lack of liquidity, only to be bought out later by JPMorgan Chase[5]. On September 15, 2008, Lehman Brothers filed for Chapter 11 bankruptcy, while Merrill Lynch agreed to sell itself to Bank of America[6]. To analyze the effects of shocks from the subprime market on global stock index returns via CDS indices, the relationships between contagion effects and variance decompositions are examined in the global high-and low-risk countries. Since CDO are mostly related to subprime asset-backed securities (ABS), we explore the relationship from CDO prices to global stock index returns for high- and low-risk countries via CDS indices.

An ABX index, used to measure CDO prices in relation to subprime asset-backed securities (ABS), consists of daily closing values for the home-equity CDOs of diverse credit ratings from their respective dealers[7]. The five ABX indices are reconstituted

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[1] The Fed funds rate fell from 6.5% to 1% as of the end of June 2003 where it remained for a year.

[2] As the Fed began to raise the interest rate in June 2004, the Fed funds rate rose from 1% to 5.25% within two years.

[3] The boom in the US housing market resulted in a steep rise in property prices and mortgage balances. As of the third quarter of 2008, the mortgage balance amounted to US$12 trillion. Via securitization, financial institutions sold mortgaged-backed securities (MBSs) amounting to US$7.5 trillion to global investors by repackaging MBSs into collateral debt obligations (CDOs).

[4] In the late 2006, the U.S. housing market slowed after two years of increases in official interest rates. Delinquencies rose, leading to a wave of bankruptcies.

[5] On September 18, 2007, the Fed's half-point interest rate cut triggered a spate of global interest rate cuts.

[6] On December 16, 2008, the Federal Funds Rate fell to 0-0.25%, talking the United States into an era of zero interest.

[7] ABX indices with five ratings of AAA, AA, A, BBB and BBB- (the tranches must be rated by Moody's and Standard and Poor's, where the lesser of the ratings applies) refer to the indicator for market quotations of a specific basket of CDOs of diverse credit ratings.

every six months, and each ABX index is a simple average of the prices of the twenty CDOs (or tranches) in the basket, where the prices are quoted relative to a $100 notional position[1]. A credit default swap (CDS) index is used as an important credit derivative to isolate credit risks of bonds or loans[2]. A CDS index is composed of more than a dozen of the most actively traded CDSs in the same class and with similar ratings, such as the North American CDS index, the emerging market CDS index, and the Europe, Asia, and Australia iTraxx indices. It monitors the default risks of all the corporate bonds included in its adopted indices[3]. A CDX-US index measures the CDS prices of North American corporate bonds and serves as the benchmark of the markets' credit risks, as it is well standardized, liquid, and efficient, enabling hedging via efficient index updates and speedy electronic trading. According to the Depository Trust & Clearing Corporation (DTCC), the total of MBS-based CDSs fails to exceed 1%. Although a CDX-US index is not a direct indicator of subprime loans, it serves as the most important CDS index. A CDS index also measures credit and liquidity risks in financial environments and provides important information on the risks of credit, liquidity, and counterparties as well as forecasts[4]. Typically, to avoid CDO risks, an investor buying an ABX index is likely to purchase a CDS. Thus, any change in the ABX indices inevitably impacts the CDX-US indices representing global credit and liquidity risks.

The related studies on CDS market quotations and the pricing of stocks and bonds indicate that the CDS market performs the function of price discovery in the bond market[5]. Nonetheless, the leading position of the CDS market in relation to the stock market is still in doubt[6]. Therefore, this study will identify the leading position of the CDS market in regard to the stock market. Moreover, this study follows the definition of financial contagion proposed by Kaminsky, Reinhart, and Vegh (2003), Bae, Karolyi, and Stulz (2003), and many others who posit that after a shock occurs in one market, there is a significant increase in cross-market linkages, perhaps due to a significant increase or decrease in the correlation between the indices in financial markets[7]. Differing from the definition by Forbes and Rigobon (2002), a significant decrease in the correlation between the indices in financial markets can be regarded as a contagion effect. Kim and Ying (2007) indicated that open financial markets accelerate financial shocks[8]. Empirical studies have identified cross-market contagion effects through the use of several methods, including cross-market correlation coefficients analysis, the GARCH model, cointegration analysis, and a vector auto-regression (VAR) framework[9]. By using the VAR framework, the empirical results derived by Longstaff (2010) showed that ABX index returns forecasted stock returns and Treasury and corporate bond yield changes by as much as three weeks during the subprime crisis[10].

Longstaff (2010) merely inquired whether there were contagion effects of ABX indices with diverse ratings on stock and bond markets. On the one hand, an investor buying an ABX index tends to purchase a CDS to avoid CDO-related risks. Nevertheless, the relatively few studies in the literature explore the relationship between the CDO and CDS markets. On the other hand, the findings of Norden and Weber (2004) indicate that the CDS market is the leading indicator in relation to the stock market. However, few studies use contagion effects to explore the correlation between the CDS and stock markets. Meanwhile, the contagion effect is used to analyze significant changes in the correlation between financial markets. Moreover, Kutan (2007) pointed out that the variance decomposition technique uses out-of-sample unit shocks to decompose the total forecasting error, rather than estimating the coefficients from within the sample. Therefore, this study has

[1] The AAA index is based on a portfolio of twenty subprime home-equity CDOs with initial credit ratings of AAA. The AA index is based on a portfolio of twenty subprime home-equity CDOs with initial credit ratings of AA. Likewise, the other three indices are based on portfolios of subprime home-equity CDOs with credit ratings of A, BBB and BBB-.

[2] A CDS transaction demands that a protection buyer shall pay periodically to a protection seller for payment of claims (credit payments) upon credit incidents stated in the contract.

[3] The enterprises in the index are updated semiannually (in March and September) to replace active members by deleting defaulting CDSs.

[4] The difference in interest rates measures the probability of defaults and the risk of counterparties. For instance, the changes in banking CDS differences indicate the level of financial shocks.

[5] The findings of Longstaff, Mithal, and Neis (2003) show that CDS and stock returns lead corporate bond yields. Zhu (2004) identified the CDS returns in the US and the EU as moving ahead of bond yields. By applying the VECM, Blanco, Brennan, and Marsh (2005) found that the CDS market moves ahead of the bond market.

[6] Norden and Weber (2004) discovered the leading position of the CDS market in relation to the stock market. Forte and Pena (2009) addressed the leading situation of the stock market in regard to the CDS market.

[7] The statistics from low to high values indicate the cross-market contagion effects whereas those from high to high represent the interdependence.

[8] The findings of Kutan (2007) show that when there are significant entry barriers (based on China-backed A shares and B shares), there is no evidence of contagion effects. However, when there are fewer entry barriers (based on H shares, red chips, and American Depository Receipts), the contagion effects are severe. It is suggested that increasing entry barriers serves as an effective tool in reducing contagion effects.

[9] The cross-market correlation coefficients analysis is used by Lee and Kim (1993) and Calvo and Reinhart (1995), the GARCH model is used by Hamao, Masulis, and Ng (1990), Edwards (1998) and Edwards and Susmel (2000), cointegration analysis is used by Chou, Ng, and Pi (1994) and Longui and Slonik (1995), and a vector autoregression (VAR) framework is used by Longstaff (2010).

[10] The results of Longstaff (2010) support the hypothesis that financial contagion was propagated primarily through liquidity and risk premium channels, rather than through a correlated information channel.

two parts in that it integrates the high correlation between the ABX and CDS indices with that between the CDS and stock indices. In section 1, we simultaneously inquire into the contagion effects and variance decomposition of the ABX indices on the CDS indices. In section 2, we explore the diffusion by using a similar technique involving the impact of CDS indices on high-risk and low-risk stock markets.

