Volatility Transmissions between Stock and Bond Markets: Evidence from Japan and the U.S.

Victor Fang[1], Yee-Choon Lim[2], and Chien-Ting Lin[3]

[1] Department of Accounting and Finance,
Monash University , Caulfield 3145 Australia
Victor.Fang@buseco.monash.edu.au
[2] Prudential Asset Management, Singapore
Yee.Choon.Lim@prudential.com.sg
[3] Adelaide Graduate School of Business and School of Commerce,
University of Adelaide, Adelaide SA 5000 Australia
chienting.lin@adelaide.edu.au

Abstract

This study attempts to investigate the transmission of market-wide volatility between the equity markets and bond markets of Japan and the U.S. To measure the volatility transmission, the BEKK (Baba, Engle, Kraft and Kroner, 1990) method, a decomposition approach of the multivariate GARCH (1,1) model, is used to examine the cross-market contemporaneous effect of information arrival. The time series analysis provides evidence to the long-run phenomena of causality in conditional variances of paired assets within the local and international markets. Within various pairings, some evidence of bi-directional volatility transmissions such as informational linkages have been observed. Our empirical results suggest that within the domestic cross markets, the volatility transmission is unidirectional from the stock market to the bond market. Evidence from international cross-market analysis is mixed, with strong evidence on volatility spillover among these international stock markets, but weak evidence between international stock and bond markets. In addition, there are significant directional volatility transmissions between DJI index and FTSE100 index, and between DJI index and DAX200 index. The volatility transmission between these two markets indicates that the international diversification of bonds is not prevalent.
Keywords. Comovement, Volatility Transmissions, Idiosyncratic Conditional Varaince, GARCH(1,1)

I. Introduction

The correlation of stock and bond returns has been observed in a variety of models and evidence overall has shown that the relationship varies over time, particularly under exogenous influences. Volatility inducing events such as the October crash in 1987 cause an acute convergence of investors’ sentiments and may lead to the transmission of price variance between stocks and bonds across domestic as well as international markets. The significance of this area of research is further highlighted by the increased resilience of the financial markets to monetary policies and regulation.

In addition, repeated failures of financial institutions and the subsequent contagion effect could enhance the transmission of volatility to other markets. This is evident in the Long-Term Capital Management debacle and the Argentine debt crisis in the past decade. It is therefore important to fully comprehend and if possible, anticipate the flow of volatility among major financial markets specifically between stock and bond markets. For portfolio investors, understanding the transmission of volatility between complimentary assets such as stocks and bonds allows them to diversify their portfolio more effectively. Most often, the benefits of diversification for bonds are overstated especially within the mean-variance approach.

Owing to the nature of the cash flows (fixed and variable payments for bond and stock respectively), both assets are regarded by portfolio investors as compliments for diversification. Hence, both markets should display upward comovement in prices during bull markets. However, the relationship may change if the dynamics of international markets are considered. Countries with disparate interest rates (risk-free bond returns) may serve as substitutes. For instance, if risk-free bonds of the U.S are not able to provide a sufficient required rate of return, investors may turn to foreign bonds of equivalent risk exposure. This could then distort the theoretical supposition about both assets held within a single country.

The earliest analysis on the relation between stocks and bonds was pioneered by Merton (1974) [1]. He posits that the negative relation of both assets during periods of higher volatility are based on the premise that bond holders can be regarded as owners of risk-free bonds who issue put options to equity holders. Therefore, if implied volatility of the firm increases, thus affecting default risk, bond prices should fall while stockholders benefit from an increase in the value of the put option. It is important to note that the volatility in question must come from a combination of idiosyncratic and market-wide (or systematic) factors; and that they exhibit different trends over time. Campbell et al. (2001) [2] find that market wide volatility behaves indifferently while idiosyncratic volatility has trended upwards since mid-1970s in U.S. In a subsequent study, Campbell and Taksler (2003) [3] explore the impact of equity volatility on corporate bond yields. Their findings provide strong evidence for the proposition of Merton (1974) [1], where idiosyncratic volatility has as much influence as credit ratings on bond yields.

