The cross-country transmission of credit risk between sovereigns and firms in Asia

Abstract

This paper uses Credit Default Swap (CDS) data for Asian reference entities to examine cross-country credit risk spillover effects between sovereigns and firms. Data for three East Asian countries (China, Japan and South Korea) over the period 2009-2018 are analysed. We analyse changes in the CDS spreads of a sovereign debtor and those of a foreign firm via a bivariate GARCH-full-BEKK model; thus, spillovers in mean spread changes as well as in volatility are considered. The main findings indicate that strong credit risk interdependence exists between the East Asian countries given that credit shocks from a common creditor such as Japan appear to spill over to the other two Asian nations. Compared to their non-financial counterparts, financial institutions are more sensitive than non-financial firms to changes in the credit risk of a foreign sovereign debtor; financial institutions such as banks may hold debt of foreign sovereigns which makes their CDSs sensitive to this source of credit risk.

Keywords: Credit risk; cross-country; spillover effects; Asia.

JEL Classification: G1; G2; G32; G33.

1. Introduction

Scholars in the finance area have shown an increasing interest in the study of credit risk using information from CDS contracts; such an interest is hardly surprising since these derivatives have grown in popularity as a risk management tool over the past decade. In a CDS, one party (i.e., the protection buyer) pays a periodic fee to another party (i.e., the protection seller) in return for compensation in the event of default (or another similar credit-related event) by a reference entity. The findings from prior research such as Longstaff et al. (2005) and Forte and Pena (2009) have suggested that CDS spreads (i.e., the default swap premium) accurately reflect the market price of credit risk for a reference entity. Since CDS spreads correspond to a realisable stream of cash flows depending on the occurrence of specific credit events, any change in the possible occurrence of the credit-related event will be impounded into the CDS spreads assuming that the market is efficient.

Following the 2008 global financial crisis, findings from various studies have concluded that CDSs on sovereign and corporate reference entities are connected and contain information which may be valuable to policy-makers in measuring potential systemic risk. However, the process whereby default risk is transferred across different entities is still not yet fully understood. This is especially true when the entities are located in different countries. Moreover, there is not a great deal of information about linkages among CDSs traded outside of the US and Europe. The few investigations such as Lahmann (2012) that has been conducted in this area have mostly focused on credit risk linkages between or within sovereigns and financial sector firms. Thus, a study of cross-country credit risk transmission between sovereigns and (financial as well as non-financial) Asian firms should yield interesting insights.

Such transmission of credit risk might exist because of the geographic proximity of the different markets involved and the importance of trade as well as financial linkages among the Asian countries considered; the literature reports equity cross-holdings among Asian firms (Fan and Wong, 2002) and sizeable trade links among the different nations in the region (Dornbusch et al., 2000; Goldberg and Klein, 1997). Furthermore, countries in Asia have made remarkable progress in terms of economic as well as financial integration; the degree of financial integration in the region used to lag significantly behind trade linkages but this is no longer the case. For example, in order to promote financial integration,

Southeast and East Asian nations launched the Asian Bond Market Initiative in 2002 and established the Asian Infrastructure Investment Bank in 2016; this bank has its headquarters in Beijing, China and aims to provide financial support to member nations, including some of our sample countries (i.e., China and South Korea).

This paper examines spillover effects between the credit risks of a sovereign in one country and firms in another Asian nation using daily CDS spread changes. In particular, it looks at the spillover effects between advanced and emerging economies sharing similar cultures and located in the same region. The time span of the data sample covers the period from January 2009 to December 2017, yielding 2,346 daily observations for each series. A total of 85 CDS series from China, Japan and South Korea are examined including those of 3 sovereigns, 15 financial institutions and 67 non-financial firms. Unlike prior studies which tend to focus on mean spillover effects, this paper employs a Bivariate Generalised Autoregressive Conditional Heteroscedasticity (Bivariate GARCH) model within a full-BEKK setting to identify spillovers among the mean spread changes as well as their volatilities. We analyse changes in the CDS spreads of a home-state sovereign and those of a foreign firm, corresponding to 164 pairs of entities in total. Linkages between past changes in one series and current changes in another series are studied; any significant findings of linkages from past to current CDS spread changes would contradict the weak-form of the efficient markets hypothesis (EMH). By identifying the presence of credit risk spillover effects, our findings may also be used in risk management decisions and heighten policy-makers' awareness of the nature of credit risk transmission between sovereigns and sectors across countries. Moreover, unlike prior studies which typically examine 5-year CDS data, the analysis of this paper uses information from 1-year CDS contracts; the 1-year market has become more liquid in recent years.[1] Therefore, findings from this paper should also help to shed light on the credit risk spillover effects in this increasingly important short run segment of the CDS market.[2]

[1] The notional amount outstanding of short-term CDSs (i.e., one year or less than one year CDSs) surpassed that of over 5-year CDSs at the end of 2011. For example, the notional amount outstanding of short-term CDSs was US$3,408 billion compared with US$2,142 billion for CDSs having maturities of at least 5 years according to the records of International Swap and Derivatives Association (ISDA) in 2011.

[2] Nevertheless, a robustness check is conducted by using the information from 5-year CDS contracts of the same sample firms.

Our evidence suggests that there are significant cross-country credit risk spillover effects between Asian CDS reference entities. These effects are present in the mean CDS spread changes, their shocks and their volatilities, although the magnitudes and directions of spillover effects vary across sectors and countries. According to the findings associated with credit risk spillovers between the sovereign of one nation and financial institutions in another country, a significant bidirectional transmission of risk in the past changes of CDS spreads is evidenced for all pairs over the period 2009-2017. By contrast, credit risk spillovers between the sovereign of one country and foreign non-financial firms mainly involves the Japanese sovereign. Thus, a common creditor, such as the Japanese sovereign, links the credit risk of non-financial firms in the region.[3]

The remainder of the paper is organised as follows. Section 2 discusses prior studies regarding credit risk spillover effects using information from CDS markets. Section 3 describes the data employed and sets out the framework of analysis. Section 4 presents the findings about cross-country credit risk spillovers. Finally, Section 5 provides some concluding remarks.

2. Literature Review

As one of the paper's main aims is to identify and examine credit risk spillover effects using Asian CDS spreads, this section summarises empirical tests for the presence of any credit risk spillovers from a number of investigations based on CDS spreads. The discussion of the findings should provide a comprehensive review of evidence regarding i) credit risk linkages between sovereigns and financial firms and ii) credit risk linkages between sovereigns and non-financial firms.

(i) Credit risk linkages between sovereigns and financial firms

As a result of the significant growth of credit derivatives and the greater availability of CDS data, an increasing number of academic studies have analysed credit risk from a credit derivative perspective (particularly using CDS spreads). A number of studies (Baba and Inada, 2009; Blanco et al., 2005; Chan-

[3] An upward trend is identified for Asian name CDSs during 2015 because of the increasing notional amount of single-named CDSs with Japan and other Asian countries; the figure increased from US$116 billion to US$137 billion for single-named CDSs with a Japanese entity as their counterparty in 2015. Thus, Japan's CDS dealers (i.e., Japanese financial institutions) seem to play important role in linking and transmitting credit risk via CDSs.