A country's risk level is based on its economic and political factors, and can exert tremendous impacts on that country's financial markets and investment environment. Generally speaking, variables relevant to significant impacts thereon refer to the import/export ratio, government deficit, ratio of money supply/foreign exchange reserves, foreign debt ratio, savings interest rate, the loans-deposits ratio, and the capital adequacy ratio. According to Krugman (1979), a crisis occurs when a nation attempts to alleviate its financial deficit through an expansionary monetary policy. In terms of Radelet and Sachs (1998), any inaccurate monetary policy, interest policy, and/or currency exchange policy made during the crisis period will only exacerbate the financial crisis; moreover, both short-term debt and foreign exchange reserves serve as indicators of the financial crisis[1]. Kaminsky, Reinhart, and Vegh (2003) point out that there are six types of currency crises that depict the fundamental vulnerability of an economy under discontinuous impacts from a current account deficit, excessive financing (extremely high foreign debt), and a financial deficit[2]. Thus, a comparatively high-risk country/region is likely to suffer greater damage and shock than other countries/regions when confronted with a financial crisis[3]. The latter part of this study uses the stock market indices of seven pairs of high-/low-risk countries structured by Merrill Lynch (2008) to analyze how the subprime crisis affected the stock markets through credit risk indices[4]. The countries are listed in Table 1.

Table 1. Ranking of country risk

Top Seven (high-risk countries)	Abbreviation	Bottom Seven (low-risk countries)	Abbreviation
Australia	AUS	Mexico	MEX
Switzerland	SWI	Philippines	PHI
Korea	KOR	Colombia	COL
Hungary	HUN	Indonesia	IND
Sweden	SWE	Peru	PER
United Kingdom	UK	Russia	RUS
United States	US	China	CHI

Source: Merrill Lynch (2008). Global Economics, Everything you've ever wanted to know about the world. For details see Table 4.

Building on the research of Longstaff (2010), this study aims to examine how the shocks of subprime-related financial indices during the subprime crisis were transmitted via credit risk indices, so as to affect the stock market indices in the global high-risk and low-risk countries in addition to the contagion effects. Contagion caused by the subprime crisis increased credit and liquidity risks. The causation of the CDX-US indices on the stock indices is identified; afterwards, the impulse response and contagion effects of the ABX indices on the CDX-US indices and CDX-US indices on the stock indices in the seven pairs of countries are assayed. The findings' conclusions are offered as a valuable reference to the government as it formulates financial risk policies, and to institutions and investors as they engage in investment strategies. Given these overall objectives, this study attempts to discuss the following hypotheses:

H_1: Does the CDX-US index spread shocks more readily to the stock indices in high-risk and low-risk countries in the subprime crisis period than in the pre-crisis period?

$H_{2\text{-}1}$: Is the CDX-US index more affected by changes in ABX index returns of various ratings in terms of variance decomposition in the subprime crisis period than in the pre-crisis period?

$H_{2\text{-}2}$: Is the CDX-US index more affected by changes in lower-rated ABX index returns than those in higher-rated ABX index returns in the subprime crisis period?

$H_{3\text{-}1}$: Are the variance decomposition ratios of the CDX-US index to the stock index returns in seven high-risk countries significantly greater in the subprime crisis period than in the pre-crisis period?

$H_{3\text{-}2}$: Are the variance decomposition ratios of the CDX-US index to the stock index returns of seven high-risk countries significantly greater than those to the stock index returns of seven low-risk countries in the subprime crisis period?

[1] The empirical results from Baharumshah, Masih, Mansur and Azali (2002) indicate that a currency rate manipulated by a governmental expansionary monetary policy is likely to impact the stock market by attracting hot money in the short term, but will only fail in the long run.

[2] According to Bernstein (1989), money depreciation results from overestimated domestic currency rates and deteriorating current accounts.

[3] The most direct way to evaluate a country's risks is to measure the volatility in its financial market, such as a sudden plummet in share prices, obvious volumes of foreign currency trading, and ongoing increases in net sales volume from foreign investments.

[4] Merrill Lynch (2008) lists 10 high-risk countries and 10 low-risk countries pursuant to seven country-risk variables known as: (1) the capital gap of current accounts; (2) the foreign exchange reserve/short-term foreign debt ratio; (3) the export/GDP ratio; (4) the credit loan/GDP ratio; (5) individual loan growth; (6) the loan-to-deposits ratio; and (7) the bank capital adequacy ratio. Nevertheless, only the data on stock indices of the 7 high-risk and the 7 low-risk countries are available.

$H_{4\text{-}1}$: Do the correlations of ABX indices of various ratings on the CDX-US index become significantly higher during the period of subprime crisis to discern whether a contagion effect exists between the pairs of CDO and CDS markets?

$H_{4\text{-}2}$: Are the contagion effects of lower-rated ABX indices more pronounced than those of higher-rated ABX indices in the subprime crisis period?

$H_{4\text{-}3}$: Do the correlations of the CDX-US index on the stock index returns in seven pairs of high-risk and low-risk countries become significantly higher in the subprime crisis period to discern whether a contagion effect exists between CDO and CDS market pairs?

$H_{4\text{-}4}$: Are the contagion effects of the CDX-US index return on the stock index returns in high-risk countries more pronounced than those on the stock index returns in low-risk countries?

$H_{4\text{-}5}$: Did the direction of contagion move from high-risk stock markets to low-risk stock markets in the subprime crisis period?

1. Methodology

1.1. Period and variables. *1.1.1. Period.* The data covers the period from when ABX indices became available on January 19, 2006, to September 30, 2009, when the subprime mortgage crisis came to the end. Thus, the time before 2007 refers to the pre-crisis period, and the time after 2007 refers to the crisis period. Since the Bear Stearns buyout and bankruptcy of Lehman Brothers took place on March 16, 2008, and September 15, 2008, respectively, the timeline of the crisis in this study is divided into three parts: the early stage (January 4, 2007 to March 13, 2008), the development stage (March 16, 2008 to September 12, 2008), and the outburst stage (September 15, 2008 to September 30, 2009).

1.1.2. ABX index. The data for the ABX indices were extracted from the daily closing values of ABX.HE 1, ABX.HE 2, ABX.HE 3 and ABX.HE 4, as disclosed by Reuters[1]. To integrate these four ABX indices into an overall ABX index, this study provides a unique sequence capable of fully disclosing specific terms by sequentially rolling the old version to the new one as employed by Longstaff (2010)[2].

1.1.3. CDS index. The CDS index used in this study is considered the major corporate-bond-related CDS index, and is the most loose investment-grade North-American CDX index (CDX-US) represented in this study[3]. Despite the total MBS-based CDS being less than 1% and the difficulty in obtaining the data relevant to ABX-based CDS indices in individual financial institutions, the proportion of corporate-bond-related CDS indices to total CDS indices is the highest. Moreover, CDS indices not only offer key information on global credit and liquidity risks in financial environments, but also have reliable forecasting power. Any changes in the CDS returns shed light on the impact of financial turbulence in global financial markets. Thus, changes in corporate-bond CDS indices before and after the subprime crisis are employed to determine how the subprime credit and liquidity risks affect the global financial markets. The duration of CDX-US indices is the most standardized five-year term, and the data come from the daily closing values as provided by Bloomberg.

1.1.4. Stock indices of seven pairs of high-risk and low-risk countries. The daily stock closing indices in seven pairs of high-risk and low-risk countries with complete trading data listed in a report on country risks released by Merrill Lynch in 2008 are used to examine how the subprime crisis affected stock indices in seven country pairs via credit risk indices. All data are obtained from Datastream.

1.2. Vector auto-regression (VAR) model. To clarify whether information traders exercise a flight to quality or actually participate in the CDX-US market, this study assays whether a CDX-US index has leading information in contrast to a stock index in the process of price discovery. Hence, this study employs a bivariate VAR model to test CDX-US index returns and stock index returns in high-risk or low-risk-country stock index returns, and also performs a Granger causality test on the pre-crisis period and the crisis period. A Granger causality test is used to infer whether the CDX-US index separately spread shocks to stock indices in high-risk and low-risk countries during the crisis period.

[1] The data for ABX.HE 1 on five credit ratings of AAA, AA, A, BBB and BBB- refer to the daily closing values of ABX indices from January 19, 2006 to August 30, 2009. The data for ABX.HE 2 on five credit ratings refer to the daily closing values of ABX indices from July 19, 2006 to September 30, 2009. The data for ABX.HE 3 on five credit ratings refer to the daily closing values of ABX indices from January 19, 2006 to September 30, 2009. The data for ABX.HE 4 on five credit ratings refer to the daily closing values of ABX indices from July 19, 2006 to September 30, 2009.

[2] An integrated ABX index via rolling refers to the daily closing values of ABX.HE 1 obtained on January 19, 2006 and those of ABX.HE 2 obtained on June 19, 2006; likewise, the data for ABX.HE 3 and ABX.HE 4 were obtained on January 19, 2007 and July 19, 2007, respectively.

