Bond Spreads, Market Integration and Contagion in the 2007-2008 Crisis

Jae-Young Kim, Dong-Hyeon Ahn and Eun-Young Ko

Yield spreads on sovereign bonds represent market expectations for the economic performance of issuing countries. In the international financial market, yield spreads also reflect the extent to which the issuing countries are integrated into the global market. We analyze market integration and interconnectedness for several countries by studying the characteristics of yield spreads of long-term bonds from December 1, 2006 to March 31, 2010. Our analysis is based on a latent factor model with the following factors: world factor, the regional factor, the country-specific factor, and the US shock. Our results show that there are clear contagion effects of the 2007-2008 crisis, which originated from the U.S., on all emerging economies under consideration. Stronger effects are observed on countries with relatively higher susceptibility to world factors before crisis. Mixed effects of regional factors are shown with similarities and differences across regions and countries. Relatively stronger effects of country-specific factors are shown in Korea, Japan, the U.K., and the U.S.

Keywords: Market integration, Contagion, Economic crisis, Factor analysis

JEL Classification: C22, F36, F41

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I. Introduction

Market linkages are becoming increasingly important in the international environment. In particular, linkages in financial markets receive more attention during financial crisis as decision makers in markets become keener to receive available information across markets. The financial crisis, which began in 2007, is mainly a crisis in debt markets. For example, the market of mortgage-backed securities in the U.S. had been in extreme downturn since August 2007. In this paper, we study the nature of market integration and linkages around the period of recent financial crisis by analyzing bond spreads during the period.

Yield spreads of bonds with the same maturity represents relative attractiveness of the bonds affected by profitability, default risk, and liquidity. These determinants of bond values are closely related to market connectedness and integration in the international environment. We need a multivariate specification to consider common shocks to bond spreads of multiple economies. We may need to consider heteroskedastic nature of volatilities of shocks. In these cases, the number of parameters to be estimated is usually very large. To avoid this curse of dimensionality and reduce the dimension of parameters, we use a latent factor model. This approach makes it possible to decompose observed volatility in bond spreads to various components with interpretable identification. The latent factor approach also has the advantage of quantifying the effects of contagion of shocks across markets.

We consider four potential factors that influence bond spreads, as follows: the world factor, the regional factor, the country-specific factor, and the U.S. risk factor. The first, second and fourth factors are common factors. The third factor is country specific. The world factor captures the effect of worldwide events. In the period of seemingly worldwide boom before the 2007-2008 crisis, most countries were able to issue bonds under favorable conditions. The regional factor reflects common events in each region. Financial markets within each region are integrated to a certain degree among one another, and such integration often causes movements of markets in the same direction. For example, in the period of Asian economic crisis, many economies underwent similar adverse effects in their financial markets. The country specific factor affects only each country. For example, the credit card crisis in Korea in the early 2000s caused a slowdown of Korean economy but did not have noticeable effects on other economies or regions. The fourth factor is for the contagion channel of shocks originating from the U.S. in 2007-2008.

The latent factor model describes dynamics of bond yield spreads with unobservable factors. This approach helps avoid modeling of a specific structure and allows us to absorb it in latent factors. Thus, this approach not only reduces the dimension of parameters to estimate but also avoids the problem of model misspecification. A number of authors use the latent factor model to analyze financial markets. Diebold and Nerlove (1989), Ng, Engle and Rothschild (1992), Mahieu and Schotman (1994), King, Sentana and Wadhwani (1994), and Forbes and Rigobon (2002) studied currency and equity markets based on the latent factor model. Gregory and Watts (1995) explored bond yields across countries. Dungey, Martin and Pagan (2000) applied a latent factor model to bond spreads. Kose, Otrok and Whiteman (2003) studied the common dynamic properties of business-cycle fluctuations across countries, regions, and the world based on a Bayesian dynamic latent factor model. The problem of transmission and contagion of financial crises has been studied by Dungey *et al.* (2011) based on the latent factor model.

