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Abstract

The benefits of investing internationally depend on three conditions, namely cross-country correlations, market volatilities, and future changes in currency risks (see Odier and Solnik (1993)). This paper investigates these conditions for several countries. Many papers have modelled both domestic interactions across asset markets and international interactions in individual asset markets in isolation, but rarely have they examined international interactions across asset markets. The paper fills this gap by modelling the international interactions across stock, bond and foreign exchange markets. Two models that meet these purposes are the VARMA-AGARCH model of McAleer et al. (2009) and the VARMA-GARCH model of Ling and McAleer (2003). The countries that will be modelled in this paper are Australia, Japan, Singapore, New Zealand and USA.

Keywords: Cross-country correlations, Market volatilities, Currency risks, Domestic interactions, International interactions, Stocks, Bonds, Foreign exchange markets.

I. INTRODUCTION

The modern theory of portfolio choice by Markowitz (1952) shows that an efficient portfolio, namely one that maximizes expected returns for a given degree of risk or, alternatively, minimizes risk for a given expected return, can be obtained by diversifying assets across several markets with low correlations. Within a domestic economy, there is a degree of independence of asset returns that provides diversification opportunities. However, there is a tendency for asset returns to respond uniformly to the influence of overall domestic activity. This reduces the independence of individual asset returns and, therefore, limits the gains from diversification within a given country.

The long-run benefit from international portfolio has been analyzed by Chang et al. (2006). Diversification of portfolios across countries offers smaller correlations of expected returns than within a country for two reasons: (1) the economy and political environment evolve differently across countries, and (2) countries have different industries in their stock market indices (see Heston and Rouwenhost (1994)). Diversifying portfolios across countries should also consider the possibility of added risk from unanticipated changes in exchange rates. Evidence on exchange rate risk from investing in foreign stocks has been analysed in Eun and Resnick (1988). They suggest that the exchange rate contributes a fraction of the volatility of home currency rate of returns of unhedged foreign assets through the direct effect of the exchange rate volatility itself, and the indirect effects of the covariances among exchange rates and local stock returns.

In order to further optimize the portfolio, diversification should also consider investing in different classes of assets, both within and across countries.

Such assets to be considered are domestic and foreign bonds. Bonds are important in portfolio construction for several reasons. First, long-term government bond returns can explain the cross-sectional variation in portfolio risk premia (see Chen, Roll and Ross (1986)). Second, many instrumental variables, such as short-term T-bill yields, can forecast stock and bond returns very well (see, for example, Campbell (1987), Fama and French (1989), and Hoti et al. (2009)).

The issue of the currency risk associated with foreign bonds is addressed in Odier and Solnik (1993). They show that the contribution of exchange rates to the riskiness of bonds is much larger than for stocks. This result arises from the negative correlation between the stock price and currency value, and the positive correlation between bond price and currency value.

Given the theoretical and historical evidence that supports the benefit of investing internationally, the prospects of these benefits depend on cross-country correlations, market volatilities, and currency risks to change in the future (see Odier and Solnik (1993)). Following the liberalization of capital markets and the development of technology information in most countries, international financial market tend to become more integrated. If assets are priced in an internationally integrated capital market, diversifying portfolios on international assets will merely compensate for their systematic risk. On the other hand, if assets are priced in segmented or non-integrated capital markets, diversifying portfolios among international asset provides special benefits compared with diversifying portfolios only among domestic assets. Therefore, the question that remains to be answered is whether international diversification still provides benefits given more integrated financial markets.

Motivated by the problems discussed above, the paper models the interactions across international stock, bond and foreign exchange markets in order to optimize portfolio diversification. Specifically, the paper will model spillovers of the conditional first moment (or mean) and conditional second moment (or volatility) of the assets. Evidence of mean and volatility spillovers can be interpreted as those markets being integrated. The countries to be examined are Australia, Japan, New Zealand, Singapore and USA.

II. LITERATURE REVIEW

The literature of asset market linkages has been surveyed in several papers, such as Andersen et al. (2003) and Ehrmann et al. (2005). In this paper, the literature on financial market spillovers will be categorised into three groups: the first group includes papers that investigate the domestic transmission of asset price shocks, the second group includes papers that investigate international transmission on individual asset prices in isolation, and the third group analyses international transmissions not only in individual asset prices, but also across different classes of assets.