Lau and Kim, 2005; Longstaff et al., 2003) have examined the price discovery relationship between bond spreads and CDS spreads. Empirical evidence from this group of studies suggests that CDS spreads capture changes in default risk earlier than bond spreads in advanced economics, but no particular market dominates in developing nations. Another stream of academic research (Hull and White, 2000a, 2000b; Jarrow and Turnbull, 1995; Miyakawa and Watanabe, 2014) has developed credit risk pricing models based on CDS spreads. For example, research in this area has utilised CDS spreads to derive an entity's probability of default while suggesting that the conventional approach to this issue (based on Merton's (1974) model) under-predicts the probability of default (Chan-Lau, 2003; Han and Jang, 2013; Hilscher and Nosbusch, 2010). A related but separate group of studies has examined credit risk spillovers from one sector to another within an economy. For example, researchers in this area have suggested that the bailout of banks by governments leads to the transfer of credit risk from the financial sector to the Sovereign entity. Similarly, if the State (the lender of last resort in a country) gets into financial difficulties, the possibility of default on sovereign debts will increase (e.g. Greek sovereign debt crisis) and the liquidity support provided to the banking sector may be withdrawn resulting in a greater chance of default in the financial sector. Empirical investigations have documented an increased level of credit risk spillover between European sovereigns and banks during and after government bailout programmes; a two-way feedback relationship between the credit risks of European sovereigns and banks was uncovered at the time of the recent financial crisis (Acharya et al., 2014; Alter and Beyer, 2014; Alter and Schüler, 2012)[4].

Several empirical studies have sought to enhance our understanding of systemic risk at an international level and also to contribute to the burgeoning literature on the link between systemic risk and sovereign debt, especially during the 2008 global financial crisis and the 2010 Euro debt crisis. Alter and Schuler (2012) were among the first scholars to examine changes in the credit risk interdependence

[4] A number of academics have also proposed that credits risk spillovers may arise between non-financial firms and either financial or sovereign entities. They suggest that a deterioration in the operating and financial environment of the non-financial sector usually results in a large increase in default rates and lower loan repayment rates. These may result in the failure of banks and lower tax revenues for the government. As a result, investors may believe that the credit standing of the financial sector and the government may also deteriorate. Thereby, a destructive feedback loop is triggered and CDS spreads of firms in all sectors increase. This may explain why defaults tend to cluster around times of adverse economic conditions, as reported by Heise and Kühn (2012).

of European Governments and banks after aid schemes were implemented in Europe between June 2007 and May 2010. They used 5-year daily sovereign CDS spreads for seven European countries and 5-year CDS spreads for the banks from each country in order to represent their credit risk. The results showed that the interdependence of government and bank credit risk was heterogeneous across European countries, but homogeneous within the same country. In other words, the effects of a sovereign's credit risk shock on its domestic banks' credit risk were significant within each sample country, but different for foreign banks' credit risk. In particular, Alter and Schuler (2012) suggested that the heterogeneous interdependence could be partially explained by the different exposures of the banking sector in various countries to the change in a nation's sovereign credit risk. A further study by Pagano and Sedunov (2016) extended Alter and Schuler's (2012) sample size from seven to 15 European countries and provided some additional insight into the relationship between systemic risk exposure and sovereign debt. In particular, they found a 'flight-to-quality' effect whereby an increased level of systemic exposure in distressed European countries led to a lower level of sovereign credit spreads in France, Germany and the UK because investors shifted to sovereign debt instruments issued by these countries since they were perceived to be safer.

Although studies on the transmission of credit risk between Asian sovereign and bank CDS spreads are scarce, there is some evidence on this topic in the literature. For example, Lahmann (2012) examined whether there was evidence of contagion effects between sovereign and bank CDS spreads on a global scale (including the Asia-Pacific and Middle East regions as well as Russia, the US and European countries) from October 2005 to April 2011. The empirical results provided evidence of the interaction between the CDS spreads of banks during and after the crisis period (i.e., 01/10/2015 to 28/02/2007). With the bursting of the subprime bubble (i.e., 01/03/2007 to 31/07/2008), Asia-Pacific sovereign CDS spreads were led by American and European bank CDS spreads. The author also reports the Granger causal effect from changes in European sovereign CDS spreads to changes in Asia-Pacific banks' CDS spreads during and after the financial crisis period (i.e., 01/08/2008 to 30/04/2011).

The findings of various studies exploring the credit risk transmission between sovereigns and banks have reached a general conclusion: public bailout programmes may have created a potential credit

risk transmission channel between sovereigns and banks due to the strong financial interdependencies which may exist; this effect has been identified across several European countries. However, there is a dearth of literature on the existence of credit risk transmission between sovereigns and financial institutions using CDS data in Asian countries. With this in mind, the analysis of the current paper on the cross-country credit risk transmission between the sovereign of one Asian country and financial institutions in another Asian country should contribute to the knowledge of this topic.

(ii) Credit risk linkages between sovereigns and non-financial firms

Recent studies have also focused on how non-financial firms react to credit risk spillover effects in the economic system. There are several explicit transmission channels of credit risk between the sovereign debtor and the non-financial sector. At the domestic level, the direct transmission mechanism is linked with the process of taxation; when the credit risk of the sovereign debtor increases, the government responds by raising future tax rates. Hence, the future growth of corporate profitability may be reduced. Another channel is constituted by 'sovereign ceilings', which means that the highest credit rating that a firm can have is indicated by the credit rating of its respective home-country; in other words, non-sovereign entities cannot usually borrow on better terms than the government (Borensztein et al., 2013). As a consequence, the credit risk of non-financial firms may be affected by the increased credit risk of the sovereign debtor (Almeida et al., 2017). At a cross-country level, the transmission of credit risk can also be conveyed via investments and consumption, as an increase in sovereign credit risk may be associated with a decline in the public demand for goods and services, which can affect some non-financial firms that heavily depend on intra-region spending and trading. In addition, the sovereign of one country may affect the non-financial firm in another country through any joint venture agreement between home and foreign non-financial firms. Alternatively, the non-financial firm may have a subsidiary located in the jurisdiction of another sovereign.

Several studies have attempted to investigate the impact of sovereign credit risk on the corporate CDS spreads. For example, Haerri et al. (2014) found a positive correlation between sovereign CDS spreads and their corresponding corporate CDS spreads in 2009-2011; in particular, this credit risk

relationship expanded during the period of the 2010 Euro debt crisis. Augustin et al. (2016) conducted an event study in order to examine the credit risk spillovers from sovereign to corporate CDS spreads by using the changes affecting 226 firms in 15 European countries. They focused on the analysis of a short sample period ranging from February 2010 to June 2010 in order to detect any changes in the transmission of credit risk before and after the Greek bailout. The results were in line with Haerri et al. (2014), who suggested a positive significant interdependence between the changes in sovereign CDS spreads and changes in non-financial firms' CDS spreads, while no statistically significant linkage was identified before the Greek bailout.

The findings from these studies suggest that CDS spreads play an important role in researching credit risk spillover effects. However, the literature in this area has a number of limitations. One limitation is that the different studies frequently focus on CDS spreads within a single country (such as the US) or within a region (such as Europe); others focus on the sovereign or banking sector among a group of countries; see, for example, Ballester et al. (2019,) Cho et al. (2014), Dooley and Hutchison (2009), Hassan et al. (2017) and Kang and Suh (2015). Very few published works focus on international linkages between sectors in Asia. In order to expand our knowledge of credit risk spillover effects between sovereigns and firms in East Asia and to compare any differences in the credit risk spillover effects between advanced economies and emerging markets, this paper considers data for three countries: China, Japan and South Korea. Another limitation of prior studies is that their investigations commonly focus on 5-year CDS data instead of shorter maturity derivatives, because they assumed that 5-year CDS markets were more liquid during the periods of their analyses. However, the liquidity of the 1-year CDS market has significantly improved in recent times. In addition, the number of Asian participants in the CDS markets, particularly in Japan, shows an upward trend. This new feature of global CDS markets calls for studies to utilise more recent short-term CDS data to investigate the credit risk of Asian CDS reference entities. Moreover, most of the previous studies apply a VAR framework in their investigations. In contrast, this paper employs a multivariate GARCH model to allow for time-varying conditional interdependency to be investigated from the perspective of both mean spread spillover effects and shocks, as well as volatilities spillover effects in CDS spread changes. Therefore, the analysis of this paper should help to broaden our knowledge of short-term credit risk spillover effects between Asian countries.