We analyzed data from 9 countries as follows: 3 Latin American countries (Argentina, Brazil, and Mexico), 3 Asian countries (Indonesia, Korea, and Philippines), and 3 developed countries (Japan, UK, and US). The data are daily observations of spreads on bond yields from December 1, 2006 to March 31, 2010. The spreads of the six emerging economies (Latin America and Asia) are the long-term sovereign bonds and are related to a comparable risk-free bond, whereas the spreads of the developed economies are the long-term BBB corporate bonds issued in the domestic economy and is related to a comparable risk free benchmark.

We obtained the following results from our empirical analysis. First, for most countries, the level and volatility of bond spreads have shown an overall increase during the financial crisis. Second, the absolute value of correlation of bond spreads has increased in most cases during the crisis. Third, there are clear contagion effects of the 2007-2008 crisis, which originated from the U.S. Fourth, contagion from the U.S. shock has global-level effects on all the emerging economies under consideration. Fifth, mixed effects of regional factors are shown, with similarities and differences across regions and countries. Finally, contagion effects are stronger for countries with relatively higher susceptibility to world factors before the crisis.

Our discussion in the rest of the paper proceeds as follows. Section II presents the model and explains estimation methods used for our empirical analysis. We used the latent factor model with a contagion effect. The empirical characteristics of the data in Section III-A are discussed. The main empirical results are presented and discussed in Section III-B. Concluding remarks are provided in Section IV.

II. The Model and Estimation Methods

Our analysis is based on a latent factor model with four factors. We introduce the basic model of interdependence of asset markets during non-crisis periods. Then, we explain the extension of the model to include the effect of a crisis. Our model originated from the factor models used in Sharpe (1964) and Solnik (1974). Similar models are used by Corsetti, Pericoli and Sbracia (2001, 2005), Forbes and Rigobon (2002), Kim and Park (2004), Bekaert, Harvey and Ng (2005), Dungey *et al.* (2006, 2011), and Dungey and Martin (2007).

A. The model

Let $r_{i,t}$ be the bond yield of the i-th ($i = 1, \ldots, N$) market at time t and $r_{0,t}$ be the bond yield of a comparable risk-free benchmark. The bond spread of the i-th market is $s_{i,t} = r_{i,t} - r_{0,t}$. The spread $s_{i,t}$ is also considered the premium of the i-th bond yield over a risk-free counterpart.

Let w_t be the world factor that has common effects on all the markets, R_t^A and R_t^L be the regional factors for Asia and Latin America, respectively. These regional factors have common effects on all the markets in each region. Also, let $u_{1,t}$ be the idiosyncratic factor that captures specific shocks to the i-th market. These factors affect the variation of bond spreads, Δs_t as follows:

$$\Delta s_{i,t} = \lambda_i w_t + \gamma^{i,A} R_t^A + \gamma^{i,L} R_t^L + \sigma_i u_{i,t} \tag{1}$$

where λ_i, $\gamma^{i,A}$, $\gamma^{i,L}$, σ_i are factor loadings, respectively, for the world factor, the two regional factors, and the country-specific shock. With the factor loadings, we can normalize the variances of the factors to be unity. We also assume that all the factors are independent of each other: $E[w_t, R_t^k] = 0$ for $k = A, L$, $E[R_t^A, R_t^L] = 0$, $E[u_{i,t}, u_{j,t}] = 0$ for $i \neq j$, $E[u_{i,t}, w_t] = 0$ for $i = 0, 1, \ldots, N$ and $E[u_{i,t}, R_t^k] = 0$ for $i = 0, 1, \ldots, N$ and $k = A, L$.