Within each group, the papers can also be characterised further, namely whether they model correlations, volatility spillovers, or both. Earlier papers tended to investigate the unconditional correlations, while more recent papers have considered volatility spillovers in the context of modelling conditional covariances and/or correlations.

Domestic Transmission of Asset Markets

Significant research has been undertaken in the first group, namely the domestic transmission of asset price shocks. Some papers have investigated the link within domestic stock markets. Kroner and Ng (1998) investigate the asymmetric comovements of asset returns in the USA. Using the Generalized Dynamic Covariance (GDC) and Asymmetric Dynamic Covariance (ADC) models, they find that large firm returns can affect the volatility of small firm returns. Billio, Caporin and Gobo (2006) investigate the link among sectorial stock indexes in Italian stock markets. Using the CCC, DCC and a novel Flexible DCC (FDCC) model, they find evidence of dynamics in the conditional correlations and volatilities of those assets.

Some papers have tried to investigate the linkages between stock and bond markets. Earlier work on linkages between stock and bond markets focused on the correlations between the markets, such as Shiller and Beltratti (1992) and Campbell and Ammer (1993), who found positive correlations between the US stock and bond markets. Other papers have modelled the volatility spillovers across stock and bond markets in the USA using various models. For example, Fleming, Kirby and Ostdiek (1998) use a Stochastic Volatility model, Bollerslev, Engle and Wooldridge (1988) use a VECH model, Stivers and Sun (2002) used a univariate GARCH model, and Scruggs and Glabadanidis (2003) estimate the Asymmetric Dynamic Covariance model of Kroner and Ng (1998). These authors tended to support volatility spillovers from bond to stock markets, but not in the other direction.

International Transmission in Individual Asset Markets

There have been several papers that analyse international spillovers on individual asset prices in isolation. Several papers investigate the correlations across international stock markets, such as Longin and Solnik (1995), McAleer et al. (2008), Daly (2003), and Kearney and Poti (2004). Most of these authors have investigated the case of developed countries, except Daly (2003). Using both unconditional and conditional correlations, they have suggested that correlations between stock markets increase over time, except for the correlations of the Hang Seng and Nikkei markets, which are constant (see McAleer et al. (2008)).

Many authors have investigated the mean and volatility spillovers across international stock markets, in developed markets, emerging markets, or both, using various univariate and multivariate GARCH models (see, for example, Hamao et al. (1990), Koutmos and Booth (1995), Choudry (1996), Koutmos (1996), Ng (2000), In et al. (2001), In et al. (2003), Miyakoshi (2003), Bala and Premaratne (2004), Worthington and Higgs (2004), and da Veiga and McAleer (2005)). These authors suggest that spillovers move in the direction of developed to emerging markets. Moreover, emerging markets have been shown to be more integrated, so that volatility spillovers across emerging markets in the same region have tended to strengthen.

Linkages across international bond markets have been investigated in several papers. McCauley and Jiang (2004) analyse Asian local currency bonds and find that their correlations are low, and hence offer scope for diversification. Bond returns are correlated with the Australian, US and Japanese bond markets. Skintzi and Refenes (2006) examine US and European bond linkages and have found significant volatility spillovers from both the aggregate Euro area and US bond markets to the individual European bond markets.

Investigation of the linkages within exchange rate markets has been conducted by several authors. Several have investigated the correlations among exchange rates, such as Bollerslev (1990) and McNelis (1993), who conclude that the correlations are significant. Volatility spillovers among these markets have also been investigated by Engle et al. (1990) and Hurley and Santos (2003) using various GARCH models, and evidence of spillovers has been found.

