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

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Abstract

Yield spreads on sovereign bonds represent market expectation for economic performance of issuing countries. In the international financial market yield spreads also reflect the extent to which the issuing countries are integrated into a global market. We analyze market integration and interconnectedness for several countries by studying the characteristics of yield spreads of long-term bonds in the period from December 1, 2006 to March 31, 2010. Our analysis is based on a latent factor model with the world factor, the regional factor, the country-specific factor, and the US shock as its latent factors. Our empirical results show that there are clear contagion effects of the 2007-2008 crisis originated in the US on all emerging economies under consideration, with stronger effects on those 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. Also, relatively stronger effects of country specific factors are shown in Korea as well as Japan, the UK, and the US.

*The authors are grateful to a co-editor and two anonymous referees for helpful comments on the earlier version of this paper. The research of this paper was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2014S1A3A2044637). Correspondence: School of Economics, Seoul National University, Seoul, 151-746, Korea. e-mail: jykim017@snu.ac.kr.

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1 Introduction

Market linkages become more and more 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 information available across markets. The financial crisis that 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 of 2007. In this paper we study nature of market integration and linkages around the period of recent financial crisis by analyzing bond spreads in the period.

Yield spreads of bonds with the same maturity represents relative attractiveness of the bonds affected by profitability, default risk, liquidity, etc. 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. Also, we may need to consider heteroskedastic nature of volatilities of shocks. In these cases the number of parameters to be estimated are usually very large. To avoid this curse of dimensionality and reduce the dimension of parameters we use a latent factor model in this paper. An important feature of this approach is that it is possible to decompose observed volatility in bond spreads into various components with interpretable identifications. The latent factor approach also has the advantage of quantifying the effects of contagion of shocks across markets.

We consider four potential factors which have influence on bond spreads: 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, and 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 in favourable conditions. The regional factor reflects common events in each region. Financial markets within each region are integrated to a certain degree with each other, which 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, on the other hand, has effect only on each country. For example, the credit card crisis in Korea in early 2000's caused 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 originated in the U.S. in the period of 2007-2008.

The latent factor model that we use describes dynamics of bond yield spreads with unobservable factors. This approach helps us to avoid modelling 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 allows researchers freedom from the problem of model misspcification. A number of authors use the latent factor model for analyzing 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, and 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 is studied by Dungey, et al. (2011) based on the latent factor model.

We analyzed data of nine countries: three Latin American countries (Argentina, Brazil and Mexico), three Asian countries (Indonesia, Korea and Philippines), and three advanced countries (Japan, UK and US). The data are daily observations of spreads on bond yields from December 1, 2006 through March 31, 2010. The spreads of the six emerging economies (Latin America and Asia) are the long-term sovereign bonds relative to a comparable risk-free bond, while the spreads of the advanced economies are the long-term BBB corporate bonds issued in the domestic economy relative 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 overall increased during the period of financial crisis. Second, the absolute value of correlation of bond spreads has increased in most cases during the crisis period. Third, contagion emerges quite substantially from the U.S. shock in the period of recent financial crisis. Fourth, contagion from the U.S. shock has global-level effects over 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 those countries with relatively higher susceptibility to world factors before crisis.

Our discussion in the rest of the paper goes as follows. Section 2 presents the model and explains estimation methods used for our empirical analysis. The model used is the latent factor model with a contagion effect. This is followed by a discussion of the empirical characteristics of the data in Section 3.1. Main empirical results are presented and discussed in Section 3.2. Concluding remarks are provided in Section 4.

2 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 extension of the model to include the effect of a crisis. Our model has its origins in the factor models used in Sharpe (1964) and Solnik (1974). Also, 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).