To complete the specification of the basic model, we assume that the disturbance processes are distributed as the mean-zero Gaussian processes with the autoregressive conditional heteroskedasticity (ARCH) in the conditional variance as follows:

$$\begin{aligned} f_{j,t} &= v_{j,t}, \\ v_{j,t} &\sim N(0, \sigma_{j,t}^2) \\ \sigma_{j,t}^2 &= (1 - \alpha_j) + \alpha_j\, \sigma_{j,t-1}^2. \end{aligned} \tag{2}$$

where $j = 1, 2, 3$ and $\{f_{1,t}, f_{2,t}, f_{3,t}\} = \{w_t, R_t^A, R_t^L\}$. This structure of factors has been used by Diebold and Nerlove (1989) to analyze the exchange rate volatility, by Engle, Ng, and Rothschild (1990) to analyze the treasury bills and by Kim and Park (2004) to analyze bond spreads of emerging economies during the Asian financial crisis. Dungey *et al.* (2000) and Dungey *et al.* (2011) have studied the volatility of various assets.

We want to include the effect of the financial crisis that originated from the U.S. in 2007-2008 in the model. We augment the model (1) by including the idiosyncratic shocks from the U.S. $u_{us,t}$ for the crisis period (via the indicator I_t in (3)) into each equation of the factor model. Then, the full factor model for country i is represented by the following:

$$\Delta s_{i,t} = \lambda_i\, w_t + \gamma^{i,A}\, R_t^A + \gamma^{i,L}\, R_t^L + \sigma_i\, u_{i,t} + \zeta_i\, I_t\, u_{us,t}, \tag{3}$$

where the strength of contagion from the U.S. market is controlled by the parameter ζ_i, and I_t is the indicator that takes 1 for the crisis period. Notice that $\zeta_{us} = 0$ for identification, which implies that the U.S. risk factor is included in the idiosyncratic shock of the U.S.[1] Based on the model (3), we can evaluate the contribution of each factor to the total volatility in the movement/variation of the yield spread of each country.

[1] Notice that the U.S. risk factor is distinct from the world factor since the former presents only in the crisis period while the latter presents in the whole period.

Thus, the variance of the yield spread variation can be decomposed as follows:

$$\begin{aligned}\mathrm{Var}(\Delta s_{i,t}) &= \mathrm{Var}(\lambda_i\, w_t) + \mathrm{Var}(\gamma^{i,A}\, R_t^A) + \mathrm{Var}(\gamma^{i,L}\, R_t^L) \\ &+ \mathrm{Var}(\zeta_i\, I_t\, u_{us,t}) + \mathrm{Var}(\sigma_i\, u_{i,t}).\end{aligned} \tag{4}$$

The contribution of each factor to the volatility of the bond spread variation is, then, defined as follows:

Contribution to the world factor $\dfrac{\lambda_i^2}{\mathrm{Var}(\Delta s_{i,t})}$,

Contribution to the regional factor $\dfrac{(\gamma_i^k)^2}{\mathrm{Var}(\Delta s_{i,t})}$,

Contribution to the idiosyncratic factor $\dfrac{\sigma_i^2}{\mathrm{Var}(\Delta s_{i,t})}$,

Contribution to the contagion facto $\dfrac{\zeta_i^2 I_t}{\mathrm{Var}(\Delta s_{i,t})}$. (5)

where $\mathrm{Var}(\Delta s_{i,t}) = \lambda_i^2 + (\gamma_i^A)^2 + (\gamma_i^L)^2 + \zeta_i^2 + \sigma_i^2$.

B. Estimation Methods

We obtain an estimate of the parameter by using the Kalman filter. However, the estimation by Kalman filter yields inconsistent estimator because of the nonlinearity of the ARCH structure. For this reason, Gourieroux, Monfort and Renault (1993) and Gourieroux and Monfort (1996) recommended the estimation of the model by a simulation-based indirect inference method. We explain the simulation-based indirect inference method in the following.

Denote by $M = M(\theta)$ a given model where θ is a vector of parameters that characterize the model M. Suppose that a direct estimation method such as the maximum likelihood method, the method of moments or the least square method is not tractable to this model. In this case, we consider an approximate model M^α, which is more tractable than M. We call it an instrumental model for the estimation of θ. The instrumental model is characterized by a vector of parameters θ^α, $M^\alpha = M^\alpha(\theta^\alpha)$.