International Transmission Across Asset Markets

The literature on the linkages across stock and bond markets is limited. Cappiello, Engle and Sheppard (2003) investigate the asymmetric dynamics in the correlations of global equity and bond returns in Australasia, Europe and North America. Using a new Asymmetric Dynamic Conditional Correlation model, they find strong evidence of market volatility correlations for European, EMU, USA and Australasian equities, but the evidence is less clear for bond market volatilities. In addition, they also find that the equity-bond returns correlations are low, and lower during periods of financial turmoil. Volatility spillovers between stock and bond markets for the US market, aggregate European market, and individual European markets have been investigated by Christiansen (2004). Using the DCC model, it was found that national bond (stock) volatilities are mainly influenced by bond (stock) effects. Overall, global, regional and local volatility effects are all found to be important.

Correlations between stock and foreign exchange markets have been investigated by several authors. Rahman et al. (2002) find evidence of bi-directional short-run causality between the two markets, while Johnson and Soenen (1998) find evidence of correlations between foreign exchange (USD and Japanese Yen) and stock markets in some Pacific-Basin countries. Volatility spillovers across both markets have been investigated in several papers, both in developed and emerging markets. For developed countries, they have tended to suggest that the volatility spillovers are from stocks to foreign exchange rates (see, for example, Kanas (2000), Yang (2003), and Chiang and Yang (2003)). Investigation of the correlations for emerging markets has been conducted by Assoe (2001), Fang (2001), and Abid et al. (2003), who have suggested that the volatility spillovers occur in both directions.

The linkages among stock, bond and foreign exchange markets have to date enjoyed little attention in the literature. A few authors have investigated the linkages (see, for example, Najand and Yung (1997) and Eharmann et al. (2005)). Using the univariate GARCH model, Najand and Yung (1997) examined the relation between US stock index futures and Treasury bonds futures against the foreign currency futures of the British pound, Deutsche mark, Canadian dollar, Japanese yen, and Swiss franc. They find that returns on foreign currency futures are positively correlated with returns on stock index futures and negatively correlated with returns on Treasury bond futures. Ehrmann et al. (2005) investigate the shock transmission between the US and Euro area financial markets. They estimate a model that consists of structural and reduced forms for the first moment, and GARCH and Regime Switching models for the second moment. It was found that, in the USA, bond yields and equity markets are much more strongly affected by changes in short-term interest rates than in the case of the Euro area. By contrast, Euro area short rates and equity markets are relatively more affected by bond yields and exchange rates as compared with the US market.

III. METHODS

The primary purpose of the paper is to model returns and volatility spillovers across stock, bond and foreign exchange markets, and to provide empirical evidence regarding the usefulness of alternative models. Two multivariate models will be estimated for this purpose, namely the VARMA-AGARCH model of McAleer et al. (2009) and the VARMA-GARCH model of Ling and McAleer (2003). For further details regarding the structural and statistical properties of various time-varying univariate and multivariate conditional volatility models, see Li et al. (2002), Ling and McAleer (2002a, 2002b) and McAleer (2005).

In order to see whether the conditional variances of the stock and foreign exchange returns follow the GARCH process, univariate AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models will be estimated. If the properties of the univariate models are satisfied, then it would be sensible to extend the models to their multivariate counterparts.

The VARMA-AGARCH model of McAleer et al. (2009) can be formulated as follows:

$$Y_t = E(Y_t | F_{t-1}) + \varepsilon_t \qquad (1)$$

$$\Phi(L)(Y_t - \mu) = \Psi(L)\varepsilon_t$$

$$\varepsilon_t = D_t \eta_t$$

$$H_t = W + \sum_{l=1}^{r} A_l \vec{\varepsilon}_{t-l} + \sum_{l=1}^{r} C_l I(\eta_{t-l})\vec{\varepsilon}_{t-l} + \sum_{l=1}^{s} B_l H_{t-l} \qquad (2)$$