While insightful, the study assumes that volatility is confined within the domestic market. If one were to consider the possibility of cross-border volatility transmission due to flight to quality, the inferences from Campbell and Taksler (2003) [3] may be questioned. For instance, if investors hold international diversified portfolios and there is an uncertainty in the U.S. interest rates, it may cause a rebalancing in the portfolios. As a result, the volatility observed on bond yield spreads is confounded. In other words, the market-wide uncertainty of major stocks and bond markets can be spilled over to its foreign counterparts and confound the information signals emanating from local economic conditions (of the foreign counterparts).

The empirical evidence presented by Shiller and Beltratti (1992) [4], Kwan (199) [5] and Campbell and Ammer (1993) [6] documents a negative correlation between stocks and bonds, albeit to varying degrees. Although the methods employed are robust to their studies, they have ignored the informational role of variance in the time series data. This motivates us to investigate the causality between both assets via temporal volatility (or conditional variances). Moreover, it is a common knowledge that variance of returns reflects the flow of information between investors. Therefore, if causality is observable in variance, these assets (and their markets) should be information-linked.

In all, the aim of this study is to investigate market-wide volatility spillovers between two markets: the U.S. and Japan. The investigation will give us insights to other possible causes of volatility in both markets that were unexplained by previous studies. Furthermore, to our knowledge, this area of research has not been fully conducted.

II. Data and Methodology

Our analysis looks at both the major stock and government bond indices. The sampled stock indices of Japan and the U.S. are Nikkei 225 Stock Average and Dow Jones Industrial respectively. The corresponding Government bond indices are complied by JP Morgan, and all data are retrieved from Datastream. In order to increase the reliability of the statistical procedures, the daily observation starts from 1/1/1988 and ends on 2/13/2004. We begin the sampling period from 1998 to avoid any significant distortion that might occur in the empirical results due to 1987 October crash.

Since most time-series studies on volatility involve large samples and singular structural breaks, they tend to neglect confounding effects of other events within the sample period. We argue that the problems inherent in a single structural break and the large sample required (of volatility studies) tend to lead to inferential complications, such that sources of volatility are difficult to identify and their effects are difficult to capture. Hence, our choice of sample period is driven by the objective of understanding on the causality of informational transmission between both assets over a given period, rather than explaining the effects of a single event. The purpose of our study is therefore to measure the aggregated effects of volatility on affine markets and this involves collating market-wide volatility inducing events. Nonetheless, our preliminary tests confirm that the inclusion of the October crash of 1987 distorts both the statistical and economic inferences.

Table 1 presents statistical summaries and preliminary diagnostics for the daily returns of all stock and bond indices for the sample period from Jan 1, 1988 to Feb.13, 2004. The sample moments for all return series indicate that the distributions have heavy tails relative to the normal distribution. There is some negative skewness especially in the U.S. index returns and excess kurtosis in both series. The Ljung-Box statistics for raw and squared returns series reject the null hypothesis of white noise for all series at the 95% level, suggesting a strong evidence of non-linear dependence of the return series possibly due to changing conditional volatility over time.

To test the information linkages among these markets, we follow the methods of Karolyi (1995) [7] and Caporale et al. (2002) [8]. They incorporate simple granger causality tests through a multivariate GARCH (1,1) framework within the BEKK (Baba, Engle, Kraft and Kroner) representation of Baba et al. (1990) [9]. They have also provided evidence to the robustness of this test based on the applications on currencies and stock returns respectively. For the scope of discussion, we shall summarize the relevant methods that may be applied to our study.