3. Data and Methodology

The data sets used in this study consist of the daily observations of CDS spreads obtained from Thomson Reuters Datastream. The information about China, Japan and South Korea covering sovereign, financial and non-financial CDSs were selected for investigation. The time span of the study covers the period from January 2009 to December 2017 giving a total of 2346 observations for each series. To avoid any problem with heterogeneity in the type of CDSs studied as well as variations in market regulations, this paper only analyses the spreads of single-name senior full restructuring CDSs, as the full-restructuring contract was the most frequently traded for Asian CDS reference entities according to the ISDA. In order to analyse short-term credit risk spillover effects, the main focus of this paper is on 1-year CDS contracts. Nevertheless, a robustness test is also conducted using the 5-year CDS spreads of the same sample.[5] The distribution of sample entities is reported in Table 1. There are 85 series of CDS spreads in total, including those for 3 sovereigns, 15 financial institutions and 67 non-financial firms. Japanese CDSs dominate the Asian market, representing about 50% out of the total CDS sample studied. Due to a low borrowing cost, the bond market in Japan is more active than its counterparts in other Asian countries and large Japanese corporations tend to finance their activities via debt issues (Rajan and Zingales, 1995). Consistent with the global CDS market, non-financial firms account for 77% of the total reference entities for which CDS contracts are written in the selected sample; this highlights the importance of analysing CDS spreads for non-financial firms.

[Insert Table 1 about here]

[Insert Figure 1 about here]

Figures 1 and 2 show the evaluation of the CDS time series of 1-year and 5-year CDS spreads, respectively. In Figure 1 the sharp rises of 1-year CDS spreads in the beginning of the sample period reflect changes in the expectations of investors about credit risk after many US financial institutions went bankrupt or were bailed out during the global financial crisis. In particular, the average 1-year CDS spreads of the financial sector increased from 270bps to 330bps in the beginning of 2009. By contrast,

[5] Details of estimates from 5-year CDSs can be provided upon request.

the increases in CDS spreads in 2011 were possibly due to the sovereign and corporate debts of several countries, including those in Asia, being downgraded. This trend is documented by the evaluation of 5-year CDS spreads in the Figure 2 as well; for example, the average 5-year CDS spreads of the financial sector rose steeply from approximately 320bps to 380bps. This finding also provides evidence for the fact that long-term uncertainty may be compounded to the 5-year CDS spreads which calls for a need of studies on short-term credit risk transmission in Asia. Table 2 reports summary statistics both for the CDS spreads and the CDS spread changes. A visual inspection of the CDS spreads in Table 2 highlights that the level of Japan's credit spreads were lower than that of China and South Korea, indicating a low expectation of default risk on Japanese debts. The ADF test results from the changes in CDS spreads reject the null hypothesis of a unit root at the 1% level of significance; this suggests that the sample series used in this research are stationary, so the analysis of spillovers using CDS spread changes is appropriate.

[Insert Table 2 about here]

Due to a large number of entities in the sample and the limitation of multivariate GARCH estimation, all relationships cannot determined at the same time. Here, we pair our reference entities and employ a bivariate GARCH-BEKK framework (named after Baba, Engle, Kraft and Kroner, 1990) – that is, an entity from one given sector and country is paired with other entities from different sectors and countries taken one at a time. Relationships between each pair of CDS spread change series is estimated using a bivariate VAR(1)-GARCH(1,1)-full-BEKK representation. The BEKK representation can highlight the extent to which shocks will have a significant impact on the variance of CDS spread changes. The BEKK model is selected over other multivariate GARCH specifications because it guarantees a positive-definite covariance matrix, and it allows estimated correlations between the CDS returns to be time-varying. Linkages between the credit risks of any two entities are said to exist either if the changes in the CDS spread of an entity react to the changes in the CDS spread of another entity or if a shock and/or a volatility spike in the CDS spread of an entity spills over to those of another entity in a different country. These interactions imply that investors holding CDS contracts for an entity react to the change in credit status of another entity and incorporate the information about this other entity in pricing the CDS contracts they are holding.

In its most general specification, the mean equation of the bivariate VAR(1)-GARCH(1,1) full BEKK process takes the following form[6]:

$$\begin{bmatrix} \Delta cds_{it}^{SOV,C_i} \\ \Delta cds_{jt}^{S_j,C_j} \end{bmatrix} = \begin{bmatrix} \gamma_{i0} \\ \gamma_{j0} \end{bmatrix} + \begin{bmatrix} \gamma_{ii} & \gamma_{ij} \\ \gamma_{ji} & \gamma_{jj} \end{bmatrix} \begin{bmatrix} \Delta cds_{it-1}^{SOV,C_i} \\ \Delta cds_{jt-1}^{S_j,C_j} \end{bmatrix} + \begin{bmatrix} \varepsilon_{it} \\ \varepsilon_{jt} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} h_{ii,t} & h_{ij,t} \\ h_{ji,t} & h_{jj,t} \end{bmatrix} = \begin{bmatrix} m_{ii} & 0 \\ m_{ji} & m_{jj} \end{bmatrix} \begin{bmatrix} m_{ii} & 0 \\ m_{ji} & m_{jj} \end{bmatrix}' + \begin{bmatrix} a_{ii} & a_{ij} \\ a_{ji} & a_{jj} \end{bmatrix} \begin{bmatrix} \varepsilon_{it-1}^2 & \varepsilon_{jt-1}\varepsilon_{it-1} \\ \varepsilon_{jt-1}\varepsilon_{it-1} & \varepsilon_{jt-1}^2 \end{bmatrix} \begin{bmatrix} a_{ii} & a_{ij} \\ a_{ji} & a_{jj} \end{bmatrix}' + \begin{bmatrix} g_{ii} & g_{ij} \\ g_{ji} & g_{jj} \end{bmatrix} \begin{bmatrix} h_{ii,t-1} & h_{ij,t-1} \\ h_{ji,t-1} & h_{jj,t-1} \end{bmatrix} \begin{bmatrix} g_{ii} & g_{ij} \\ g_{ji} & g_{jj} \end{bmatrix}' \quad (2)$$

where $\Delta cds_{it}^{SOV,C_i}$ represents the first difference of daily CDS spreads of an sovereign entity *i* in country C_i, at time *t.* As already indicated, the non-sovereign sample entities in this paper are divided into two different sectoral groups (S): they are: (1) financial institutions (*F*) and (2) non-financial firms (*NF*). Thus, $\Delta cds_{jt}^{S_j,C_j}$ is the daily CDS spread changes of a non-sovereign entity *j*, which belongs to sector S_j located in country C_j. γ_{i0} and γ_{j0} are intercepts in the mean equation. The diagonal elements in equation (1), γ_{ii} and γ_{jj}, measure an entity's own spillover effects of changes in the CDS spread while the off-diagonal elements capture the cross-entity spillover effects of changes in the CDS spread. The parameters of the autoregressive terms γ_{ij} and γ_{ji} measure mean spillovers for the spread changes between entities *i* and *j*. For instance, if China's sovereign debtor (i.e., entity *i*) is paired with a financial institution in Japan (i.e., entity *j*), the coefficient γ_{ij} measures the impact of past spread changes of the Japanese financial institution on the current spread changes of the Chinese sovereign debtor. In contrast, γ_{ji} measures the cross spillover effects of past CDS spread changes of the Chinese sovereign debtor on the current CDS spread changes of the Japanese financial institution.