Let $X_T(\theta) \equiv \{x_t(\theta)\}_{t=1}^{T}$ be a sequence of observed data. Let $\hat{\theta}_T^{\alpha} = \hat{\theta}^{\alpha}(X_T(\theta))$ be an estimator of $\hat{\theta}^{\alpha}$ based on $X_T(\theta)$. Denote by $X_{sT}(\theta) \equiv \{x_t^s(\theta)\}_{t=1}^{T}$ a sequence of simulated data from the model M conditional on the parameter θ for $s = 1, \ldots, S$. Let $\hat{\theta}_{sT}^{\alpha} = \hat{\theta}^{\alpha}(X_{sT}(\theta))$ be an estimator of θ^{α} based on $X_{sT}(\theta)$. Then, our indirect estimator of θ, $\hat{\theta}_{ST}$ is defined as follows:

$$\hat{\theta}_{ST}(W) = \arg\min_{\theta} \left[\hat{\theta}_T^{\alpha} - \frac{1}{S} \sum_{s=1}^{S} \hat{\theta}_{sT}^{\alpha}(\theta) \right]' W \left[\hat{\theta}_T^{\alpha} - \frac{1}{S} \sum_{s=1}^{S} \hat{\theta}_{sT}^{\alpha}(\theta) \right] \quad (6)$$

where W is the weighting matrix.

When we assume the ARCH structure for the variances of the factors, we can use the indirect inference method explained above for consistent estimation. In the estimation process, we use the Kalman filter as the likelihood function of an approximate model. The state-space model for the Kalman filter is represented as follows:

$$\text{(Observation equation)}\ \Delta s_t = \Gamma f_t + \sigma u_t, \quad (7)$$

$$\text{(State equation)}\ f_{j,t} = \sqrt{(1-\alpha^j) + \alpha^j f_{j,t-1}^2}\,\eta_{j,t}$$

where $\Gamma = \{\lambda, \gamma^A, \gamma^L\}$ and $\alpha = \{\alpha^w, \alpha^A, \alpha^L\}$. $\eta_{j,t}$ is the i.i.d. standard normal process and is independent of u_t. Although the state equation is nonlinear, we can apply the Kalman filter to have an updated f_t from f_{t-1} for the state equation.

III. Empirical Results

A. Data and Descriptive Statistics

Data are obtained from 9 countries: 3 Latin American countries (Argentina, Brazil, and Mexico), 3 Asian countries (Indonesia, Korea, and Philippines), and 3 developed economies (Japan, the U.K., and the U.S.). This choice of countries for our data set is partially due to the existing work of Dungey *et al.* (2011). The choice of countries for our data set, when compared with alternatives (*i.e.*, other countries), is somewhat arbitrary. The empirical results might depend on the choice of the set of countries to some extent.

The spreads of the six emerging economies (Latin America and Asia) are the long-term sovereign bonds related to a comparable risk-free bond. These sovereign bonds are issued in the U.S. dollar, and the

TABLE 1
DESCRIPTIVE STATISTICS

Before the Crisis (December 2006 – July 2007)

	mean	variance	Min	Max
AR	319.6	92.0	223.2	627.2
BR	125.8	26.9	79.1	185.6
MX	1.6	10.6	-23.9	41.0
IN	192.3	27.0	160.0	271.0
KR	79.5	3.1	70.8	86.8
PH	166.9	23.3	117.9	220.8
JP	45.4	12.6	15.6	64.9
UK	103.3	13.5	88.9	142.5
US	123.0	18.9	99.3	182.5

*The unit is bp.