Table 1. Summary statistics of the U.S and Japanese bonds and stocks

	Dow Jones	US Bond	Nikkei 225	Japan Bond
Mean	0.0004	4.11E-05	-0.0002	6.43E-05
Medium	0.0002	0	0	-7.18E-05
Std. Dev.	0.0102	0.0028	0.0142	0.0073
Skewness	-0.3640	-0.3097	0.2004	0.4401
Kurtosis	8.3249	4.8892	6.9061	7.1352
Jarque-Bera	5060.86**	692.57**	2701.41**	3131.80**

** indicates significance at the 1 percent level.

Cheung and Ng (1996) [10] use the residual cross-correlation function (CCF) on conditional mean and conditional variance estimates obtained from the univariate time-series models. This simple approach allows the orthogonal relations in both variables to be tested, *per se;* a probable relation exists in either moment. This method is particularly appealing because it allows analysis to various lag lengths. However, if more than one asset and market is introduced, a decomposition approach similar to BEKK will be required to parameterize the relation. On the other hand, the BEKK is not able to parameterize possible lagged relations; instead, time varying volatility is being modeled based on the second-order nonlinear dependence of the GARCH (1,1).

Given the properties of the techniques discussed here, we employ the multivariate GARCH (1,1) – BEKK representation (Engle and Kroner (1995) [11]) to model the relationship. Suitably, the model is applicable to two or more variables in both moments while not requiring excessive estimation of parameters. It also alleviates complications arising from re-parameterization (inherent of the VAR). In addition, the quadratic specification allows us to treat problematic negative covariance matrices faced by other specifications (such as the VECH). First, it requires an estimate of the conditional variances from the GARCH (1,1) model[1]:

$$x_t = \gamma + \beta x_{t-1} + \varepsilon_t \quad \textbf{(1)}$$

Where x_t denotes the returns on the stock index SI_t and bond index BI_t. The residual vector $\varepsilon_t = (e_{1,t}, e_{2,t})$ is bivariate and normally distributed $\varepsilon_t \mid \Phi_{t-1} \sim (0, H_t)$ with its corresponding conditional variance covariance matrix given by:

$$H_t = \begin{bmatrix} h_{11t} & h_{12t} \\ h_{21t} & h_{22t} \end{bmatrix}$$

In a univariate GARCH (1,1) process, the conditional variance $\sigma_t^2 \mid \Phi_{t-1}$ is obtained from the variance equation (2). We adopt the BEKK representation, which is essentially a spectral decomposition of the conditional variance-covariance matrix. A multivariate GARCH(1,1) model (3) is derived from the operation.

$$\sigma t2 = \mu + \alpha 1 \varepsilon t\text{-}1 + \beta \sigma t\text{-}12 \quad \textbf{(2)}$$

$$Ht = \Omega'\Omega + \alpha '\varepsilon\, t\text{-}1\varepsilon't\text{-}1\, \alpha + \beta'H\, t\text{-}1\beta \quad \textbf{(3)}$$

The spectral decomposition follows as:

$$\mathrm{H_t} = \Omega_0'\Omega_0 + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}' \begin{bmatrix} e_{1,t-1}^2 & e_{1,t-1}e_{2,t-1}' \\ e_{1,t-1}e_{2,t-1}' & e_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix}' \mathrm{H_{t-1}} \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \quad \textbf{(4)}$$

The BEKK representation decomposes the GARCH (1,1) process into its multivariate constituents and models the time-varying process of H_t conditional on the lag values of the residuals of the mean and variance equation. The model facilitates the interaction between the conditional variance and covariance and thus allowing us to observe the impact of information arrival upon two different markets. The matrix is restricted to the upper triangle to observe the unidirectional causality as shown in equation (5):

$$\mathrm{H_{2t}} = \Omega_{12}^2 + \Omega_{22}^2 + \alpha_{12}^2 e_{1t-1}^2 + 2\alpha_{12}\alpha_{22}e_{1t-1}e_{2t-1} + 2\beta_{12}\beta_{22}h_{12t-1} + \alpha_{22}^2 e_{2t-1}^2 + \beta_{12}^2 h_{1t-1} + \beta_{22}^2 h_{2t-1} \quad \textbf{(5)}$$