The residuals (ε_{it} and ε_{jt}) are assumed to have a conditionally normal distribution with conditional mean values of zero. Their corresponding conditional variances and covariances are given in matrix H_t expressed in equation (2). Elements in this matrix ($h_{ii,t}$ *and* $h_{jj,t}$) are the conditional variances for entities *i* and *j* at time *t*, and $h_{ij,t}$ describes the conditional covariance between them. Equation (2) models

[6] The bivariate GARCH approach is employed here to analyse the volatility spillover between the credit risks of two entities. However, we note that the long-term relationship between CDS spreads can be studied using the co-integration approach.

the dynamic process of H_t as a function of its own past values H_{t-1} and of past values of innovations ($\varepsilon_{it-1}\ and\ \varepsilon_{jt-1}$), allowing for own and cross influences in the conditional variances. However, tracking the impact of shocks in CDS spread changes is not straight forward due to the non-linearity of the GARCH models; the impact of a shock depends on past shocks in entity *i* and entity *j* and their interactions, as well as their past variances and covariance. Thus, equation (2) can be rewritten as:

$$h_{ii,t} = m_{ii}^2 + m_{ji}^2 + a_{ii}^2\varepsilon_{i,t-1}^2 + 2a_{ii}a_{ij}\varepsilon_{j,t-1}\varepsilon_{i,t-1} + a_{ij}^2\varepsilon_{j,t-1}^2 + g_{ii}^2h_{ii,t-1} + 2g_{ii}g_{ij}h_{ij,t-1} + g_{ij}^2h_{jj,t-1} \quad (3)$$

$$h_{ij,t} = m_{ii}m_{ji} + m_{jj}m_{ji} + a_{ii}a_{ji}\varepsilon_{i,t-1}^2 + (a_{ii}a_{jj} + a_{ji}a_{ij})\varepsilon_{j,t-1}\varepsilon_{i,t-1} + a_{ij}a_{jj}\varepsilon_{j,t-1}^2 + g_{ii}g_{ji}h_{ii,t-1} + (g_{ii}g_{jj} + g_{ji}g_{ij})h_{ij,t-1} + g_{ij}g_{jj}h_{jj,t-1} \quad (4)$$

$$h_{jj,t} = m_{ij}^2 + m_{jj}^2 + a_{ji}^2\varepsilon_{i,t-1}^2 + 2a_{jj}a_{ji}\varepsilon_{j,t-1}\varepsilon_{i,t-1} + a_{jj}^2\varepsilon_{j,t-1}^2 + g_{ji}^2h_{ii,t-1} + 2g_{ji}g_{jj}h_{ij,t-1} + g_{jj}^2h_{jj,t-1} \quad (5)$$

In the variance equation, the credit shocks to entity *j* can affect the variance of CDS spread changes for entity *i* through (a) the direct effect of past shocks in entity *j* and (b) the indirect effect from the interactions between credit shocks to entities *i* and *j*. In addition, the volatility of CDS spread changes for entity *i* can vary with past variances of CDS spread changes for entity *j* and the covariance between the spread changes of both entities. Thus, the parameters a_{ij} and g_{ij} in equation (2) respectively measure the cross transmission of past credit shocks (ε_{jt-1}) and conditional variances ($h_{jj,t-1}$) from firm *j* to sovereign *i* while a_{ji} and g_{ji} measure the cross linkages in the other direction. The log likelihood function $l(\theta) = -\frac{TN}{2}log2\pi - \frac{1}{2}\sum_{t=1}^{T}(log|H_t| + I_t'H_t^{-1}I_t)$ is maximised using the procedure introduced by Berndt et al. (1974) known as BHHH in order to obtain the estimates of equations (1) and (2) for each pair of entities.[7] θ denotes the set of 11 unknown parameters to be estimated (m_{ii}, m_{ij}, m_{jj}, a_{ii}, a_{ij}, a_{ji}, a_{jj}, g_{ii}, g_{ij}, g_{ji}, g_{jj}) and N is equal to two which refers to the number of CDS series in every pairing.

[7] The BEKK parameterization is selected over other multivariate GARCH specifications because it guarantees that the covariance matrix is positive-definite, it also allows the estimated correlations between the changes of CDS spreads to be time-varying (Li and Racine, 2007). Previous studies such as Li (2007) have employed this algorithm. McFadden and Train (2000) highlighted that the BHHH methods is "a more practical procedure for estimating time series" (p.8).

4. Empirical Findings

The results presented in this section should shed light on cross-country credit spillover effects between: (i) sovereign entities and financial institutions and (ii) sovereign entities and non-financial firms. Table 3 discusses the main findings from the models used to examine cross-country credit risk spillover effects between sovereigns and financial institutions; the estimates for the sovereigns and non-financial firm pairings are reported in Table 4. Each table is structured in the same fashion both for the sake of simplicity and in order to facilitate a visual inspection of the results. In particular, there are two panels included in each table; Panel A displays the averaged values of the parameters while Panel B shows the percentages of significant parameters multiplied by 100. The average value of a parameter is calculated by summing up the significant values for a parameter from each pairing and then dividing the sum by the total number of pairings. Such a procedure sets the value of the insignificant parameters to be zero. The associated country names of the underlying sovereign debtor and the firms are listed in the first row of each table. The parameters are presented in the first column of the table. The number of models estimated for each group is reported in the last row of each table. The spillover effects for the mean spread changes (i.e., γ_{ii}, γ_{ji}, γ_{ij} and γ_{jj}), shocks (i.e., a_{ii}, a_{ji}, a_{ij} and a_{jj}) and volatilities (i.e., g_{ii}, g_{ji}, g_{ij} and g_{jj}) are discussed in the remainder of this section.

Table 3 presents the findings for credit risk spillover effects between a sovereign in one country and a foreign financial institution. A number of findings emerge from a visual inspection of this table. First, a bidirectional transmission of spillovers in mean spread changes is identified for all pairs. The coefficients, γ_{ij} and γ_{ji}, are all significant at the 5% significance level according to the Panel B in Table 3. This finding is not surprising as financial institutions such as banks often hold international government debt creating a direct financial linkage with foreign sovereigns (IMF, 2010). For example, banks (including domestic and foreign) hold 43.03% of Japanese local currency government bonds in 2009, and foreign holding increased from 6.94% in 2009 to 11.23% in 2017. If the government's credit risk increases, the debt will be worth less and the bank's portfolio of assets may suffer a capital loss. In addition, if the bank gets into financial difficulty, it may sell the Government bonds in its portfolio holding which may increase the yield on the sovereign debt. Further, it may not purchase new sovereign

bonds adversely impacting the government's credit risk. Thus, a two-way feedback relationship between a "home" sovereign and foreign banks exists in our Asian sample of countries. The significant, large and positive values of the spillover coefficients for the mean spread changes imply a potential for financial contagion among the countries examined. When a bank faces a marked rise in the non-performing loans of one country, it is usually forced to recapitalise, lend less and adjust to its lower level of assets. This may lead to a significant deterioration of the financial position of sovereigns in other countries as the bank may be forced to lower its holding of their bonds. In addition, if the bank reduces its lending to companies in other countries, lower tax receipts may arise for the sovereign.