Correlation Coefficients

	AR	BR	MX	IN	KR	PH	JP	UK	US
AR	1.00								
BR	0.22	1.00							
MX	0.17	0.64	1.00						
IN	0.82	0.48	0.50	1.00					
KR	-0.17	-0.37	-0.25	-0.17	1.00				
PH	0.52	0.77	0.70	0.86	-0.26	1.00			
JP	-0.72	0.14	0.24	-0.42	0.03	-0.10	1.00		
UK	0.88	0.12	0.24	0.86	-0.14	0.58	-0.66	1.00	
US	0.84	0.19	0.32	0.89	-0.11	0.64	-0.58	0.93	1.00

spread is calculated against the corresponding U.S. Treasury bill rate. The sovereign bond reflects the true costs of new foreign capital for the issuing country. The spreads of the developed countries, on the other hand, are the long-term BBB corporate bonds issued in the domestic market relative to the comparable risk-free Treasury bond in each country. The data period is from December 1, 2006 to March 31, 2010. This data period is from the pre-crisis period to the period of crisis and afterward. All data are obtained from *Datastream*. The descriptive statistics for the bond spread is presented in Table 1. The mean and standard error of spread series for most countries showed large increases during the crisis period. The correlation coefficient of each pair of bond spreads (reported in Table 1) measures linear association of the pair of spreads. Correlations of the bond spread increase during

Table 1
(Continued)

During the Crisis (August 2007 – September 2008)

	mean	variance	min	Max
AR	1256.1	921.8	350.8	3522.2
BR	217.4	102.3	75.3	581.9
MX	208.0	131.0	7.8	489.4
IN	463.9	241.0	190.5	1486.3
KR	206.3	138.3	70.8	562.5
PH	297.8	137.9	148.1	785.1
JP	83.0	25.5	17.7	138.3
UK	282.1	74.7	134.5	416.8
US	351.4	116.4	159.0	652.2

Correlation Coefficients

	AR	BR	MX	IN	KR	PH	JP	UK	US
AR	1.00								
BR	0.92	1.00							
MX	0.93	0.90	1.00						
IN	0.92	0.94	0.92	1.00					
KR	0.97	0.91	0.94	0.93	1.00				
PH	0.88	0.94	0.91	0.93	0.91	1.00			
JP	0.25	0.18	0.44	0.24	0.28	0.27	1.00		
UK	0.70	0.62	0.83	0.67	0.70	0.64	0.71	1.00	
US	0.77	0.69	0.80	0.69	0.73	0.68	0.45	0.78	1.00

the crisis. This result reflects risk spillover effects in the international market. Risk spillover effects in financial markets during crisis have been studied by Hwang and Kim (2015), among others.

We then check the persistence of spread series by testing the unit root. The unit root null is not rejected for the spread series of all countries. In Table 2, we show the results of unit root tests for the bond spreads. As shown, the unit root null is not rejected at 5% test for the spread series of all the countries. The persistence and instability of bond spreads are well expected during the period of 2007-2008 financial crisis, as implied in the unit root hypothesis. In our factor analysis, we use the first difference of bond spreads, which is the variation of spread series to remove the unit root. Appendix Figure 1 shows the series of bond spreads and their first differences. The bond spread variation measured by the difference of the series clearly exhibits common time-

TABLE 2
RESULTS OF UNIT ROOT TESTS

ADF-Test, 5% level

	AR	BR	MX	IN	KR	PH	JP	UK	US
T-stat	-1.9358	-1.7917	-1.2296	-1.8115	-1.3223	-1.6105	-2.5882	-1.4012	-2.2243
P-value	0.3158	0.3849	0.6634	0.375	0.6209	0.4768	0.0958	0.5829	0.1978

PP-Test, 5% level

	AR	BR	MX	IN	KR	PH	JP	UK	US
T-stat	-1.5107	-1.8564	-1.1487	-2.1032	-1.3706	-1.7044	-2.5011	-1.6524	-1.8555
P-value	0.5279	0.3532	0.698	0.2436	0.5978	0.4287	0.1155	0.4553	0.3536

TABLE 3
PARAMETER ESTIMATES

	λ_i	γ_i^L	γ_i^A	φ_i	κ_i
AR	0.332	-0.152		-0.092	-0.878
BR	0.047	0.093		0.038	-0.053
MX	0.031	0.050		-0.081	-0.039
IN	0.072		0.109	0.221	-0.139
KR	-0.000		0.024	0.122	-0.026
PH	0.042		0.102	0.064	-0.069
JP	0.005			-0.060	0.006
UK	0.013			0.132	0.009
US	0.232			0.085	

varying volatility. This feature of the series can be properly modelled by ARCH.