Following from the above, we test for the hypothesis of causality in conditional variances between the bond and stock markets within the country and between the individual assets of both countries in a pair-wise fashion. By restricting the matrix to the upper triangle, it allows us to investigate the causality effect of h_{1t} on h_{2t}.[2] Therefore, the null hypothesis H_0: $\alpha_{12}=\beta_{12}=0$ is established as a result of the restriction; implying that h_{1t} does not have a causal effect on h_{2t}. To test for a bidirectional relation, we run the restricted model twice on each pair of asset, with each asset being the independent variable on each run. This simulates a full model without unnecessary parameterization. Given a sample of T observations of the return vector, x_t, the parameters, θ of the model are obtained from the conditional density function as:

$$f(x_t \mid \Phi_{t-1};\theta) = (2\pi)^{-1}|\mathrm{H_t}|^{-1/2}\exp\left(-\frac{\varepsilon_t'(\mathrm{H_t^{-1}})\varepsilon_t}{2}\right) \quad \textbf{(6)}$$

The log likelihood function is:

[1] Bivariate Garch (1,1) representation in Engle and Kroner (1995) [11]

[2] The procedure is similar to Caporale et al. (2002) [8].

$$L = \sum \log f(x_t \mid \Phi_{t-1}; \theta) \quad \textbf{(7)}$$

where θ is the vector of parameters and standard errors are calculated from the quasi-maximum likelihood method by Bollerslev and Wooldridge (1992) [12] which are robust to the density function underlying the residuals.

III. Empirical Results

Domestic Cross-market Influences

Panels 1 and 2 in Table 2 report the domestic cross-market influences between stocks and bonds for Japan and the U.S. To reduce distributional complications, we restrict our inferences to 1 per cent significance, as suggested by Karolyi [1995], in order to compensate for any biasness that may arise. Overall, the results indicate that the GARCH (1,1) specification captures satisfactorily the persistence in the squared return series. The degree of volatility persistence is captured by the coefficient β_{11}. The four estimated coefficients β_{11} fall within the range 0.9566 – 0.9786. This finding of market volatilities indicates high persistence in both the daily stock and bond index returns. The conditional variance in each market is significantly affected (positively) by its own past innovations (α_{11}) with values between 0.1771 and 0.2834, while the cross-market volatility dependence varies in magnitude and sign across countries.

In Panel 1, the estimate of α_{12} in the U.S. is statistically significant at the 1% level, with a negative value of -0.0069. This suggests that a 1 percent increase in the volatility of the stock market causes its own bond market volatility to decrease by 0.69%. For Japan, the estimate of β_{12} (a measure of the degree of volatility persistence) is statistically significant at the 1 % level, with value equals to 0.0035. This implies that previous days' volatility in Nikkei225 carries significant influence on its current bond markets' volatility.

In Panel 2, the estimates of α_{12} and β_{12} are statistically insignificant, suggesting that the domestic bond market of each respective country has no influence on its own stock market in conditional variance.

Overall, the evidence shows that the volatility transmission is unidirectional between domestic cross-markets in that domestic stock market tends to exert influence over the domestic bond market and not vice versa.

International Cross-market Influences

We apply the same methodology to study the relation between the stock and bond markets between Japan and the U.S. This allows us to investigate the possible flow of information, via the conditional variances of each market to the corresponding market. Between these two countries, a further pairing of assets is made and provides us with four pairs of asset-to-asset transmission.

Table 3 reports the results of volatility transmission between the U.S. stock market and the Japanese stock and bond markets. In Panel 1, it is found that shocks on the U.S. stock market have a negative effect on the Nikkei225 conditional variances. [3] The coefficient of cross-market volatility (α_{12}) from U.S. Dow Jones index (DJI) to Japan Nikkei225 is statistically significant at the 1 % level with values equal -0.0038. It implies that the U.S. stock market being the dominant market has a strong influence on the Japanese stock market. However, the U.S. stock market has no influence on the government bond index in variance.

[3] Nikkei index returns have been adjusted accordingly to reflect the different time zones of these markets.