Second, these spillovers among the mean spread changes vary according to the nationality of the different pairings. For example, the average influence from foreign financial institutions to a sovereign (i.e., γ_{ij}) ranges from 0.155 for Japan's financial institutions and the Chinese sovereign to 0.630 for the South Korean sovereign and financial institutions in China. Meanwhile, financial institutions in China and South Korea are more affected by the Japanese sovereign debtor; the coefficients vary from 0.166 to 0.506 for the Japanese sovereign and Chinese financial pairing; the coefficients range from 0.138 to 0.664 for the Japanese sovereign and South Korean financial pairing. This finding suggests that the changes in the credit risk of Japanese sovereign debtor have strong effects on the financial institutions from other Asian states. By contrast, the sovereign debtor in South Korea was affected more by credit risk changes among financial institutions in China and Japan - given the large and positive average values of γ_{ij} documented; these varied from 0.630 for the Chinese financial institutions to 0.332 for the financial institutions of Japan. Taken together, the results from analysing spillovers in the mean spread changes suggest that there is a strong bidirectional transmission of credit risk between sovereigns and foreign financial institutions in Asia.

Third, the results for the conditional variance-covariance equations report the transmission of credit shocks and volatility spillover effects. The diagonal elements (i.e., a_{ii}, a_{jj}, g_{ii} and g_{jj}) in equation (2) capture the entity's own shock and volatility credit risk spillover effects. It is clear that, the diagonal elements are consistently significant across all pairs of countries in Table 3. Thus, the significant diagonal elements indicate a strong GARCH(1,1) process driving the conditional variances of CDS spread

changes for most Asian entities in 2009-2017. It is particularly true in the case of volatility spillovers, as the percentage of significant credit risk transmission from a sector's own past volatility is 100% (i.e., g_{ii} and g_{jj}). In addition, the sum of the coefficients regarding the GARCH (1,1) process on each variance equation measure the volatility persistence. The sum of coefficients on the GARCH effects from Table 3 tends to unity; therefore there is a high degree of volatility persistence in Asia.

Fourth, the off-diagonal parameters in the variance and co-variance equations capture the cross-transmission of shock and volatility. It is clear that with the exception of one pair (the sovereign debtor in South Korea and the financial institutions in China), there are significant bidirectional cross-country transmissions of both of shock and volatility spillover effects in the pairings studied. A unidirectional transmission of volatility spillovers is identified from the financial institutions in China to the sovereign debtor in South Korea. In contrast, the credit risk from all of the financial institutions in Japan spilled over via the volatility of spread changes to the sovereign debtors in China and South Korea. This finding again highlights the significant impact of Japan in transmitting credit risk spillovers in Asia.

Table 4 presents the results of the credit risk spillover effects between a home sovereign and a foreign non-financial firm. Looking at the mean spillovers part of this table, significant bidirectional linkages exist in the credit risks of sovereigns and non-financial firms. The corresponding large and positive parameters for the off-diagonal (i.e., γ_{ji} and γ_{ij}) indicate a positive interdependence between the sovereign credit risk in one country and the credit risk of non-financial firms in another country. As discussed before, the credit risk spillovers between sovereigns and non-financial firms are mainly through the lending and borrowing channel. Avdjiev et al. (2014) have pointed out that the increased borrowing of non-financial firms in emerging markets in their home country may give rise to financial stability concerns; in these circumstances, funds can be obtained abroad through their foreign affiliates and transferred to the home country; as a result, credit risk linkages between a non-financial firm and an foreign sovereign may arise from capital flows that are driven by financial operations rather than real activities. In particular, the magnitudes of γ_{ji} in Table 4 which are associated with the impact of past changes in sovereign's credit risk on non-financial firms are sizeable. Thus the large and significant value of γ_{ji} for pairs which include Japan's sovereign debtor suggests that changes in credit risk of the non-

financial firms in China (0.292) and South Korea (0.497) are largely associated credit risk changes for the Japanese sovereign. In addition, combining the findings from the mean spillovers of spread changes in Table 3, it is clear that Japan's sovereign debt plays an important role in linking the credit risk throughout North-East Asia regardless of the countries and sectors considered.

Turning to the transmission of credit risk from non-financial firms to sovereign entities, it is clear that the non-financial firms in Japan also exhibited a significant amount of influence on the Chinese sovereign debtor; the corresponding value of γ_{ij} for this pairing is 0.055 comparing with a value of 0.032 for γ_{ji}. One possible reason for this finding could be that Japanese non-financial firms have outsourced some of their production activities to China, which in turn has important implications for the tax revenues earned by the Chinese State; connections between China's sovereign and the credit risk of Japanese non-financial firms therefore appears to be important.

In contrast, the relationship between home sovereign and foreign non-financial firms is not symmetrical; Japan's non-financial firms are not affected by the credit risk of the sovereign debtors of China and South Korea. This finding is evidenced by the smaller percentages of significant off-diagonal parameters. For instance, the credit risk of less than half (i.e., 48%) of Japan's non-financial firms were affected by the credit risk of China's sovereign debt and on average the effect is insignificant while the credit risk of 44% of Japanese firms can affect the credit risk of China's sovereign debt with the effect being highly significant. The opposite is found between Japanese non-financial firms and South Korean sovereign debtor; on average, the spillover effect from Japanese firms to South Korean sovereign debtor is significant, but the reverse is not.

Furthermore, shocks and volatility spillovers are uncovered for different pairs involving non-financial firms. There is a strong GARCH(1,1) process driving the variance and covariance matrices and the sum of diagonal elements are approaching unity indicating the persistence of the GARCH process in the Asian credit derivative markets. A unidirectional transmission of volatility is present in the results comparing the corresponding values of g_{ij} and g_{ji}; that is, past volatility from the Chinese non-financial firms can directly impact the credit risk of sovereign debtors in South Korea. In contrast, a bidirectional transmission of short-term shocks (i.e., a_{ij} and a_{ji}) is identified between them. In other words, the credit

risk of the sovereign debtor in South Korea was strongly associated with the past shocks and volatilities from the Chinese non-financial firms in 2009-2017.

As a robustness check, we also repeat the analysis using 5-year CDS spread changes for the same sample. The results are similar to the findings reported in Table 3 and Table 4, in that bidirectional linkages between the sovereign debtor in one country and the financial institutions in another country are evidenced in long run. This result further highlights the strong cross-country interdependence of credit risk in the region. In other words, the transmission of credit risk can start either from the financial institutions or the sovereign debtor in one country to one of the other two Asian nations considered in this investigation. Furthermore, the intermediary role of Japan is confirmed by the 5-year data; past changes in Japan's CDS were strongly associated both with the credit risk of financial and non-financial firms in China as well as South Korea. In particular, changes in the credit risk of Japan's non-financial firms had significant impact on the credit risk of China and South Korea' sovereigns, respectively.

5. Conclusion

This paper investigates the credit risk spillover effects between sovereigns and firms across three Asian countries (i.e., China, Japan and South Korea) using daily CDS spread changes from January 2009 to December 2017. In order to examine sectoral characterises in the transmission of credit risk, firms are classified as financial institutions or non-financial firms. Credit risk spillover effects from past changes in CDS spreads, from past shocks and from past volatilities are estimated using the VAR(1)-bivariate-GARCH(1,1)-full-BEKK model proposed by Engle and Kroner (1995). In particular, equations for 164 pairs of CDS series are computed; one of the pair involves CDS data for one country's sovereign and the other in the pairing involves a foreign firm. Averaged values of parameters and the percentages of significant parameters are reported to identify the signs and magnitudes as well as the quantities of credit risk spillovers.