[3] CDX. NA.IG Index.

We then calculate the percentage of forecasting error variance decomposition by a VAR model and therefore judge the cross-variate relative explanation. Kutan (2007) proposed that the advantage of using the variance decomposition procedure was that the endogeneity problem in the local and foreign returns might be determined simultaneously[1]. The percentage of forecasting error variance decomposition in this study explains the relationships between the ABX index returns of diverse ratings and CDX-US index returns and those between CDX-US index returns and stock index returns in high-risk or low-risk countries, demonstrating whether a variable is under its own impact (powerful exogenous variables) or under the impact of other variables[2].

1.3. Contagion effects. This study extends the correlation framework transmitted between market returns proposed by Longstaff (2010) to survey whether there were contagion effects of ABX index returns of a certain credit rating on CDX-US index returns during the subprime crisis period, and to investigate whether there were contagion effects of the CDX-US index returns on stock index returns of seven pairs of high-/low-risk countries during the crisis period. This study separately integrates a GJR-GARCH model with a residual under the AR approach to capture the time-series heterogeneity of the volatile residual returns under daily intervals, and asymmetric volatility under the negative news in connection with the subprime crisis. Also, in analyzing the correlation of a CDX-US index on seven pairs of stock indices, we use the AR model rather than the VAR model, as there was only one CDX-US index. By controlling for the lagged CDX-US index returns, the spillover effects of the ABX index of a certain rating on the CDX-US index are tested. Then, by controlling for the stock index returns of seven pairs of high-/low-risk countries, the spillover effects of the CDX-US index on the stock index returns of seven pairs of countries are tested. When dealing with contagion effects, we focus on the coefficients of the dummy variables before and after the subprime crisis through estimation to differentiate the impact of the ABX indices of various ratings on the CDX-US index and that of the CDX-US index on the stock indices of the seven pairs prior to and following the onset of the crisis. Furthermore, this study surveys whether most of the stock indices in the high-risk countries are contagious in relation to the stock indices in the low-risk countries. We separately estimate the AR-GJR-GARCH model from a different ABX index to the CDX-US index, from the CDX-US index to a different stock index of a high-risk country (or low-risk country) and from a different stock index of a high-risk country to a different stock index of a low-risk country. These AR-GJR-GARCH models are as follows:

1. Are there contagion effects from ABX indices to the CDX-US index?[3]

$$\Delta CDX_t = \alpha_0 + \sum_{i=1}^{q} \alpha_{1,i} \Delta CDX_{t-i} + \alpha_{2,i} I_{pre} \Delta ABX_{t-i}^m + \alpha_{3,i} I_{post} ABX_{t-i}^m + \varepsilon_t ,$$

$$h_t = \phi_0 + \phi_1 \varepsilon_{t-1}^2 + \phi_2 h_{t-1} + \phi_3 \varepsilon_{t-1}^2 I_{t-1} ,$$

$$\begin{cases} I_{t-1} = 1, if\ \varepsilon_{t-1} < 0 \\ I_{t-1} = 0, if\ \varepsilon_{t-1} \geq 0 . \end{cases} \tag{1}$$

2. Are there contagion effects from the CDX-US index to the stock indices of seven pairs of countries?[4]

$$\Delta P_t^s = \beta_0 + \sum_{i=1}^{q} \beta_{1,i} \Delta P_{t-i}^s + \beta_{2,i} I_{pre} \Delta CDX_{t-i} + \beta_{3,i} I_{post} \Delta CDX_{t-i} + \varepsilon_{s,t} ,$$

$$h_{s,t} = \delta_0 + \delta_1 \varepsilon_{s,t-1}^2 + \delta_2 h_{s,t-1} + \delta_3 \varepsilon_{s,t-1}^2 I_{s,t-1} ,$$

[1] This is because the variance decomposition approach is based on a vector autoregressive (VAR) model, allowing us to control for structural relationships in the data (Dornbusch, Park, and Claessens, 2000).

[2] The forecasting error variance decomposition measures the impact of each variable and others on the forecasting error variance.

[3] In equation (1), ΔCDX_t represents CDX-US index returns, while ΔABX_t^m represents ABX index returns of credit rating m. I_{pre} is a dummy variable with the value of 1 before the crisis and 0 otherwise. I_{post} is a dummy variable with a value of 1 after the crisis occurs and 0 otherwise. h_t is a conditional variance of CDX-US index returns.

[4] In equation (2), ΔP_t^s represents stock index returns of seven pairs of high-low-risk countries, respectively, while ΔCDX_t represents CDX-US index returns. The statement of dummy variables is the same as that in footnote 4 on page 125. $h_{s,t}$ is a conditional variance of stock index returns, and $h_{l,t}$ is a conditional variance of stock index returns of low risk countries.

$$\begin{cases} I_{s,t-1} = 1, if\ \varepsilon_{s,t-1} < 0 \\ I_{s,t-1} = 0, if\ \varepsilon_{s,t-1} \geq 0 . \end{cases} \quad (2)$$

3. Are there contagion effects from the stock indices in the high-risk countries to the stock indices in the low-risk countries?

$$\Delta P_t^l = \gamma_0 + \sum_{i=1}^{q} \gamma_{1,i} \Delta P_{t-i}^l + \gamma_{2,i} I_{pre} \Delta P_{t-i}^h + \gamma_{3,i} I_{post} \Delta P_{t-i}^h + \varepsilon_{l,t} ,$$

$$h_{l,t} = \rho_0 + \rho_1 \varepsilon_{l,t-1}^2 + \rho_2 h_{l,t-1} + \rho_3 \varepsilon_{l,t-1}^2 I_{l,t-1} ,$$

$$\begin{cases} I_{l,t-1} = 1, if\ \varepsilon_{l,t-1} < 0 \\ I_{l,t-1} = 0, if\ \varepsilon_{l,t-1} \geq 0 . \end{cases} \quad (3)$$

Following the method of Longstaff (2010), the Akaike AIC criterion is used in the selection of lags. First, in equation (1), the coefficients $\alpha_{2,i}$ and $\alpha_{3,i}$ capture the relationships between the ABX index returns of *m* rating and the subsequent CDX-US index returns before and after the crisis, respectively. Then, in equation (2), the coefficients $\beta_{2,i}$ and $\beta_{3,i}$ capture the relationships between the CDX-US index returns and subsequent stock index returns of seven pairs of high-/low-risk countries before and after the crisis. If there were contagion effects between various ABX index returns (CDX-US index returns) and CDX-US index returns (stock index returns of seven pairs of countries) during the subprime crisis, we anticipate that the correlation becomes significantly higher after the crisis than before the crisis. Afterwards, we not only perform tests as to whether the t-values are zero on the coefficients $\alpha_{2,i}$ ($\beta_{2,i}$) and $\alpha_{3,i}$ ($\beta_{3,i}$), but also whether the F-values are jointly zero on coefficients $\alpha_{2,i}$ ($\beta_{2,i}$) and $\alpha_{3,i}$ ($\beta_{3,i}$), in order to analyze whether there is a significant difference in the correlation between various ABX index returns (CDX-US index returns) and CDX-US index returns (stock index returns of seven pairs of countries) during the crisis period as compared with the pre-crisis period. The coefficients $\alpha_{3,i}$ ($\beta_{3,i}$) become highly significant once the crisis began, providing clear evidence of an obvious increase in cross-market linkages for the CDO and CDS markets (CDS and stock markets). The results show that ABX indices (CDX-US indices) have significant forecasting power in relation to CDX-US indices (stock indices). Moreover, in equation (3), the coefficients $\gamma_{2,i}$ and $\gamma_{3,i}$ capture the relationships between the stock index returns in high-risk countries and the subsequent stock index returns in low-risk countries before and after the crisis. If many of the t-statistics and p-values of the stock indices in the high-risk countries on those in the low-risk countries reject the null hypothesis after the onset of the subprime crisis, most of the stock indices in the low-risk countries are significantly predictable by the high-risk countries once the crisis began.