Table 2. Volatility Transmission between domestic stock market and domestic bond market using GARCH (1,1) BEKK model for daily returns from January 1988 to February 2004

	Panel 1 Volatility Transmission from domestic stock market to domestic bond market		Panel 2 Volatility Transmission from domestic bond market to domestic stock market	
	U.S.	Japan	U.S.	Japan
μ_{11}	0.0006 4.97*	0.0003 2.05	4.9E-05 1.26	3.7E-05 0.36
μ_{12}	0.0001 1.60	3.3E-05 0.32	0.0006 4.95*	0.0003 2.04
Ω_{11}	0.0009 13.65*	0.0013 17.50	0.0003 11.48*	0.0011 15.45*
Ω_{12}	0.0002 5.77*	-0.0002 -2.16	0.0005 4.44*	-6.5E-05 -0.35
Ω_{22}	0.0005 4.44*	0.0010 14.54*	0.0008 12.91*	.0013 16.51*
α_{11}	0.2090 33.68*	0.2834 34.95*	0.1771 22.13*	0.2081 25.50*
α_{12}	-0.0069 -3.06*	-0.0078 -1.58	-0.0017 -0.05	.0173 0.92
α_{22}	0.1738 20.65*	0.2018 25.46*	0.2145 33.50*	0.2809 34.74*
β_{11}	0.9736 554.00*	0.9566 414.91*	0.9786 479.97*	0.9672 368.36*
β_{12}	0.0003 0.40	0.0035 2.44*	-0.0103 -1.24	-0.0020 -0.31
B_{22}	0.9779 430.59*	0.9695 395.67*	0.9724 536.86*	0.9575 415.82*

* indicates significance at the 1 percent level.

In Panel 2, the results indicate that the Japanese government bonds have an influence on the U.S. stock market in variance. The coefficients (α_{12}) are statistically significant with a value of –0.036. Therefore, the results suggest that there is uni-directional volatility transmission between DJI and NIKKEI 225 and between the Japanese bonds and DJI. A reasonable explanation for a significant influence of the Japanese government bond on the U.S. stock market may be related to cross-border portfolio diversification.

Table 4 presents the findings of volatility transmissions between the U.S. bond market and the Japanese stock and bond markets. Panel 1 shows that the volatility of U.S. bond market has a significant influence on the volatility of the Nikkei225. However, it has no significant influence on the volatility of the foreign bond market. In Panel 2, the results suggest that there is not much volatility persistence from NIKKEI 225 to the U.S. bond market. Similarly, we do not find the causal effect in variance from the Japanese bond market to the U.S. bonds. Our findings show that in general, the bond markets are influenced by its own country-specific factors.

Table 3. Volatility Transmission between the U.S. stock market and the Japanese stock and bond markets using GARCH (1,1) BEKK model for daily returns from January 1988 to February 2004

	Panel 1 Volatility Transmission from the U.S. stock market to Japanese stock and bond market		Panel 2 Volatility Transmission from Japanese stock and bond markets to the U.S. stock market	
	Nikkei 225	Bond Index	Nikkei 225	Bond Index
μ_{11}	0.0006	0.0005	0.0004	-2.1E-05
	4.39*	3.94*	2.22*	-0.21
μ_{12}	0.0004	-2.6E-05	0.0006	0.0005
	2.58*	-0.25	4.42*	4.03*
Ω_{11}	0.0007	7.7E-04	0.0014	0.0012
	11.72*	11.69*	16.67*	16.81*
Ω_{12}	0.0002	-0.0001	8.7E-05	-0.0001
	0.73	-0.72	0.77	-1.35
Ω_{22}	0.0013	0.0013	0.0008	0.0008
	17.89	15.73*	11.64*	9.73*
α_{11}	0.1706	0.1817	0.2885	0.2259
	29.25*	27.97*	31.89*	23.77*
α_{12}	-0.0038	-0.0071	0.0086	-0.0360
	-2.27*	-0.91	1.22	-3.21*
α_{22}	0.2877	0.2324	0.1791	0.1867
	31.4*	23.64*	27.76*	29.83*
β_{11}	0.9830	0.9805	0.9552	0.9596
	785.64*	655.65*	366.41*	297.38*
β_{12}	0.0044	0.0016	-0.0023	0.0104
	1.29	0.76	-1.02	2.76*
B_{22}	0.9548	0.9562	0.9810	0.9794
	317.98*	259.45*	645.16*	645.93*

* indicates significance at the 1 percent level.