The findings can be summarised as follows. First, there is evidence of a significant spillover from an entity's own past credit risk implying a rejection of the weak form of the EMH; each Asian CDS series tends to be characterised by a strong GARCH(1,1) process. Second, the findings clearly indicate

evidence of cross-country credit risk spillovers between different sectors and countries both in relation to past mean spread changes, past shocks and past volatility. In particular, the transmission of shocks and volatilities are more pronounced than the transmission of credit risk news from past mean spread changes, although the magnitudes of shocks and the nature of the spillovers vary significantly from one country to another. In general, there are significant bidirectional transmissions of credit risk between sovereign and foreign (financial and non-financial) firms. This feature is especially pronounced for financial institutions since banks are more likely to hold international debts of foreign governments. Third, it is noticeable that the credit risk of Japan plays an important role in the spillover of credit risk to the two other Asian countries considered. This finding documents the results from Eichengreen and Luengnaruemitchai (2004), who identified the central importance of the Japanese debt markets in Asia. This finding also contributes to the literature using a more recent sample data drawn from credit derivative markets.

So far, the findings from a great number of empirical studies have evidenced that CDS contracts help to diversify and transfer default risk since the CDS market is relatively liquid and the aggregate views of millions of investors are distilled into CDS spreads by the many thousands of transactions involving these derivative instruments which take place every day. The findings on credit risk transmission in this paper suggest that the CDS market for Asian entities is immature and the potential for credit risk contagion between Sovereign and firm debt is quite sizeable. Forbes and Rigobon (2002) note, a fundamental change in cross-market linkages after a shock to one market is contagion, while interdependence implies a high transmission of risk during a given time period without any significant change in a cross-market relationship. However, the degree of interdependence between two entities or markets can indicate the possibility of contagion when a shock occurs to one entity or in a market. As Allen and Gale (2000) suggested, market completeness and interconnectedness are two characterises of the structural market affecting the financial contagion, meanwhile the extremely amplified interdependence between entities after a shock can lead to a risk of contagion. There is a trade-off in terms of the propagation of contagion between completeness and interconnectedness. Thus, policy-makers should take possible spillover effects into consideration when designing a policy (especially during the crisis) in order to protect the country against credit risk spillover.

The risk transmissions found in this paper point to the possibility of credit risk contagion and raise questions about how contagious any credit risk could possibly be between entities if a credit crisis occurs to an Asian entity or whether a financial system is resilient to a rise in the credit risk of one entity. A challenge for future work will be to explore the different channels of credit risk transmission between different sectors and countries. For example, the analysis of a number of factors which potentially determine or explain credit transmission channels will add to our understanding in this area. In addition, investigation of entities' asset holdings and liabilities to identify direct credit risk linkages between different CDS underlying reference entities located in advanced nations and developing countries would be particularly insightful for any analysis of spillover effects and their transmission channels. Finally, only three countries are studied in the current investigation; a broader study of more pairs of countries might add to our understanding of how credit risk is transmitted throughout Asia.

Figure 1
Evaluation of 1-year CDS time series: 2009-2017
This figure displays the dynamic of mean daily CDS spreads for sovereigns (SOV), financial institutions (F) and the non-financial firms (NF) for short and long runs, respectively. The averaged CDS spreads is calculated using the no-weighted averaged values of the CDS spreads for a given sector.

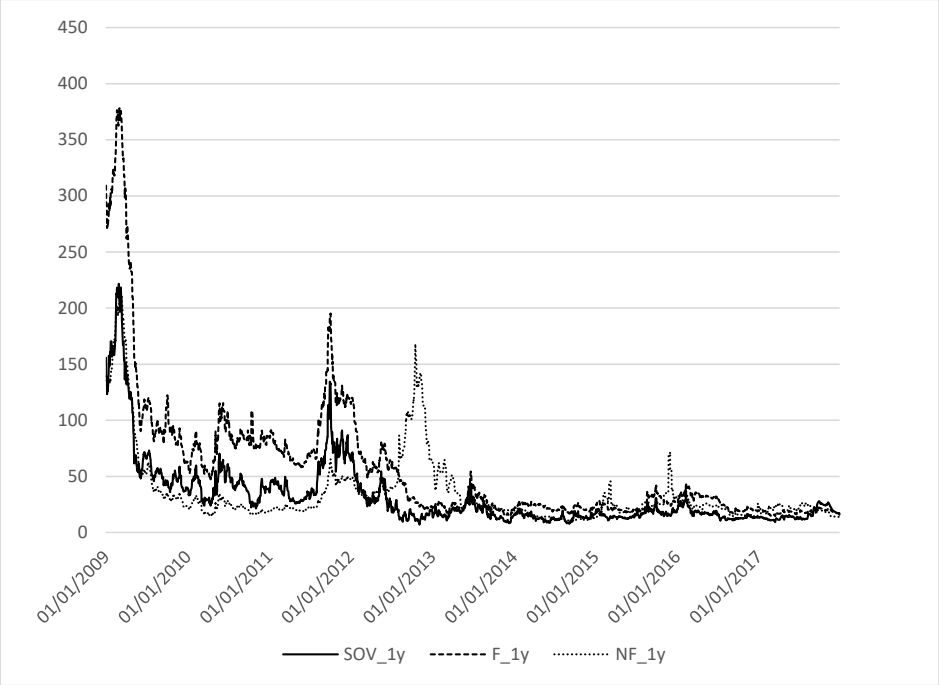

Figure 2
Evaluation of 5-year CDS time series: 2009-2017
This figure displays the dynamic of mean daily CDS spreads for sovereigns (SOV), financial institutions (F) and the non-financial firms (NF) for short and long runs, respectively. The averaged CDS spreads is calculated using the no-weighted averaged values of the CDS spreads for a given sector.

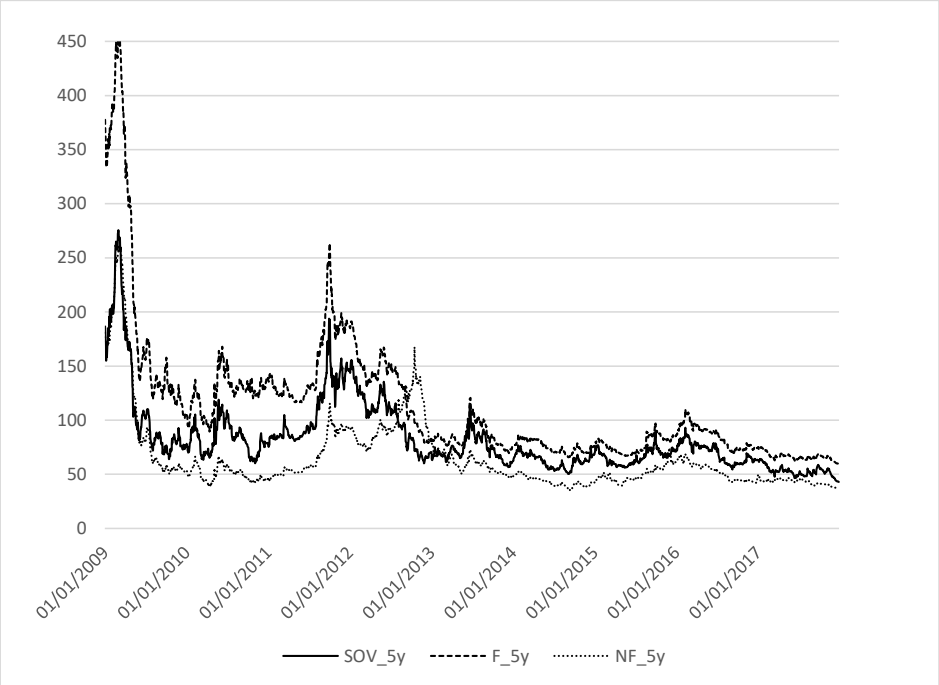

Table 1
Distribution of CDS sample
This table displays the number of sample firms according to their repsective sectors and countries. In particular, there is only one sovereign for each country in Panel A. Panel B displays the number of financial institutons in the financial sector and that for the non-financial sector is reported in Panel C.