2. Empirical results

2.1. The findings of summary statistics. Table 2 provides the results of summary statistics for the daily ABX index returns and CDX-US index returns. The ABX index returns of various ratings experienced larger negative returns in the crisis period than in the pre-crisis period. Among these ABX index returns, the largest negative returns occur in the initial period. The CDX-US index returns experienced larger negative returns in the development period than in the pre-crisis period. The volatilities of ABX index returns and CDX-US index returns were significantly higher in the crisis period than in the pre-crisis period. In sum, the highest volatilities occurred in the development period. However, the volatility of ABX index returns is not monotonically related to credit rating. The ABX BBB index was the most volatile index during the initial period, the ABX BBB-index was the most volatile index during the development period, while the ABX AAA index was the most volatile index during the outburst period.

Table 2 also shows that there were major changes in the relation among the different ABX index returns and the CDX-US index return during the sample period. During the pre-crisis period, the average correlation of returns across all ABX indices was 0.494. During the initial period, the measure increased to 0.660. The measure declined to 0.336 during the development period, but it increased to 0.634 during the outburst period, approximating its value during the initial period. The absolute value of the average correlation of CDX-US index returns increased during the crisis period. The value is the largest in the outburst period.

Table 2. Summary statistics of the daily ABX index and CDX-US index returns

Period		Mean	Std. dev	Min	Max	Correlation					
						AAA	AA	A	BBB	BBB-	CDX-US
Pre-crisis	AAA	-0.0008	0.0010	-0.1697	0.0499	1.0000					
	AA	-0.0005	0.0023	-0.3689	0.2091	0.7095	1.0000				
	A	-0.0036	0.0028	-0.2696	0.1710	0.4653	0.5767	1.0000			
	BBB	-0.0125	0.0095	-0.8223	0.5388	0.1055	0.1866	0.5799	1.0000		
	BBB-	-0.0175	0.0108	-0.9022	0.5636	0.1385	0.1902	0.5969	0.8083	1.0000	
	CDX-US	-0.1353	0.1255	-5.9209	13.4065	0.0451	0.0435	-0.0168	-0.0760	-0.1628	1.0000
Initial	AAA	-0.2377	0.0910	-10.3522	6.4136	1.0000					
	AA	-0.5603	0.1765	-18.8504	10.2070	0.8316	1.0000				
	A	-0.6597	0.1973	-16.8303	17.6675	0.7345	0.8230	1.0000			
	BBB	-0.7493	0.2023	-19.8701	17.6720	0.5253	0.6026	0.6615	1.0000		
	BBB-	-0.7527	0.1905	-15.6278	11.1939	0.4459	0.5039	0.5842	0.8895	1.0000	
	CDX-US	0.5204	0.2724	-20.5866	18.6126	-0.3277	-0.2855	-0.3046	-0.2383	-0.2591	1.0000
Development	AAA	-0.0572	0.1522	-4.5786	6.7506	1.0000					
	AA	-0.6047	0.2759	-15.6671	7.6200	0.6283	1.0000				
	A	-0.5882	0.2521	-14.9181	6.2226	0.3185	0.3659	1.0000			
	BBB	-0.7296	0.2434	-8.0882	6.2153	0.1502	0.2800	0.2288	1.0000		
	BBB-	-0.7366	0.2788	-9.8556	5.4067	0.0912	0.3676	0.2117	0.7206	1.0000	
	CDX-US	-0.1677	0.3957	-20.5866	13.0462	-0.3711	-0.3212	-0.1158	-0.0518	0.0575	1.0000
Outburst	AAA	-0.2071	0.2124	-15.9879	17.2713	1.0000					
	AA	-0.4030	0.2080	-27.1867	17.3715	0.6489	1.0000				
	A	-0.3279	0.1529	-19.0751	7.1036	0.4645	0.7430	1.0000			
	BBB	-0.2436	0.1117	-12.5726	5.2736	0.4454	0.7076	0.6422	1.0000		
	BBB-	-0.2335	0.1076	-14.9666	5.0644	0.4338	0.7009	0.6681	0.8822	1.0000	
	CDX-US	-0.1656	0.2903	-21.3037	25.2282	-0.5227	-0.3378	-0.2451	-0.3051	-0.3063	1.0000

2.2. Causal test. Panel A in Table 3 shows that there are significant lead-lag relations from the US stock to CDX-US indices and from the CDX-US to stock indices in the 6 other high-risk countries where there are significant two-way influences between stock indices in Australia, Switzerland, the UK and CDX-US indices in the pre-crisis period. During the crisis period, there were significant lead-lag relations from the CDX-US to stock indices in all high-risk countries, where there are significant two-way influences between stock indices in the UK, the US and CDX-US indices. Panel B in Table 3 shows that there were significant lead-lag relations from the CDS-US to stock indices in Columbia, Peru, the Philippines, and Russia, which are also known as the four low-risk countries, during the pre-crisis and crisis periods. During the crisis period, there were significant increasing lead-lag relations from the CDX-US to stock indices in China and from stock indices in Mexico to CDX-US indices. These results indicate that there were significant lead-lag relations from the CDX-US to stock indices in all high-risk countries during the crisis period, when there were significant increasing influences from the CDX-US to Chinese stock indices and from the Mexican stock to CDX-US indices. The findings above tend to support hypothesis H_1. That is, the CDX-US index spread shocks more readily to the stock indices in high-risk and low-risk countries in the subprime crisis period than in the pre-crisis period. This also verifies that there are significant lead-lag returns from the CDX-US indices to stock indices following the onset of the subprime crisis as compared with pre-crisis period, which is consistent with the view that the CDS markets lead the stock markets, as mentioned by Norden and Weber (2004).

Table 3. Results of Granger causality test between the CDX-US index and stock index in high-risk and low-risk countries

Panel A. High-risk countries								
Items		AUS	SWI	KOR	HUN	SWE	UK	US
Before	1	13.8868 (0.0000)	3.05765 (0.0493)	7.72929 (0.0006)	7.97940 (0.0005)	3.29597 (0.0391)	6.00129 (0.0030)	0.25316 (0.7766)
	2	2.86775 (0.0593)	3.08176 (0.0482)	0.67390 (0.5109)	0.15301 (0.8582)	1.63172 (0.1983)	5.16643 (0.0065)	2.80645 (0.0629)
During	1	34.8489 (0.0000)	5.20872 (0.0057)	16.5782 (0.00000)	3.68906 (0.0256)	6.32251 (0.0019)	5.19357 (0.0058)	4.60671 (0.0915)
	2	1.42989 (0.2402)	2.06622 (0.1276)	0.66166 (0.5164)	0.53383 (0.5867)	0.79879 (0.4504)	2.39770 (0.0919)	5.17999 (0.0059)

Table 3 (cont.). Results of Granger causality test between the CDX-US index and stock index in high-risk and low-risk countries

Panel B. Low risk countries								
Items		MEX	COL	IND	PER	PHI	RUS	CHI
Before	1	0.99060 (0.3734)	18.3115 (0.0000)	0.49658 (0.6095)	8.16975 (0.0004)	2.5765 (0.0789)	5.05136 (0.0074)	1.70300 (0.1851)
	2	1.06519 (0.3469)	0.39604 (0.6736)	0.53354 (0.5875)	1.16920 (0.3130)	0.87048 (0.4206)	1.98167 (0.1409)	1.76406 (0.1744)
During	1	2.17520 (0.1147)	19.9274 (0.0000)	1.62614 (0.1978)	5.12582 (0.0063)	4.34511 (0.0135)	2.54632 (0.0989)	14.1376 (0.0000)
	2	3.01739 (0.0498)	2.23988 (0.1076)	0.01024 (0.9898)	0.80605 (0.4472)	0.12283 (0.8844)	0.47591 (0.6216)	0.83404 (0.4349)

Notes: The numbers in parentheses are p-values. The data period before the subprime crisis is from January 19, 2006 to December 29, 2006, and the data period during the subprime crisis is from January 4, 2007 to September 30, 2009. Row 1 comprises the t-statistics (p-values) of the causality test from the CDX-US index to the stock index in high- or low-risk, and row 2 comprises the t-statistics (p-values) of the causality test from the stock index in high- or low-risk countries to the related CDX-US index.