B. Empirical Findings

Our main empirical findings are presented in Table 4, which is explained in the following. First, the world factor has certain amount of effects on the volatility of yield spreads for all emerging economies. This implies that the emerging economies are highly integrated into the global market. Second, idiosyncratic domestic factors dominate in all the developed countries, including Korea, which is classified as an advanced emerging economy.

Third, contagion effects of the U.S. shock emerge quite substantially

Table 4
Variance Decomposition

Non-Crisis Period
(Dec. 2006 – July 2007, Oct. 2008 – March 2010) (Unit: %)

	world	Latin	Asia	idiosync
AR	77.7	16.3	-	6.0
BR	18.0	70.0	-	12.0
MX	9.8	25.1	-	65.1
IN	7.9	-	17.9	74.2
KR	0.0	-	3.8	96.2
PH	11.1	-	64.0	24.9
JP	0.7	-	-	99.3
UK	1.0	-	-	99.0
US	11.8	-	-	88.2

Crisis Period (August 2007 – Sept. 2008) (Unit: %)

	world	Latin	Asia	idiosync	U.S. risk
AR	12.1	2.5	-	0.9	84.5
BR	14.6	56.9	-	9.7	18.7
MX	8.5	21.8	-	56.5	13.1
IN	6.1	-	13.9	57.4	22.6
KR	0.0	-	3.7	92.0	4.4
PH	8.6	-	49.7	19.3	22.4
JP	0.7	-	-	98.4	0.9
UK	1.0	-	-	98.5	0.5
US	11.8	-	-	88.2	-

for all the included emerging economies. The contribution of contagion to total volatility in bond spreads of emerging economies ranged from 13.1% (to Mexico) to 84.5% (to Argentina). Fourth, contagion from the U.S. shock has global-level effects on all the emerging economies considered, even if the degree of influence differs among countries and regions. Countries that have been subjected to higher world factor influence before the crisis have larger contagion effects from the crisis. In particular, Argentina that had the highest influence from the world factor has the largest contagion effects. Fifth, there are clear regional effects which, however, are mixed with similarities and differences across regions and countries. In the crisis period, the world-wide contagion effects along with the world factor outweigh the regional factor for majority of the emerging economies under study. Contagion effects are usually regional in nature, *e.g.*, in the east Asian crisis of

1997 and in the Russian (eastern Europe) crisis of 1998. However, the U.S. shock in the 2007-2008 crisis has considerable global effects on all the emerging countries under consideration.

Finally, strong effects of country specific factors are shown in Korea, Japan, the U.K., and the U.S. For the developed economies, Japan, the U.K. and the U.S., the extremely high values of country specific effects may be partially due to our identification scheme of no regional factor for these economies. For these economies regional factors, which would have minor effects as the Korean case shows, are included in the country specific factors.

IV. Concluding Remarks

We analyzed bond spreads of nine countries in the period from December 1, 2006 to March 31, 2010 to see how much markets are integrated and as well how the 2007-2008 crisis affects the international market. Our analysis is based on an augmented latent factor model with the US factor as well as the world factor, the regional factor, and the domestic factor. Our empirical results have several interesting implications. The 2007-2008 crisis that originated from the US has clear contagion effects on all emerging economies under consideration, with stronger effects on countries with relatively higher susceptibility to world factors before the crisis. Regional effects are mixed with similarities and differences among regions and countries. In the crisis period, the world-wide contagion effects together with the world factor outweigh the regional effects for majority of the emerging economies considered.

Our analysis is mainly for the effects of the U.S. shock on the role of latent factors and market integration. Our study did not include the analysis of effects of the recent EU crisis that followed the U.S. shock. We can adopt an extended model with some EU countries and an appropriate implementation of EU shocks in any future study. Other researchers may want to perform similar analysis for some different sets of countries with different identification schemes with respect to regions and periods of contagion. These directions of analyses are recommended for future study.