	China	Japan	South Korea	Total number
Panel A: Sovereign sector				
Sovereign	1	1	1	3
Panel B: Financial sector	4	4	7	15
Bank	3	2	5	10
Other financial institution	1	2	2	5
Panel C: Non-financial sector	5	48	14	67
Consumer goods	0	3	1	4
Electric power	0	2	3	5
Energy company	0	1	3	4
Manufacturing	3	25	5	33
Service company	0	5	0	5
Telephone	1	2	1	4
Transportation	1	9	1	11
Other non-financial firm	0	1	0	1
Total number	10	53	22	85

Table 2
Summary statistics of Asian CDSs in 2009-2017
This table reports the statistics characterises of the sample used in this analysis. The maximum and minimum values of CDS spreads are shown in the left part of table. The mean and standard deviations of CDS spread changes are reported in the right part. The results of the stationarity tests of CDS spreads and changes in CDS spreads are reported as well. A 'YES' indicates the stationarity of all data series, while a 'NO' indicates that some series of data are non-stationarity.

	CDS spreads(bps)			CDS spread changes(bps)		
	Max.	Min.	Stationarity	Mean	SD	Stationarity
Panel A: 1-year CDSs						
Sovereigns						
China	156.01	5.74	No	-0.05	3.09	Yes
Japan	85.00	1.00	No	-0.01	2.10	Yes
South Korea	448.50	5.40	No	-0.12	4.85	Yes
Financial institutions						
China	307.00	5.27	No	-0.10	3.72	Yes
Japan	950.00	0.75	No	-0.11	8.44	Yes
South Korea	751.50	1.29	No	-0.16	4.71	Yes
Non-financial firms						
China	371.25	3.12	No	-0.09	2.90	Yes
Japan	981.71	0.50	No	-0.02	17.59	Yes
South Korea	742.50	3.91	No	-0.13	5.09	Yes
Panel B: 5-year CDSs						
Sovereigns						
China	259.50	47.03	No	-0.06	3.38	Yes
Japan	152.64	20.80	No	-0.01	2.43	Yes
South Korea	465.00	40.16	No	-0.11	4.45	Yes
Financial institutions						
China	397.50	50.73	No	-0.12	3.82	Yes
Japan	867.33	21.31	No	-0.12	7.32	Yes
South Korea	850.00	43.41	No	-0.16	4.82	Yes
Non-financial firms						
China	525.00	28.00	No	-0.11	3.19	Yes
Japan	996.23	0.16	No	-0.03	10.22	Yes
South Korea	850.00	28.77	No	-0.15	4.95	Yes

Table 3
Credit risk spillover effects between home-state sovereign and foreign financial institutions (1-year)
This table shows the results for the cross-country credit risk spillover effects between sovereigns and financial institutions using 1-year CDS spread changes. Panel A reports the averaged values of parameters at the 5% significance level and the percentages of significant parameters are shown in Panel B. The values in parenthesis are standard errors.

	CN^{SOV}:JP^{F}	CN^{SOV}:SK^{F}	JP^{SOV}:CN^{F}	JP^{SOV}:SK^{F}	SK^{SOV}:CN^{F}	SK^{SOV}:JP^{F}
Panel A: Averaged values of parameters						
γ_{ii}	0.000	-0.053	0.000	0.000	0.000	0.000
	(0.000)	(0.022)	(0.000)	(0.000)	(0.000)	(0.000)
γ_{ij}	0.155	0.398	0.166	0.138	0.630	0.332
	(0.041)	(0.031)	(0.025)	(0.024)	(0.069)	(0.082)
γ_{ji}	0.173	0.895	0.506	0.664	0.357	0.153
	(0.057)	(0.055)	(0.065)	(0.102)	(0.043)	(0.04)
γ_{jj}	0.050	0.053	0.000	0.000	0.000	0.044
	(0.017)	(0.017)	(0.000)	(0.000)	(0.000)	(0.016)
a_{ii}	0.000	0.053	0.029	0.049	0.014	-0.018
	(0.012)	(0.013)	(0.008)	(0.031)	(0.006)	(0.011)
a_{ij}	-0.044	0.004	0.032	0.024	0.054	-0.010
	(0.049)	(0.002)	(0.01)	(0.028)	(0.022)	(0.005)
a_{ji}	-0.023	-0.002	-0.037	0.032	0.064	0.065
	(0.021)	(0.006)	(0.009)	(0.024)	(0.007)	(0.018)
a_{jj}	0.122	0.072	0.031	0.065	0.025	0.094
	(0.019)	(0.027)	(0.016)	(0.03)	(0.005)	(0.007)
g_{ii}	0.963	0.951	0.962	0.967	0.948	0.950
	(0.011)	(0.054)	(0.094)	(0.013)	(0.028)	(0.006)
g_{ij}	0.005	0.014	0.023	-0.014	-0.017	-0.027
	(0.017)	(0.006)	(0.003)	(0.006)	(0.008)	(0.005)
g_{ji}	0.021	-0.006	-0.023	-0.007	0.000	0.036
	(0.011)	(0.001)	(0.004)	(0.003)	(0.000)	(0.009)
g_{jj}	0.929	0.938	0.954	0.946	0.963	0.958
	(0.007)	(0.050)	(0.027)	(0.026)	(0.023)	(0.015)
Panel B: Percentages of significant parameters						
γ_{ii}	0	86	0	0	0	0
γ_{ij}	100	100	100	100	100	100
γ_{ji}	100	100	100	100	100	100
γ_{jj}	25	57	0	0	0	25
a_{ii}	50	43	25	86	25	75
a_{ij}	100	14	25	57	50	75
a_{ji}	50	29	50	57	25	75
a_{jj}	75	57	50	43	25	75
g_{ii}	100	100	100	100	100	100
g_{ij}	100	14	50	57	50	100
g_{ji}	100	14	50	43	0	75
g_{jj}	100	100	100	100	100	100
No. of pairs	4	7	4	7	4	4

Table 4
Credit risk spillover effects between home-state sovereign and foreign non-financial firms (1-year)
This table shows the results for the cross-country credit risk spillover effects between sovereigns and non-financial firms using 1-year CDS spread changes. Panel A reports the averaged values of parameters at the 5% significance level and the percentages of significant parameters are shown in Panel B. The values in parenthesis are standard errors.