2.3. Variance decomposition from ABX to CDX-US indices. Table 4 reports the altering percentages of variance decomposition for the ABX and CDX-US returns during the pre-crisis and crisis periods[1]. During the pre-crisis period, the percentage of the variance of CDX-US index returns from an own impulse is the largest and there is only a decrease of 22.11% of the variance of CDX-US index returns as time increases. In the development stage, there is a decrease of 45.43%, from 75.95% to 30.517%, along with increasing ratios from the various ABX index returns as time increases. This result shows that the CDX-US index was more susceptible to changes in ABX index returns of various ratings in the subprime crisis period than in the pre-crisis period, which supports hypothesis $H_{2\text{-}1}$. In the development and outburst period, the lower-rated ABX index returns enjoyed a larger increase than the higher-rated ABX index returns after 30 days (in 30 days, for example, an increase of 28.00% and 14.72% in the BBB- and BBB ratings, respectively, in the development period; an increase of 37.47% and 7.67% in the BBB- and BBB rating, respectively, in the outburst period). In sum, the largest ratio increases of the variance of CDX-US index returns from the BBB- and BBB rated ABX index returns in 30 and 45 days occured in the development and outburst periods, which is partly consistent with hypothesis $H_{2\text{-}2}$.

Table 4. Results of variance decomposition for CDX-US index returns

Panel A. Pre-crisis					
10 days		30 days		45 days	
Own	95.42%	Own	86.55%	Own	73.31%
A	2.39%	BBB-	3.45%	BBB-	11.84%
AA	0.97%	BBB	3.45%	BBB	7.26%
BBB	0.79%	AAA	3.15%	AAA	3.03%
AAA	0.26%	AA	1.53%	AA	1.70%
BBB-	0.16%	A	1.87%	A	2.87%
Panel B. Development					
Own	75.95%	Own	37.13%	Own	30.52%
A	6.83%	BBB-	28.00%	BBB-	20.53%
AA	5.84%	BBB	14.72%	BBB	17.74%
BBB	5.06%	AAA	10.10%	AAA	14.34%
AAA	3.16%	AA	6.61%	AA	11.49%
BBB-	3.17%	A	3.44%	A	5.39%
Panel C. Outburst					
Own	57.64%	Own	39.16%	Own	29.40%
A	24.46%	BBB-	37.47%	BBB-	28.40%
AA	6.93%	BBB	7.67%	BBB	16.92%
BBB	3.83%	AAA	6.55%	AAA	15.29%

[1] In terms of the crisis, this study just shows the results of variance decomposition from the ABX to CDX-US returns in the development and outburst periods, since there are no significant changes in variance decomposition during the pre-crisis and initial periods.

Table 4 (cont.). Results of variance decomposition for CDX-US index returns

10 days	30 days	45 days	10 days	30 days	45 days
AAA	3.81%	AA	6.47%	AA	5.42%
BBB-	3.33%	A	2.69%	A	4.57%

2.4. Variance decomposition from CDX-US to stock indices in high-risk and low-risk countries. Panels A and B in Table 5 report the changing percentages of variance decomposition from the CDX-US index returns to the stock returns in the high-risk and low-risk countries during the pre-crisis and crisis periods[1]. During the pre-crisis period, there was a smaller percentage of the variance of stock index returns in the high-risk countries from the CDX-US index returns, but the percentage gradually increased with time[2]. In comparing the development period against the pre-crisis period, there are increasing percentages of variance from the CDX-US index returns to the stock index returns in the high-risk countries and the percentage increased over time. In the outburst stage, there was a decrease in the variance from the CDX-US index returns to the stock index returns in Australia, Switzerland, Hungary, and the UK, whereas there was an increase in variance from the CDX-US index returns to the stock index returns in Korea, Sweden, and the US. Overall, this finding is partly consistent with hypothesis $H_{3\text{-}1}$. That is, the stock index returns in the seven high-risk countries can be more readily explained by the CDX-US indices in the development period than in the pre-crisis period. However, during the pre-crisis period, there was a smaller percentage of variance from the CDX-US index returns to the stock index returns in the low-risk countries, but the percentage gradually increased with time[3]. In the development period, there was a smaller ratio of variance from the CDX-US to stock index returns in the low-risk countries than in the high-risk countries. These results indicate that the CDX-US index returns exert a larger effect on the stock index returns in the high-risk countries than on those in the low-risk countries in the development period. This finding is partly consistent with hypothesis $H_{3\text{-}2}$. That is, the stock indices in the high-risk countries can be predicted more precisely by the CDX-US indices than those in the low-risk countries in the development period.

Table 5. Comparisons of variance decomposition for stock index returns in high-risk countries from CDX-US index returns

Panel A. High-risk countries															
		AUS		SWI		KOR		HUN		SWE		UK		US	
	Period	pre	during	pre	during	pre	during	pre	during	pre	during	pre	during	pre	during
Pre-crisis and development	10	0.149	23.7	0.38	5.112	0.849	21.32	2.023	57.96	0.261	35.11	0.397	43.14	0.413	45.24
	30	1.993	47	1.001	15.04	19.53	51.79	23.87	84.54	1.529	71.63	5.335	71.14	2.393	73.3
	45	5.996	52.26	2.967	16.18	40.43	60.36	41.74	87.55	4.473	77.55	12.2	75.04	6.811	76.83
Pre-crisis and outburst	10	0.149	0.229	0.38	0.382	0.849	21.56	2.023	2.776	0.261	17.39	0.397	1.915	0.413	6.653
	30	1.993	0.244	1.001	0.23	19.53	57.43	23.87	7.472	1.529	44.06	5.335	1.615	2.393	9.309
	45	5.996	0.247	2.967	0.414	40.43	65.31	41.74	9.671	4.473	51.17	12.2	1.47	6.811	10.39
Panel B. Low-risk countries															
		MEX		PHI		COL		IND		PER		RUS		CHI	
	Period	pre	during	pre	during	pre	during	pre	during	pre	during	pre	during	pre	during
Pre-crisis and development	10	0.939	1.283	0.21	0.964	0.175	4.083	3.85	6.765	0.039	1.178	0.558	0.793	1.753	0.304
	30	1.309	1.283	3.562	0.964	2.879	4.083	7.334	6.765	0.486	1.178	6.824	0.793	7.153	0.304
	45	4.116	1.283	8.681	0.964	5.604	4.083	7.971	6.765	1.469	1.178	13.67	0.793	13.5	0.304
Pre-crisis and outburst	10	0.939	4.686	0.21	1.001	0.175	1.627	3.85	0.578	0.039	0.86	0.558	4.822	1.753	0.508
	30	1.309	4.686	3.562	1.001	2.879	1.627	7.334	0.578	0.486	0.86	6.824	4.822	7.153	0.508
	45	4.116	4.686	8.681	1.001	5.604	1.627	7.971	0.578	1.469	0.86	13.67	4.822	13.5	0.508

2.5. Contagion effects. In the AR model, the result of the Akaike information criterion test indicates that the maximum lag number is 2. The results in Table 6 show that the χ^2 statistics of the joint tests do not attain a statistically significant level when the original residuals are included in the GJR-GARCH model, implying that the GJR-GARCH model can almost catch the asymmetric effect of positive and negative volatilities in the original residuals of the two index returns. The results for the separate ABX

[1] In terms of the crisis, this study just shows the results of variance decomposition from the CDX-US returns to the stock returns in the high-risk and low-risk countries in the development and outburst periods, since there are no significant changes in variance decomposition during the pre-crisis and initial periods.

[2] Among the countries listed, there is a major increase in variance in Korea and Hungary.

[3] Among the countries listed, there is a major increase in variance in both Russia and China.

and CDS index returns under the AR included in the GJR-GARCH model show no evidence of ARCH effects or error autocorrelation. The results of the F-tests for the relationships between the various ABX and CDX-US indices during the pre-crisis period as compared with the crisis period demonstrate that the ratio of acceptance of the null hypothesis $\alpha_{2,i} = 0$ and rejection of the null hypothesis $\alpha_{3,i} = 0$ is 100%, which means that there were indeed significant contagion effects from the ABX to CDX-US indices in the initial crisis period. Among the countries listed, the contagion effects are more significant from the lower-credit (A, BBB and BBB-) ABX to CDX-US indices. Table 6 reports that the second lagged values of the five ABX indices exhibit consistent and strong forecasting abilities for the CDX-US indices in the crisis stage. The t-statistics for the second lagged values of the five ABX indices on the CDX-US index range from -4.16 to -8.76. In other words, there is strong evidence that there was enough of a major increase in the cross-market linkages between the asset-backed CDO and CDS markets to enable significant contagion effects in the crisis period. This finding supports hypothesis $H_{4\text{-}1}$. That is, a contagion effect did exist between the CDO market and CDS market in the subprime crisis period. The negative and significant coefficients of the lagged ABX indices for the CDX-US index are negative, meaning that a negative shock from the subprime crisis to the ABX indices translated into significant increases in the subsequent CDX-US index returns. Meanwhile, there were higher credit risks for the lower-credit (A, BBB and BBB-) ABX indices than for the higher-credit (AAA and AA) ones in the crisis stage; thus, there were more significant contagion effects from the lower-credit ABX to the CDX-US indices. This finding supports hypothesis $H_{4\text{-}2}$. That is, the contagion effects of lower-rated ABX indices were more pronounced than those of higher-rated ABX indices in the subprime crisis period.