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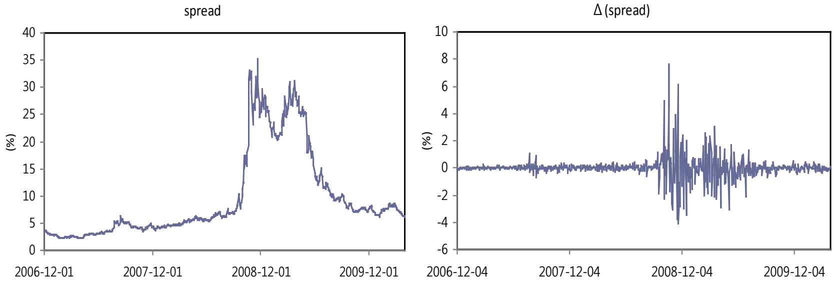
Appendix

[Latin America]
Argentina



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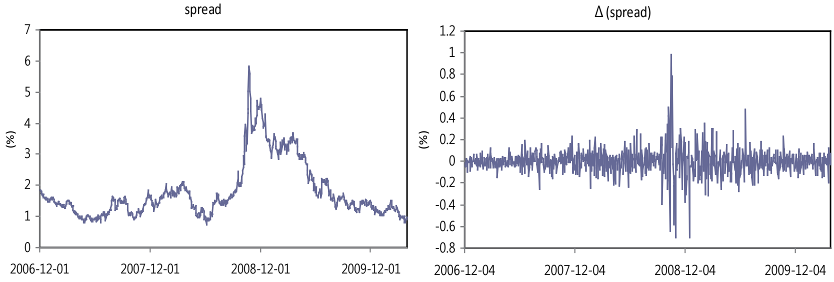

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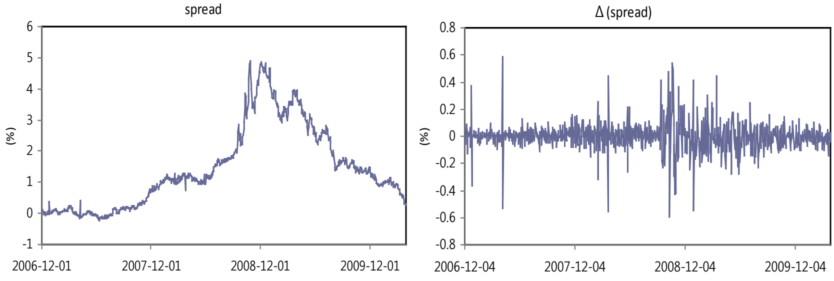
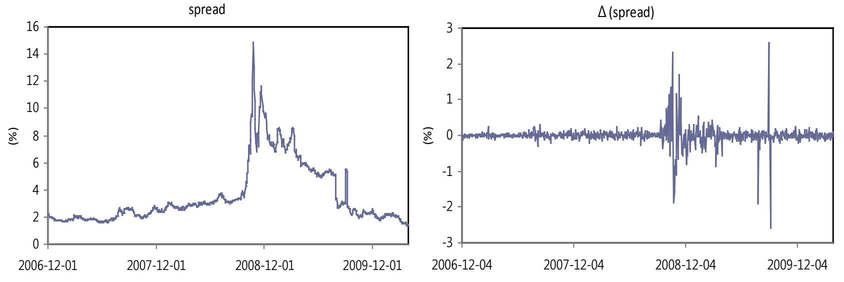
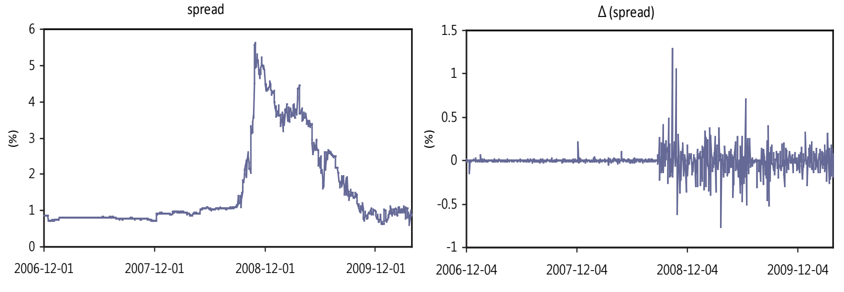


