Volatility Transmissions Between Stock And Bond Markets: Evidence From Japan And The U.S.

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EXTENDED 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 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.
1. 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 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.

The earliest analysis on the relation between stocks and bonds was pioneered by Merton (1974). 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) 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) explore the impact of equity volatility on corporate bond yields. Their findings provide strong evidence for the proposition of Merton (1974), 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) 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), Kwan (1996) and Campbell and Ammer (1993) 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.

2. 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 compiled 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) and Caporale et al. (2001). They
incorporate simple granger causality tests
through a multivariate GARCH (1,1) framework
within the BEKK representation of Baba et al.
(1987). 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

<table>
<thead>
<tr>
<th></th>
<th>Dow Jones</th>
<th>US Bond</th>
<th>Nikkei 225</th>
<th>Japan Bond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.0004</td>
<td>4.1E-05</td>
<td>-0.0002</td>
<td>6.4E-05</td>
</tr>
<tr>
<td>Medium</td>
<td>0.0002</td>
<td>0</td>
<td>0</td>
<td>-7.2E-05</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.0102</td>
<td>0.0028</td>
<td>0.0142</td>
<td>0.0073</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.3640</td>
<td>-0.3097</td>
<td>0.2004</td>
<td>0.4401</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>8.3249</td>
<td>4.8892</td>
<td>6.9061</td>
<td>7.1352</td>
</tr>
<tr>
<td>Jarque-Bera</td>
<td>5060.8*</td>
<td>692.5*</td>
<td>2701.4*</td>
<td>3131.8*</td>
</tr>
</tbody>
</table>

* indicates significance at the 1 percent level.

Cheung and Ng (1996) 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)) 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:

\[ x_t = \gamma + \beta x_{t-1} + \epsilon_t \]  

(1)

Where \( x_t \) denotes the returns on the stock index \( S_t \) and bond index \( B_t \). The residual vector \( \epsilon_t = (\epsilon_{1t}, \epsilon_{2t}) \) is bivariate and normally distributed \( \epsilon_t | \Phi_{t-1} \sim (0, H_{t-1}) \) 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 \( \sigma_t^2 | \Phi_{t-1} \) 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.

\[
\sigma_t^2 = \mu + \alpha \epsilon_{t-1}^2 + \beta \sigma_{t-1}^2
\]

(2)

\[
H_t = \Omega \Omega + \alpha \epsilon_{t-1}^2 \alpha + \beta H, \beta
\]

(3)

The spectral decomposition follows as:

\[
H_t = \Omega_0 \Omega_0 + \begin{bmatrix}
    a_{11} + a_{12} \\
    a_{21} + a_{22}
\end{bmatrix}
\begin{bmatrix}
    \epsilon_{t-1}^2 \\
    \epsilon_{t-2}^2
\end{bmatrix}
\]

(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):

\[
H_{21} = \Omega_{21}^2 + \Omega_{22}^2 + \epsilon_{2t}^2 + 2 \alpha_{12} \epsilon_{2t-1} \epsilon_{2t-1} + 2 \beta_{12} \epsilon_{2t} h_{1t-1} + \beta_{22} h_{2t-1}
\]

(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 \( h_{11} \) on \( h_{22} \). Therefore, the null hypothesis \( H_0: \alpha_{12} = \beta_{12} = 0 \) is established as a result of the restriction; implying that \( h_{11} \) does not have a causal effect on \( h_{22} \). 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, \( \theta \) of the model are obtained from the conditional density function as:

\[
f(x_T | \Phi_{t-1}; \theta) = (2\pi)^{-1/2} |H_T|^{-1/2} \exp \left( -\frac{1}{2} \epsilon_T^T H_T^{-1} \epsilon_T \right)
\]

(6)

The log likelihood function is:

\[
L = \sum \log f(x_T | \Phi_{t-1}; \theta)
\]

(7)

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

3. **EMPIRICAL RESULTS**

3.1 **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

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

2 The procedure is similar to Caporale et al. (2001).
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 $\beta_{11}$. The four estimated coefficients $\beta_{11}$ 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 ($\alpha_{11}$) 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 $\alpha_{12}$ 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 $\beta_{12}$ (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 $\alpha_{12}$ and $\beta_{12}$ 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.

### 3.2 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 evidenced that shocks on the U.S. stock market have a negative effect on the Nikkei225 conditional variances. The coefficient of cross-market volatility ($\alpha_{12}$) from U.S. Dow Jones index (DJJ) to Japan Nikkei225 is statistically significant at the 1 % level with values equal to 0.0035. 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.

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

<table>
<thead>
<tr>
<th>Panel 1 Volatility Transmission from domestic stock market to domestic bond market</th>
<th>Panel 2 Volatility Transmission from domestic bond market to domestic stock market</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Japan</td>
<td>U.S. Japan</td>
</tr>
<tr>
<td>$\mu_{11}$</td>
<td>0.0006</td>
</tr>
<tr>
<td>$\mu_{12}$</td>
<td>0.0001</td>
</tr>
<tr>
<td>$\Omega_{11}$</td>
<td>0.0009</td>
</tr>
<tr>
<td>$\Omega_{12}$</td>
<td>13.65*</td>
</tr>
<tr>
<td>$\Omega_{22}$</td>
<td>0.0002</td>
</tr>
<tr>
<td>$\Omega_{22}$</td>
<td>0.0005</td>
</tr>
<tr>
<td>$\alpha_{11}$</td>
<td>0.2090</td>
</tr>
<tr>
<td>$\alpha_{12}$</td>
<td>33.68*</td>
</tr>
<tr>
<td>$\beta_{11}$</td>
<td>-0.0069</td>
</tr>
<tr>
<td>$\beta_{12}$</td>
<td>-3.06*</td>
</tr>
<tr>
<td>$\beta_{22}$</td>
<td>0.1738</td>
</tr>
<tr>
<td>$\beta_{22}$</td>
<td>20.65*</td>
</tr>
<tr>
<td>$\Omega_{11}$</td>
<td>0.9736</td>
</tr>
<tr>
<td>$\Omega_{12}$</td>
<td>554.00*</td>
</tr>
<tr>
<td>$\Omega_{22}$</td>
<td>0.0003</td>
</tr>
<tr>
<td>$\beta_{22}$</td>
<td>0.40</td>
</tr>
<tr>
<td>$\Omega_{22}$</td>
<td>430.59*</td>
</tr>
</tbody>
</table>

* 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 ($\alpha_{12}$)
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 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

Table 4 presents the findings of volatility transmissions 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

4. CONCLUSIONS

We provide some evidence of volatility transmissions of the equity and bond markets between Japan and the U.S. A study of such nature is commonly undertaken in other
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.

5. REFERENCES