Table 6. Results of contagion effects from ABX index returns of respective ratings to CDX-US index returns

ABX	$t(\alpha_{21})$	$t(\alpha_{22})$	$t(\alpha_{23})$	$t(\alpha_{24})$	$P(\alpha_{2,i} = 0)$	$P(\alpha_{3,i} = 0)$	$Q(12)$	$Q^2(12)$	Joint test
AAA	-2.073	-0.017	1.354	-4.317	0.11371	0.00003***	15.542 [0.24589]	12.425 [0.36053]	1.215 [0.74031]
AA	-1.024	-0.675	0.418	-4.156	0.54287	0.00012***	12.538 [0.39985]	10.984 [0.56870]	1.520 [0.67224]
A	-0.327	-0.087	1.370	-6.369	0.93681	0.00000***	10.284 [0.56933]	9.862 [0.69115]	1.764 [0.52145]
BBB	-1.605	0.321	-1.435	-8.756	0.27149	0.00000***	8.312 [0.73256]	7.690 [0.79430]	2.034 [0.48534]
BBB-	-0.646	-0.552	-0.915	-8.094	0.48326	0.00000***	7.852 [0.75980]	8.530 [0.68257]	0.998 [0.78542]

Notes: $t(\alpha_{21})$ and $t(\alpha_{22})$ are the t-statistics of the α_{21} and α_{22} coefficients before the subprime crisis (January 19, 2006-December 29, 2006). $t(\alpha_{31})$ and $t(\alpha_{32})$ are the t-statistics of the α_{31} and α_{32} coefficients in the crisis period (January 4, 2007-September 30, 2009). $P(\alpha_{2,i} = 0)$ and $P(\alpha_{3,i} = 0)$ are the p-values of the joint test using F-statistics for the pre-crisis period and the crisis stage, respectively. *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. $Q^2(12)$ and $Q(12)$ are the Ljung Box Q^2 and Q tests which examine the ARCH effects and error autocorrelation respectively, and the joint test follows χ^2 statistics which examines the asymmetric effect of GJR-GARCH model.

The GJR-GARCH model notably demonstrates the asymmetric effect of positive and negative volatilities in the original residuals of the CDS- and bond-index index returns, and the two separate returns under the AR-GJR-GARCH model in Panels A and B of Table 7 also show no evidence of the ARCH effects or error autocorrelation. The results in Panel A for the F-test between the CDX-US indices and stock indices in the high-risk countries indicate that the ratio of rejecting the null hypothesis $\beta_{3,i} = 0$ is 100%, which means that CDX-US indices caused severe shocks to stock indices in the high-risk countries in the crisis period. Both acceptance of the null hypothesis $\beta_{2,i} = 0$ and rejection of the null hypothesis $\beta_{3,i} = 0$ occur in the US, the UK and Korea, indicating that there were more significant contagion effects from the CDX-US to stock indices in the 3 high-risk countries in the crisis period. The previous one-day CDX-US index provides forecasting ability for the stock indices in the US, the UK and Korea in the crisis period. The t-statistics for the first lagged values of the CDX-US index on these stock indices are -1.64, -4.12 and 5.69, respectively. In other words, there is evidence of a major increase in cross-market linkages between the US CDS markets and the stock markets in the US, the UK, and Korea, enabling contagion effects to exist in the crisis period. The negative and significant coefficients of the lagged CDX-US indices to the US and the UK stock indices demonstrate that negative shocks from the subprime crisis to the CDX-US indices translated into significant increases in the subsequent US and the UK stock index returns. On the one hand, the serious deficit and the inadequate monetary policies

implemented by the US during a financial crisis facilitate the transmission of financial contagion to other countries, as addressed by Radelet and Sachs (1998). On the other hand, the US and the UK dispersed losses caused by the financial crisis to emerging markets via securitization so as to exert positive impacts on their respective stock index returns. However, the positive significant coefficients of the lagged CDX-US to Korean stock indices show that the negative shocks from the subprime crisis to the CDX-US indices lead to a significant decrease in subsequent Korean stock index returns. On the one hand, Korea, with a high ratio of foreign debt, suffered severe distress in terms of its stock returns during the crisis period. On the other hand, developed countries disperse losses from the financial crisis to emerging markets via securitization.

The results of the F-test in Panel B between the CDX-US and stock indices in the low-risk countries show that both acceptance of the null hypothesis $\beta_{2,i} = 0$ and rejection of the null hypothesis $\beta_{3,i} = 0$ occured in China, which means that there were significant contagion effects from the CDX-US to Chinese stock indices in the crisis period. The previous one-day CDX-US index provides forecasting ability for the stock indices in China during the crisis period. The t-statistics for the first lagged values of the CDX-US index on the stock indices are 4.44. In other words, there is evidence of a major increase in cross-market linkages between the US CDS markets and the stock market in China, which is also known as a low-risk country, enabling significant contagion effects to exist during the crisis period. These findings in Panels A and B of Table 7 tend to support hypothesis $H_{4\text{-}4}$. That is, a contagion effect did exist between the CDS and stock markets in the subprime crisis period. The positive and significant coefficients of the lagged CDX-US to the China H-share indices show that negative shocks from the subprime crisis to the CDX-US indices lead to a significant decrease in the subsequent H-share returns. On the one hand, there were fewer entry barriers in the H-share market, so the contagion effects after the financial crisis occurred were fierce, as pointed out by Kutan (2007). On the other hand, developed countries dispersed losses from the financial crisis to emerging markets via securitization. These results state that there were more significant contagion effects from the CDX-US index to stock indices in the high-risk countries than in the low-risk countries in the crisis period. This finding is consistent with hypothesis $H_{4\text{-}5}$. That is, the stock returns in the high-risk countries can be predicted more precisely than those in the low-risk countries by the CDX-US returns. Overall, the findings of this study are consistent with the view that there is a major increase in shocks from a financial crisis to high-risk countries, as proposed by Radelet and Sachs (1998) and Kaminsky (2003).

Table 7. Results of contagion effects from CDX-US index returns to stock index returns in high-risk and low-risk countries

Panel A. High-risk countries									
Items	β_{21}	β_{22}	β_{31}	β_{32}	$P(\beta_{2,i} = 0)$	$P(\beta_{3,i} = 0)$	$Q(12)$	$Q^2(12)$	Joint test
AUS	-5.178	-1.629	-6.505	-0.517	0.00000***	0.00000***	17.425 [0.16338]	6.548 [0.81058]	0.580 [0.90431]
HUN	-4.367	-0.703	-2.265	-1.529	0.00006***	0.01971**	14.776 [0.20548]	6.029 [0.92674]	0.204 [0.98432]
SWI	-1.446	1.783	-2.753	1.225	0.06121*	0.01521**	16.480 [0.18022]	5.841 [0.90124]	0.284 [0.95421]
KOR	-2.956	-0.117	5.688	0.019	0.11170	0.00000**	15.562 [0.19875]	5.312 [0.95148]	0.315 [0.92084]
SWE	-2.710	-1.034	-3.658	0.191	0.01175**	0.00124**	15.020 [0.21154]	5.414 [0.93996]	0.215 [0.97053]
UK	-3.645	0.614	-4.124	0.411	0.10072	0.00020***	5.203 [1.03425]	4.993 [0.95481]	0.398 [0.90919]
US	-0.199	-0.102	-1.643	-1.780	0.97412	0.09109*	7.115 [0.88933]	7.224 [0.86025]	0.625 [0.88432]
Panel B. Low-risk countries									
MEX	-1.075	-2.130	-0.476	0.112	0.06297	0.89266	7.088 [0.88994]	7.124 [0.86328]	0.634 [0.88941]
COL	-0.465	-1.641	-0.471	0.859	0.21990	0.63198	14.973 [0.20368]	6.248 [0.91300]	0.524 [0.92037]
IND	-15.439	-12.909	-1.262	-1.975	0.00000***	0.03514**	16.784 [0.18643]	6.370 [0.88465]	0.245 [0.95598]
PER	-2.891	-1.364	-2.082	-1.301	0.00571***	0.03457**	15.950 [0.19353]	5.357 [0.94143]	0.254 [0.94345]
PHI	-4.578	-0.063	-4.540	-2.302	0.00002***	0.00000***	15.498 [0.24867]	5.985 [0.91448]	0.363 [0.92287]