2.1 The model

Let $r_{i,t}$ be the bond yield of the i-th ($i = 1, \cdots, N$) 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:

$$\Delta s_{i,t} = \lambda_i w_t + \gamma^{i,A} R_t^A + \gamma^{i,L} R_t^L + \sigma_i u_{i,t}, \tag{2.1}$$

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 $i = 0, 1, \cdots, N$ and $E[u_{i,t} R_t^k] = 0$ for $i = 0, 1, \cdots, N$ 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:

$$\begin{aligned} f_{j,t} &= v_{j,t}, \\ v_{j,t} &\sim N(0, \sigma_{j,t}^2), \text{ and} \\ \sigma_{j,t}^2 &= (1 - \alpha_j) + \alpha_j \sigma_{j,t-1}^2. \end{aligned} \tag{2.2}$$

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 was used by Diebold and Nerlove (1989) to analyze the exchange rate volatility, by Engle, Ng and Rothschild (1990) to analyze the treasury bills, by Kim and Park (2004) to analyze bond spreads of emerging economies around the period of Asian financial crisis. Dungey et. al. (2000) and Dungey et. al. (2011) to study volatility of various assets.

Now, we want to include in the model the effect of the financial crisis originated in the U.S. in 2007-2008. For this purpose we augment the model (2.1) by including the idiosyncratic shocks from the U.S. $u_{us,t}$ for the period of crisis (via the indicator I_t in (2.3)) into each equation of the factor model. Then, the full factor model for country i is represented by

$$\Delta s_{i,t} = \lambda_i w_t + \gamma^{i,A} R_t^A + \gamma^{i,L} R_t^L + \sigma_i u_{i,t} + \zeta_i I_t u_{us,t}, \tag{2.3}$$

where the strength of contagion from the U.S. market are controlled by the parameters 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 U.S. risk factor for the U.S. is included in the idiosyncratic shock of the U.S.[1]

Based on the model (2.3) we can evaluate the contribution of each factor to total volatility in the movement/variation of the yield spread of each country. Thus, the variance of the yield spread variation can be decomposed as

$$Var(\Delta s_{i,t}) = Var(\lambda_i w_t) + Var(\gamma_i^A R_t^A) + Var(\gamma_i^L R_t^L) + Var(\zeta_i I_t u_{us,t}) + Var(u_{i,t}). \tag{2.4}$$

[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.

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

$$\begin{aligned}
\text{Contribution of the world factor} &= \frac{\lambda_i^2}{Var(\Delta s_{i,t})}, \\
\text{Contribution of the regional factor} &= \frac{(\gamma_i^k)^2}{Var(\Delta s_{i,t})}, \\
\text{Contribution of the idiosyncratic factor} &= \frac{\sigma_i^2}{Var(\Delta s_{i,t})}. \\
\text{Contribution of the contagion factor} &= \frac{\zeta_i^2 I_t}{Var(\Delta s_{i,t})}. \qquad (2.5)
\end{aligned}$$

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

2.2 Estimation Methods

We can obtain an estimate of the parameter by the Kalman filter. However, the estimation by Kalman filter is known to yield inconsistent estimator because of the nonlinearity of the ARCH structure. For this reason, Gourieroux, Monfort and Renault (1993) and Gourieroux and Monfort (1996) suggested to estimate 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^a that 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^a, $M^a = M^a(\theta^a)$.

Let $X_T(\theta) \equiv \{x_t(\theta)\}_{t=1}^T$ be a sequence of observed data. Let $\hat{\theta}_T^a = \hat{\theta}^a(X_T(\theta))$ be an estimator of θ^a 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 $\hat{\theta}_{sT}^a = \hat{\theta}^a(X_{sT}(\theta))$ be an estimator of θ^a based on $X_{sT}(\theta)$. Then, our indirect estimator of θ, $\hat{\theta}_{ST}$, is defined as

$$\hat{\theta}_{ST}(W) = \arg\min_{\theta} \left[\hat{\theta}_T^a - \frac{1}{S}\sum_{s=1}^{S}\hat{\theta}_{sT}^a(\theta)\right]' W \left[\hat{\theta}_T^a - \frac{1}{S}\sum_{s=1}^{S}\hat{\theta}_{sT}^a(\theta)\right] \qquad (2.6)$$

where W is a weighting matrix.