Appendix Figure 1
Spreads and Variations of Spreads

[Asia]
Indonesia



Korea



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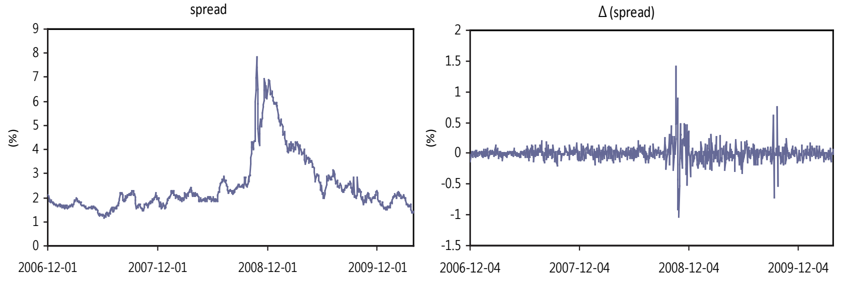
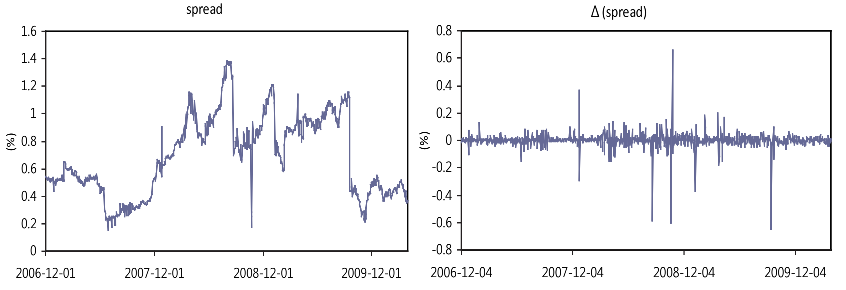


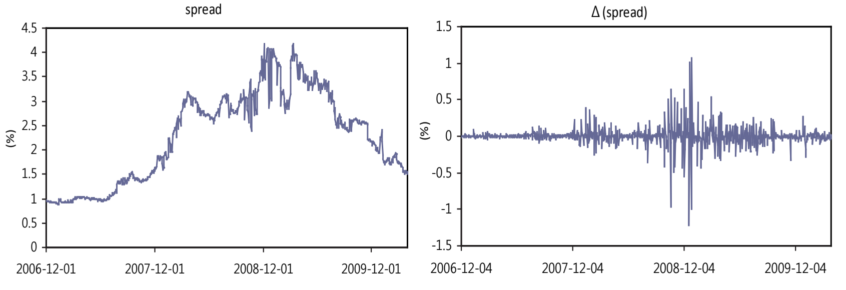
Appendix Figure 1
(Continued)

[Developed Countries]

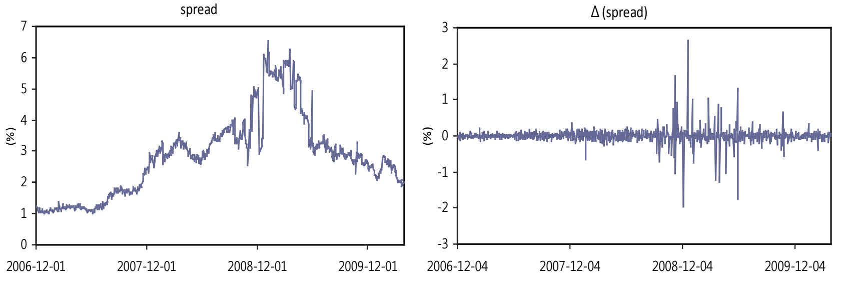
Japan



U.K.



U.S.



APPENDIX FIGURE 1

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