Table 7 (cont.). Results of contagion effects from CDX-US index returns to stock index returns in high-risk and low-risk countries

Items	β_{21}	β_{22}	β_{31}	β_{32}	$P(\beta_{2,i} = 0)$	$P(\beta_{3,i} = 0)$	$Q(12)$	$Q^2(12)$	Joint test
RUS	-2.825	-2.162	-3.491	-0.101	0.00272***	0.00152***	14.141 [0.29980]	4.979 [0.95866]	0.123 [0.99486]
CHI	-1.949	-1.703	4.435	-0.184	0.13722	0.00005***	20.543 [0.17785]	16.713 [0.23056]	0.260 [0.93997]

Notes: $t(\beta_{21})$ and $t(\beta_{22})$ are the t-statistics of the β_{21} and β_{22} coefficients before the subprime crisis (January 19, 2006-December 29, 2006). $t(\beta_{31})$ and $t(\beta_{32})$ are the t-statistics of the β_{31} and β_{32} coefficients in the crisis period (January 4, 2007-September 30, 2009). $P(\beta_{2,i} = 0)$ and $P(\beta_{3,i} = 0)$ are the p-values of the joint test using F-statistics for the pre-crisis period and the crisis stage, respectively. *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. $Q^2(12)$ and $Q(12)$ are the Ljung Box Q^2 and Q tests which examine the ARCH effects and error autocorrelation respectively, and the joint test follows χ^2statistics which examines the asymmetric effect of GJR-GARCH model.

Table 8 shows that there were fewer significant lead-lag relationships between the stock indices in the high-risk countries and those in the low-risk countries in the pre-crisis period than during the crisis period. A few of the stock indices in the high-risk countries have the ability to forecast those in the low-risk countries in the pre-crisis period, and the hypothesis that the $\gamma_{2,i}$ coefficients are jointly zero is only rarely rejected. However, more of the $\gamma_{3,i}$ coefficients become highly significant once the crisis occurs. This result provides clear evidence of a major increase in cross-market linkages between the stock indices in the high-risk countries and those in the low-risk countries, which shows significant contagion effects during the crisis period. In other words, most of the stock indices in the low-risk countries were significantly predictable on the basis of those in the high-risk countries after the onset of the subprime crisis. Since many of the t-statistics and p-values of the stock indices in the high-risk countries on those in the low-risk countries reject the null hypothesis, the direction of financial contagion is from the stock indices in the high-risk countries to those in the low-risk countries. This finding tends to support hypothesis $H_{4\text{-}5}$. In particular, the stock indices in Mexico are much more predictable by those in Korea, Switzerland, and the UK, while those in Peru are much more predictable by those in Australia, Switzerland, Hungary, Sweden, and the US.

Table 8. Results of contagion effects from stock index returns in high-risk countries to those in low-risk countries

Low-risk countries	High-risk countries	γ_{21}	γ_{22}	γ_{31}	γ_{32}	$P(\gamma_{2,i} = 0)$	$P(\gamma_{3,i} = 0)$	$Q(12)$	$Q^2(12)$	Joint test
MEX	AUS	-1.186	0.742	-0.549	0.088	0.280571	0.856702	17.143 [0.18110]	21.828 [0.11873]	4.259 [0.21943]
	SWI	-0.631	0.183	-0.650	1.607	0.803605	0.198485	14.238 [0.22356]	16.284 [0.16498]	0.618 [0.87875]
	KOR	-1.423	1.568	-0.451	0.718	0.678582	0.063282*	15.335 [0.31006]	11.434 [0.30249]	0.697 [0.86723]
	HUN	-0.769	-0.019	-0.692	1.869	0.743867	0.132881	18.310 [0.20876]	14.875 [0.28875]	0.168 [0.98141]
	SWE	-0.445	0.220	-1.334	2.202	0.882671	0.017420**	14.116 [0.26943]	19.519 [0.13799]	0.384 [0.95410]
	UK	-1.379	0.232	-1.468	2.009	0.310879	0.016541**	5.320 [0.95274]	5.424 [0.94230]	0.298 [0.96782]
	US	0.669	-1.290	-0.343	-0.682	0.278639	0.763920	5.014 [0.94024]	5.830 [0.95022]	0.518 [0.92141]
PHI	AUS	1.412	1.910	0.138	-1.949	0.146678	0.082165*	6.135 [0.93021]	5.924 [0.93867]	0.425 [0.94325]
	SWI	2.261	0.627	4.266	1.055	0.059705*	0.000093***	4.041 [0.96013]	4.441 [0.97552]	0.337 [0.94358]
	KOR	1.530	2.022	-0.190	0.404	0.907061	0.059397*	5.431 [0.93998]	5.930 [0.91487]	0.938 [0.82147]
	HUN	2.277	0.197	1.245	2.580	0.065457*	0.024736**	4.990 [0.94870]	5.643 [0.93876]	0.417 [0.93875]
	SWE	3.283	1.730	4.206	-0.782	0.000793***	0.000062***	6.941 [0.89459]	6.518 [0.87476]	0.660 [0.83490]
	UK	2.464	1.720	2.749	0.516	0.016693**	0.008528***	15.880 [0.198790]	6.435 [0.89259]	0.536 [0.91088]
	US	2.845	1.568	7.252	-2.479	0.006085***	0.000000***	16.590 [0.18199]	6.363 [0.89003]	0.324 [0.96420]

Table 8 (cont.). Results of contagion effects from stock index returns in high-risk countries to those in low-risk countries