As already mentioned, 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:

$$\begin{aligned} &\text{(Observation equation)} \quad \Delta s_t = \Gamma f_t + \sigma u_t, \\ &\text{(State equation)} \quad f_{j,t} = \sqrt{(1-\alpha^j) + \alpha^j f_{j,t-1}^2}\,\eta_{j,t}. \end{aligned} \tag{2.7}$$

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. Though 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.

3 Empirical Results

3.1 Data and Descriptive Statistics

Data are from 9 countries: 3 Latin American countries (Argentina, Brazil and Mexico), three Asian countries (Indonesia, Korea and Philippines), and three advanced 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), among others. In fact, the choice of countries in our data set against alternatives with other countries is somewhat arbitrary. The empirical results might, to some extent, depend on the choice of the set of countries.

The spreads of the six emerging economies (Latin America and Asia) are the long-term sovereign bonds relative to a comparable risk-free bond. These sovereign bonds are issued in the U.S. dollar, and the 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 advanced 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 through March 31, 2010. This data period covers pre-crisis period through the period of crisis and after. All the data are obtained from *Datastream.*

The descriptive statistics for the bond spread is given in Table 3.1. The mean and standard error of spread series for most countries experienced large increases in the crisis period. The correlation coefficient of each pair of bond spreads reported in Table 3.1 measures linear association of the pair of spreads. Correlations of the bond spread increase in the period of crisis. This result reflects risk spillover effects in the international market. Risk spillover effects in financial markets during crisis are studied in Hwang and Kim (2015), among others.

We then check persistence of spread series by testing for the unit root. The unit root null is not rejected for the spread series of all countries. In Table 3.2 we show results of unit root tests for the bond spreads. As is shown the unit root null is not rejected at 5% test for the spread series of all the countries. The persistence and instability, implied in the unit root hypothesis, of bond spreads are well expected during the period of 2007-2008 financial crisis. In our factor analysis we use the first difference of bond spreads, which is the variation of spread series to remove the unit root. Figure 3.1 shows the series of bond spreads and their first differences. The variation of bond spread measured by the difference of the series clearly exhibits common time-varying volatility. This feature of the series can be properly modelled by ARCH.

3.2 Empirical Findings

Our main empirical findings are presented in Table 3.4, which is explained in the following. First, the world factor has considerable effects on the volatility of yield spreads for all the emerging economies. This implies that the emerging economies are highly integrated into the global market. Second, idiosyncratic domestic factors dominate in all the advanced countries as well as Korea, which is classified as an advanced emerging economy.

Third, contagion effects of the U.S. shock emerge quite substantially for all the emerging economies under consideration. 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 under consideration although the degree of influence is different across different countries and regions. An interesting result is that countries with higher influence of the world factor 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 together with the world factor outweigh the regional factor for majority of the emerging economies under study. It is known in the literature that contagion effects are usually regional in nature: in the east Asian crisis of 1997, in the Russian (eastern Europe) crisis of 1998, for example. However, the U.S. shock in the 2007-2008 crisis has considerable global effects over all the emerging countries under consideration.

Finally, strong effects of country specific factors are shown in Korea as well as Japan, the UK, and the US. For the advanced economies, Japan, the UK and the US, 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.

4 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: There are clear contagion effects of the 2007-2008 crisis originated in the US on all emerging economies under consideration, with stronger effects on those countries with relatively higher susceptibility to world factors before crisis. Regional effects are mixed with similarities and differences across 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 under study.

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 US shock. We can adopt an extended model with some EU countries and an appropriate implementation of EU shocks. Also, one may want to perform similar analysis for some different sets of countries with different identification schemes with respect to regions and periods of contagions. We leave these directions of analyses for future study.

References

[1] Bekaert, G., C.R. Harvey, and A. Ng (2005), "Market integration and contagion," *Journal of Business* 78: 39-69.