	CN^{SOV}:JP^{NF}	CN^{SOV}:SK^{NF}	JP^{SOV}:CN^{NF}	JP^{SOV}:SK^{NF}	SK^{SOV}:CN^{NF}	SK^{SOV}:JP^{NF}
Panel A: Averaged values of parameters						
γ_{ii}	0.000	-0.022	0.000	0.000	0.000	0.000
	(0.000)	(0.01)	(0.000)	(0.000)	(0.000)	(0.000)
γ_{ij}	0.055	0.398	0.138	0.139	0.827	0.130
	(0.018)	(0.052)	(0.024)	(0.032)	(0.113)	(0.041)
γ_{ji}	0.032	0.645	0.292	0.497	0.277	0.022
	(0.021)	(0.052)	(0.038)	(0.097)	(0.042)	(0.016)
γ_{jj}	0.009	0.000	0.000	-0.009	0.005	0.011
	(0.003)	(0.000)	(0.000)	(0.004)	(0.017)	(0.003)
a_{ii}	0.075	0.086	0.022	0.015	0.063	0.064
	(0.029)	(0.027)	(0.009)	(0.013)	(0.01)	(0.023)
a_{ij}	0.000	0.041	0.009	-0.011	0.030	0.008
	(0.001)	(0.021)	(0.001)	(0.004)	(0.008)	(0.006)
a_{ji}	-0.006	0.008	-0.019	0.036	0.026	-0.016
	(0.003)	(0.003)	(0.007)	(0.011)	(0.011)	(0.004)
a_{jj}	0.150	0.072	0.021	0.070	0.066	0.083
	(0.022)	(0.025)	(0.027)	(0.019)	(0.008)	(0.026)
g_{ii}	0.947	0.935	0.756	0.955	0.934	0.954
	(0.029)	(0.052)	(0.012)	(0.018)	(0.049)	(0.016)
g_{ij}	0.001	-0.023	0.003	-0.001	-0.012	0.003
	(0.001)	(0.007)	(0.004)	(0.001)	(0.004)	(0.004)
g_{ji}	-0.002	0.031	0.053	-0.006	0.000	0.003
	(0.005)	(0.008)	(0.022)	(0.005)	(0.000)	(0.002)
g_{jj}	0.885	0.927	0.963	0.966	0.961	0.947
	(0.027)	(0.064)	(0.021)	(0.024)	(0.150)	(0.017)
Panel B: Percentages of significant parameters						
γ_{ii}	0	29	0	0	0	0
γ_{ij}	44	100	80	100	100	48
γ_{ji}	48	100	80	100	100	40
γ_{jj}	15	0	0	7	40	15
a_{ii}	71	57	40	43	20	60
a_{ij}	29	21	20	7	40	52
a_{ji}	15	7	40	43	20	19
a_{jj}	60	50	80	43	20	69
g_{ii}	98	100	80	100	100	100
g_{ij}	23	36	60	14	40	65
g_{ji}	17	14	40	29	0	40
g_{jj}	94	100	100	100	100	100
No. of pairs	48	14	5	14	5	48

Table 5
Credit risk spillover effects between home-state sovereign and foreign financial institutions (5-year)
This table shows the results for the cross-country credit risk spillover effects between sovereigns and financial institutions.

	CN^{SOV}:JP^{F}	CN^{SOV}:SK^{F}	JP^{SOV}:CN^{F}	JP^{SOV}:SK^{F}	SK^{SOV}:CN^{F}	SK^{SOV}:JP^{F}
Panel A: Averaged values of parameters						
γ_{ii}	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
γ_{ij}	0.161	0.475	0.221	0.199	0.678	0.225
	(0.037)	(0.032)	(0.03)	(0.031)	(0.061)	(0.056)
γ_{ji}	0.193	0.954	0.541	0.771	0.492	0.175
	(0.057)	(0.045)	(0.059)	(0.103)	(0.033)	(0.048)
γ_{jj}	0.087	0.024	0.000	0.000	0.000	0.086
	(0.031)	(0.008)	(0.000)	(0.000)	(0.000)	(0.031)
a_{ii}	0.148	0.225	0.183	0.070	0.000	0.135
	(0.053)	(0.043)	(0.038)	(0.018)	(0.000)	(0.028)
a_{ij}	0.000	0.000	0.000	-0.008	0.051	0.009
	(0.000)	(0.000)	(0.000)	(0.003)	(0.004)	(0.005)
a_{ji}	0.017	-0.001	0.000	0.000	0.008	-0.041
	(0.005)	(0.018)	(0.000)	(0.000)	(0.003)	(0.012)
a_{jj}	0.083	0.134	0.095	0.130	0.000	0.176
	(0.013)	(0.035)	(0.028)	(0.025)	(0.000)	(0.038)
g_{ii}	0.929	0.945	0.898	0.955	0.721	0.950
	(0.036)	(0.024)	(0.056)	(0.124)	(0.033)	(0.015)
g_{ij}	-0.057	0.000	0.000	0.011	0.022	-0.008
	(0.021)	(0.000)	(0.000)	(0.002)	(0.009)	(0.004)
g_{ji}	0.036	-0.015	0.016	0.000	0.000	0.002
	(0.010)	(0.006)	(0.005)	(0.000)	(0.000)	(0.009)
g_{jj}	0.962	0.933	0.965	0.706	0.711	0.935
	(0.015)	(0.032)	(0.026)	(0.014)	(0.019)	(0.028)
Panel B: Percentages of significant parameters						
γ_{ii}	0	0	0	0	0	0
γ_{ij}	100	100	100	100	100	100
γ_{ji}	100	100	100	100	100	100
γ_{jj}	50	25	0	0	0	50
a_{ii}	75	100	50	50	0	75
a_{ij}	0	0	0	25	25	25
a_{ji}	25	50	0	0	50	25
a_{jj}	50	75	75	50	0	75
g_{ii}	100	100	100	100	75	100
g_{ij}	75	0	0	25	75	50
g_{ji}	25	25	25	0	0	50
g_{jj}	100	100	100	75	75	100
No. of pairs	4	7	4	7	4	7

Table 6
Credit risk spillover effects between home-state sovereign and foreign non-financial firms (5-year)
This table shows the results for the cross-country credit risk spillover effects between sovereigns and non-financial firms.

	CN^{SOV}:JP^{NF}	CN^{SOV}:SK^{NF}	JP^{SOV}:CN^{NF}	JP^{SOV}:SK^{NF}	SK^{SOV}:CN^{NF}	SK^{SOV}:JP^{NF}
Panel A: Averaged values of parameters						
γ_{ii}	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
γ_{ij}	1.263	0.432	0.231	0.188	0.762	0.121
	(0.412)	(0.04)	(0.04)	(0.03)	(0.07)	(0.037)
γ_{ji}	0.100	0.867	0.400	0.739	0.400	0.080
	(0.033)	(0.053)	(0.048)	(0.103)	(0.031)	(0.029)
γ_{jj}	-0.004	-0.012	0.000	-0.013	0.000	-0.001
	(0.012)	(0.005)	(0.000)	(0.006)	(0.000)	(0.012)
a_{ii}	0.039	0.113	0.057	0.152	0.067	0.073
	(0.015)	(0.031)	(0.018)	(0.040)	(0.023)	(0.026)
a_{ij}	-0.004	0.009	0.028	-0.012	-0.012	0.010
	(0.004)	(0.004)	(0.004)	(0.007)	(0.007)	(0.012)
a_{ji}	0.011	-0.024	0.000	0.013	0.012	0.007
	(0.015)	(0.002)	(0.000)	(0.007)	(0.004)	(0.008)
a_{jj}	0.097	0.093	0.000	0.206	0.100	0.135
	(0.016)	(0.028)	(0.000)	(0.053)	(0.016)	(0.028)
g_{ii}	0.876	0.950	0.575	0.951	0.969	0.944
	(0.016)	(0.061)	(0.064)	(0.048)	(0.013)	(0.015)
g_{ij}	-0.003	-0.007	0.005	0.007	0.010	-0.009
	(0.002)	(0.005)	(0.001)	(0.004)	(0.003)	(0.006)
g_{ji}	0.021	0.007	0.000	0.008	-0.012	0.044
	(0.006)	(0.003)	(0.000)	(0.007)	(0.005)	(0.008)
g_{jj}	0.882	0.937	0.751	0.839	0.918	0.929
	(0.019)	(0.045)	(0.021)	(0.033)	(0.031)	(0.012)
Panel B: Percentages of significant parameters						
γ_{ii}	0	0	0	0	0	0
γ_{ij}	65	100	100	100	100	55
γ_{ji}	65	100	100	100	100	59
γ_{jj}	23	14	0	14	0	23
a_{ii}	50	64	40	79	40	65
a_{ij}	60	21	20	21	40	60
a_{ji}	42	21	0	21	20	35
a_{jj}	60	71	0	86	80	81
g_{ii}	92	100	60	100	100	100
g_{ij}	54	36	20	29	20	67
g_{ji}	42	43	0	57	40	52
g_{jj}	94	100	80	93	100	100
No. of pairs	47	14	5	14	5	47

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