Low-risk countries	High-risk countries	γ_{21}	γ_{22}	γ_{31}	γ_{32}	$P(\gamma_{2,i} = 0)$	$P(\gamma_{3,i} = 0)$	$Q(12)$	$Q^2(12)$	Joint test
COL	AUS	-0.528	-1.672	0.115	1.077	0.230841	0.554657	6.143 [0.92014]	5.841 [0.91329]	0.537 [0.91253]
	SWI	-2.945	0.827	-1.523	1.090	0.170985	0.009378***	5.991 [0.92325]	6.438 [0.89388]	0.428 [0.91849]
	KOR	0.494	0.356	-0.668	0.873	0.814540	0.558567	17.019 [0.17456]	6.580 [0.88769]	0.635 [0.90282]
	HUN	-4.412	0.440	-0.571	2.517	0.000053***	0.035746**	14.814 [0.20292]	6.174 [0.91485]	0.203 [0.98923]
	SWE	-1.149	-1.070	-1.309	1.643	0.374081	0.080629*	16.495 [0.18093]	5.838 [0.91998	0.274 [0.95870]
	UK	-3.073	-0.320	-1.549	2.401	0.008442***	0.016889**	13.554 [0.27543]	5.430 [0.941005]	0.254 [0.96468]
	US	0.575	-5.784	2.674	-0.430	0.000000***	0.026242**	14.141 [0.29179]	5.044 [0.943884]	0.098 [1.02988]
IND	AUS	42.568	36.972	0.369	0.641	0.690139	0.000000***	20.327 [0.18040]	15.903 [0.25124]	0.350 [0.96421]
	SWI	214.005	90.089	2.475	1.319	0.014712**	0.000000***	12.353 [0.29487]	18.005 [0.15892]	0.187 [0.97980]
	KOR	30.339	-172.976	-1.112	-0.261	0.532731	0.000000***	6.398 [0.93980]	5.546 [0.93270]	0.423 [0.94225]
	HUN	-21.843	146.430	2.811	2.535	0.000802***	0.000000***	3.997 [0.96674]	4.615 [0.97752]	0.543 [0.92165]
	SWE	-105.694	135.727	5.085	2.970	0.000000***	0.000000***	6.132 [0.93234]	5.975 [0.91005]	0.974 [0.72345]
	UK	97.864	97.140	14.802	2.898	0.000000***	0.000000***	4.912 [0.95937]	5.614 [0.93872]	0.327 [0.93978]
	US	-117.409	-64.022	7.654	1.950	0.000000***	0.000000***	7.117 [0.88972]	6.664 [0.87378]	0.676 [0.88763]
PER	AUS	-0.064	2.309	1.838	2.195	0.169518	0.010811**	13.198 [0.33843]	10.234 [0.51443]	1.185 [0.70532]
	SWI	-0.025	0.905	-0.463	3.983	0.664030	0.000186***	6.423 [0.84465]	7.585 [0.79995]	1.891 [0.58009]
	KOR	0.941	2.927	1.171	2.988	0.006985***	0.006750***	8.353 [0.81990]	8.293 [0.75615]	2.240 [0.52723]
	HUN	-0.003	1.661	-0.679	2.090	0.239579	0.085573*	15.874 [0.20875]	19.765 [0.13899]	2.487 [0.32594]
	SWE	-0.881	1.222	-1.346	4.245	0.303924	0.000048***	16.943 [0.20054]	18.250 [0.14386]	0.848 [0.76917]
	UK	-1.134	2.416	0.055	4.408	0.015230**	0.000045***	13.543 [0.33974]	9.148 [0.49900]	0.497 [0.98037]
	US	2.258	-0.730	1.355	1.416	0.200161	0.058168*	20.376 [0.18420]	16.215 [0.25189]	0.118 [0.99871]
RUS	AUS	-1.048	0.105	0.444	1.267	0.568546	0.426507	5.785 [0.94342]	5.654 [0.95314]	0.539 [0.92146]
	SWI	0.202	-0.690	1.653	-0.193	0.771274	0.251522	6.282 [1.03134]	4.991 [0.93437]	0.753 [0.84761]
	KOR	-0.688	1.672	-0.301	1.515	0.207290	0.297639	6.325 [0.92357]	6.532 [0.91022]	0.529 [0.93985]
	HUN	-0.993	2.228	1.202	-0.068	0.479434	0.054286*	7.110 [0.91432]	5.890 [0.89757]	0.645 [0.89164]
	SWE	-0.323	-0.106	1.626	0.888	0.939291	0.124037	17.202 [0.17569]	7.351 [0.88190]	0.646 [0.90848]
	UK	-0.365	0.735	1.206	0.707	0.705155	0.392292	14.786 [0.20922]	5.374 [0.92159]	0.321 [0.96230]
	US	3.287	0.871	5.009	0.768	0.003026***	0.000003***	16.853 [0.18758]	6.689 [0.91439]	0.357 [0.95440]

Table 8 (cont.). Results of contagion effects from stock index returns in high-risk countries to those in low-risk countries

Low-risk countries	High-risk countries	γ_{21}	γ_{22}	γ_{31}	γ_{32}	$P(\gamma_{2,i} = 0)$	$P(\gamma_{3,i} = 0)$	$Q(12)$	$Q^2(12)$	Joint test
Chi	AUS	-0.411	-0.475	-0.233	-0.852	0.843020	0.821926	5.498 [0.93345]	6.754 [0.91347]	0.975 [0.82765]
	SWI	2.790	1.500	4.096	1.139	0.007671***	0.000166***	4.921 [0.94379]	4.929 [0.93782]	0.359 [0.93852]
	KOR	0.596	1.208	-0.873	0.153	0.431375	0.676563	7.0912 [0.89872]	7.387 [0.87775]	0.647 [0.89060]
	HUN	3.368	-0.080	2.997	1.229	0.003170***	0.007751***	15.890 [0.19746]	5.875 [0.90596]	0.645 [0.90087]
	SWE	3.474	0.866	3.635	-0.232	0.001556***	0.000953***	16.891 [0.18921]	7.057 [0.89593]	0.389 [0.96092]
	UK	4.044	1.614	4.439	1.076	0.000219***	0.000050***	14.349 [0.20763]	4.897 [0.93894]	0.385 [0.95440]
	US	3.653	2.865	8.462	1.425	0.000296***	0.000000***	15.521 [0.25219]	6.412 [0.94394]	0.415 [0.94218]

Notes: $t(\gamma_{21})$ and $t(\gamma_{22})$ are the t-statistics of the γ_{21} and γ_{22} coefficients before the subprime crisis (January 19, 2006-December 29, 2006). $t(\gamma_{31})$ and $t(\gamma_{32})$ are the t-statistics of the γ_{31} and γ_{32} coefficients in the crisis period (January 4, 2007-September 30, 2009). $P(\gamma_{2,i} = 0)$ and $P(\gamma_{3,i} = 0)$ are the p-values of the joint test using F-statistics for the pre-crisis period and the crisis stage, respectively. *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. $Q^2(12)$ and $Q(12)$ are the Ljung Box Q^2 and Q tests which examine the ARCH effects and error autocorrelation, respectively, and the joint test follows χ^2 statistics which examines the asymmetric effect of GJR-GARCH model.

Conclusion

The 2007 subprime crisis provides an ideal opportunity for studying the effects of contagion in financial markets (Longstaff, 2010). Indeed, understanding contagion effects and channels helps avoid even worse global crises in the future. Based on the high correlation between the ABX and CDX-US indices and between the CDX-US and stock indices, a VAR framework by Longstaff (2010) is used to survey the contagion effects from the ABX to CDX-US indices and from the CDX-US to stock indices in high-risk and low-risk countries during the pre-crisis and crisis periods. Moreover, contagion channels and ratio of variance decomposition from the ABX to CDX-US indices and from the CDX-US to stock indices in high-risk and low-risk countries during the pre-crisis and crisis periods under a VAR framework are covered. A multiple methodology is used in this study to compare the diversity from different ratings of ABX indices to CDX-US indices and from CDX-US indices to stock indices in high-risk and low-risk countries.

In the subprime crisis period, there were significantly larger ratios of variance decomposition for lower-rated ABX index returns than higher-rated ones on CDX-US index returns. ABX index returns demonstrate more significant forecasting ability for CDX-US index returns during the crisis stage than during the pre-crisis period. That is, there were significant contagion effects between the CDO and CDS markets in the crisis stage and, furthermore, there were more significant contagion effects from lower-rated ABX index returns to CDX-US index returns than higher-rated ABX index returns to CDX-US index returns. Thus, the variance decomposition of lower-rated ABX index returns had a greater significance, as did the contagion effects, than higher-rated ABX index returns to the CDX-US index returns during the crisis period. This result indicates that public financial authorities may, through financial policies of encouraging the adjusted duration or risk premium, enhance the management of lower-rated CDOs to prevent shocks to CDS markets in the financial crisis period.

In the crisis period, the CDX-US indices spread separately to stock markets in high-risk and low-risk countries, which conforms to the view that CDS markets lead stock markets, as addressed by Norden and Weber (2004). Meanwhile, there was a steep rise in the rate of variance decomposition from CDX-US indices to stock index returns in high-risk countries compared to low-risk countries in the development period. Additionally, there were significant contagion effects between the CDS and stock markets after the onset of the crisis. In the crisis period, there were more significant contagion effects from CDX-US to stock index returns in high-risk countries than in low-risk countries; that is, there is a major increase in the linkages across CDX and stock index returns in high-risk countries as an international financial crisis takes place. Finally, the findings show that stock index returns in low-risk countries can be predicted by those in high-risk countries. In other words, financial contagion spreads from stock markets in high-risk countries to stock markets in low-risk countries. The above results conform to the view that there is a major increase in shocks from financial crises to high-risk countries, as identified by Radelet and Sachs (1998) and Kaminsky (2003).

These results indicate that the public financial authorities of high-risk countries may, through economic measures such as reducing the foreign debt ratio, lowering the deficit, increasing foreign direct investment, and adjusting the money supply, reduce shocks from CDS markets, as represented by credit risk to stock markets in the crisis period. Indeed, regardless of whether the shocks are from the ABX to CDX-US indices or from the CDX-US to stock indices in high-risk and low-risk countries, there was a major increase in the variance decomposition since the development period when the Fed came to the rescue of Bear Stearns. However, there were significant contagion effects since the initial stage of the subprime crisis. Therefore, financial authorities and investors should pay attention to contagion effects from CDOs to CDS market returns, and from the CDS market to stock returns since the early stage of the crisis, whereas they should be on the lookout for major increases in variance components concerned with the middle stage of the crisis.

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