IV. Conclusion

We provide some evidence of volatility transmissions of the equity and bond markets between Japan and the U.S. Studies in the literature are commonly associated with financial assets such as currencies and stocks on an individual basis. In this paper, we seek to understand the phenomena in a different context. By making multiple pairings of assets from these two countries, we find empirical evidence on informational linkages through the heteroscedastic nature of financial time series. Overall, the volatility of stock market has a strong influence on the volatility of the bond market. However, the causal effect is contemporaneous in U.S., while in Japan, we observe the lagged causal effect. Evidence from cross-country analysis is mixed, with strong evidence on linkages in stock markets but not in the bond markets. The volatility transmission between these assets indicates that the international diversification of bonds is not prevalent. As such, the U.S. government bonds are indeed the most popular source of diversification.

One major contribution of our study is that the strong positive relation between idiosyncratic equity volatility and corporate bond yields documented by Campbell and Taksler [2003] may be overestimated. They find that idiosyncratic equity volatility is directly associated to the cost of debt for corporate issuers. However, according to our findings, there could be volatility transmitted from markets outside the U.S. Thus, it is likely that idiosyncratic volatility documented in their study is upward biased.

Table 4. Volatility Transmission between the U.S. bond market and the Japanese stock and bond markets using GARCH (1,1) BEKK model for daily returns from January 1988 to February 2004

	Panel 1 Volatility Transmission from the U.S. bond market to Japanese stock and bond market		Panel 2 Volatility Transmission from Japanese stock and bond markets to the U.S. bond market	
	Nikkei 225	Bond Index	Nikkei 225	Bond Index
μ_{11}	5.0E-05 1.21	4.7E-05 1.14	0.0004 2.50*	-3.69E-05 -0.36
μ_{12}	4.9E-04 2.97*	-8.6E-06 -0.09	5.80E-05 1.41	4.07E-05 1.01
Ω_{11}	0.0003 9.74*	2.6E-04 9.42*	0.0015 17.31*	0.0011 15.58*
Ω_{12}	0.0005 1.50	6.4E-05 0.30	6.44E-05 2.39*	1.66E-05 0.56
Ω_{22}	0.0013 9.45*	0.0012 16.83*	0.0002 8.19*	0.0003 9.25*
α_{11}	0.1452 20.11*	1.4E-01 19.43*	0.3012 32.90*	0.2352 26.25*
α_{12}	-0.1235 -2.64*	0.0029 0.089	0.0008 0.43	0.0049 1.64
α_{22}	0.2945 31.45*	0.2358 25.42*	0.1218 16.54*	0.1574 19.77*
β_{11}	0.9849 595.87*	0.9859 612.37*	0.9505 340.81*	0.9591 312.52*
β_{12}	0.0034 0.21	0.0024 0.24	-0.0008 -1.39	-0.0013 -1.15
B_{22}	0.9526 339.71*	0.9576 304.68*	0.9576 304.68*	0.9828 511.51*

* indicates significance at the 1 percent level.

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Dr. Victor Fang is a senior lecturer in Finance at the department of Accounting and Finance, Monash University. His areas of research interest are in interest rate swaps, risk management and term structure of interest rates.

Yee-Choon Lim is a fixed income analyst with Prudential Asset Management in Singapore. He received his Honour's degree in Business, specializing in Banking and Finance from Monash University.

Dr. Chien-Ting Lin is a senior lecturer in Finance at the Adelaide Graduate School of Business and School of Commerce, University of Adelaide. He received his Ph.D. in Finance Texas Tech University and specializes in corporate finance and empirical asset pricing.