[2] Corsetti, G., M. Pericoli, and M. Sbracia (2001), "Correlation analysis of financial contagion: What one should know before running a test," Yale Economic Growth Center Discussion Paper No. 822.

[3] Corsetti, G., M. Pericoli, and M. Sbracia (2005), "Some contagion, some interdependence: More pitfalls in tests of financial contagion," *Journal of International Money and Finance* 24: 1177-1199.

[4] Diebold, F. and M. Nerlove (1989): "The Dynamic of Exchange Rate Volatility: A Multivariate Latent Factor ARCH Model", *Journal of Applied Econometrics*, Vol. 4, pp. 1-22.

[5] Dungey, M., V. L. Martin and A. Pagan (2000):"A Multivariate Latent Factor Decomposition of International Bond Yield Spreads", *Journal of Applied Econometrics*, Vol. 15, pp. 697-715.

[6] Dungey, M., R.A. Fry, B. Gonzlez-Hermosillo, and V.L. Martin. (2006), "Contagion in international bond markets during the Russian and LTCM crises," *Journal of Financial Stability* 2: 1-27.

[7] Dungey, M., and V.L. Martin (2007), "Unravelling financial market linkages during crises," *Journal of Applied Econometrics* 22: 89-119.

[8] Dungey M., R. Fry, B. Gonzlez-Hermosillo, and A. Martin (2011): *Transmission of Financial Crises and Contagion: A Latent Factor Approach*, Oxford University Press.

[9] Engle, R. and V. NG and M. Rothschild (1990): "Asset Pricing with a Factor ARCH Covariance Structure: Empricial Estimates for Treasury Bills", *Journal of Econometrics*, Vol. 45, pp. 213-237.

[10] Forbes, K. and R. Rigobon (2002), "No contagion, Only interdependence: Measuring stock market co-movements," *Journal of Finance* 57: 2223-2261.

[11] Gourieroux, C. and A. Monfort (1996): *Simulation-Based Econometric Methods*, London, Oxford University Press.

[12] Gourieroux, C., A. Monfort and E. Renault (1993): "Indirect Inference", *Journal of Applied Econometrics*, Vol. 8, pp. S85-S118.

[13] Gregory, A.W. and D.G. Watts (1995), "Sources of variation in international real interest rates," *Canadian Journal of Economics* 28: S120-S140.

[14] Hwang, J.B. and J.Y. Kim (2015), "Extreme Risk Sillover in Financial Markets: Evidence from the Recent Financial Crisis," *Seoul Journal of Economics*, vol. 28, no.2, pp.171-198.

[15] Kim, J.Y. and W.Y. Park (2004), "Emerging market bond spreads: a latent factor model," *Economic Journal*.

[16] King, M., E. Sentana, and S. Wadhwani (1994), "Volatility and links between national stock markets," *Econometrica* 62: 901-933.

[17] Kose, M.A., C. Otrok, and C.H. Whiteman (2003), "International Business Cycles: World, Region, and Country-Specific Factors," *American Economic Review*, 93, 4, 1216-1239.

[18] Mahieu, R. and P. Schotman (1994), "Neglected common factors in exchange rate volatility," *Journal of Empirical Finance* 1: 279-311.

[19] Mauro, P., N. Sussman and Y. Yafeh (2002): "Emerging Market Spreads: Then versus Now", *Quarterly Journal of Economics*, Vol. 117, pp. 695-733.

[20] Ng, V.K., R.F. Engle, and M. Rothschild (1992), "A multi-dynamic factor model for stock returns," *Journal of Econometrics*, AprilMay, 52: 245266.

[21] Sharpe, W. (1964), "Capital asset prices: A theory of market equilibrium under conditions of risk," *Journal of Finance* 19: 425-442.

[22] Solnik, B.H. (1974), "The international pricing of risk: An empirical investigation of the world capital market structure," *Journal of Finance* 29: 365-378.