where $Y_t = (y_{1t},...,y_{mt})'$, $\varepsilon_t = (\varepsilon_{1t},...,\varepsilon_{mt})'$, $H_t = (h_{1t},...,h_{mt})'$, $W = (\omega_1,...,\omega_m)'$, $D_t = diag(h_{it}^2)$, $\eta_t = (\eta_{1t},...,\eta_{mt})$, $\vec{\varepsilon}_t = (\varepsilon_{1t}^2,...,\varepsilon_{mt}^2)'$, A_l, C_l and B_l are mxm matrices with typical elements α_i, γ_i and β_i, respectively, for $i, j = 1,...,m$, $I(\eta_t) = diag(I(\eta_{it}))$ is an mxm matrix, $\Phi(L) = I_m - \Phi_1 L - ... - \Phi_p L^p$ and $\Psi(L) = I_m - \Psi_1 L - ... - \Psi_q L^q$ are polynomials in L, the lag operator, F_t is the past information available to time t, I_m is the mxm identity matrix, and $I(\eta_{i,t})$ is an indicator function, given as:

$$I(\eta_{i,t}) = \begin{cases} 1, \varepsilon_{i,t} \le 0 \\ 0, \varepsilon_{i,t} > 0 \end{cases}$$

The VARMA-AGARCH model is able to capture the possible multivariate asymmetries concerning the impact of positive and negative unconditional shocks to market i on the conditional variance of market i through the coefficient γ_i.

Restricting equation (2) by setting C_l to the null matrix yields the VARMA-GARCH model of Ling and McAleer (2003), where the conditional variance equation is as follows:

$$H_t = W + \sum_{l=1}^{r} A_l \vec{\varepsilon}_{t-l} + \sum_{l=1}^{s} B_l H_{t-l} \ . \qquad (3)$$

The VARMA-GARCH model is the same as the VARMA-AGARCH model, except that it does not capture the asymmetric behaviour of positive and negative shocks.

Upon restricting the model given by equation (2) so that the matrices A_l and B_l are diagonal, while C_l is given by the null matrix, the VARMA-AGARCH model reduces to the univariate GARCH model of Bollserlev (1986). The equation for the conditional variance is as follows:

$$h_{it} = \omega_i + \sum_{l=1}^{r} \alpha_i \varepsilon_{i,t-l}^2 \sum_{l=1}^{s} \beta_i h_{i,t-l} \ . \qquad (4)$$

The univariate GARCH model does not permit interdependence of volatilities across different markets, and does not capture any asymmetric responses to shocks.

Restricting the model given in equation (2) so that the matrices A_l, B_l and C_l are diagonal, the VARMA-AGARCH model reduces to the univariate GJR model proposed by Glosten, Jagannathan and Runkle (1993). The equation for the conditional variance is as follows:

$$h_{it} = \omega_i + \sum_{l=1}^{r} (\alpha_i \varepsilon_{i,t-l}^2 + \gamma_i I_{i,t-l} \varepsilon_{i,t-1}^2) + \sum_{l=1}^{s} \beta_i h_{i,t-l} \ . \qquad (5)$$

The univariate GJR model is the same as the univariate GARCH model, except that the model captures the asymmetric responses of the conditional variance to positive and negative shocks.

IV. DATA ANALYSIS

The data used in the paper are the daily closing price index of bond, stock, and foreign exchange rates from Australia, Japan, New Zealand, Singapore, and USA. The bond, stock and foreign exchange returns and their variable names are summarized in Table 1. All the data are obtained from DataStream database services. The sample ranges from 30/9/1998 to 12/5/2006, with 1,986 observations for each index and foreign exchange rates. The starting date was chosen to be 30/9/1998 to exclude the effects of the 1997 Asian economic and financial crises, and because the Singaporean bond data are relatively constant before the starting date.

The returns of market i at time t are calculated as follows:

$$R_{i,t} = \log(P_{i,t} / P_{i,t-1}), \qquad (6)$$

where $P_{i,t}$ and $P_{i,t-1}$ are the closing prices of stock i at days t and $t-1$, respectively. In terms of foreign exchange returns, $P_{i,t}$ and $P_{i,t-1}$ are the exchange rates of country i at days t and $t-1$, respectively. Each stock and bond price index is denominated in the local currency.

The plots of the daily returns for the 20 series are given in Figure 1. The figure shows that the mean returns are constant but the variances change over time, with large (small) changes tending to be followed by large (small) changes of either sign. This ‘stylized fact’ seems appropriate to be modelled using Engle’s (1982) ARCH and Bollerslev’s (1986) GARCH models. Tests of ARCH and GARCH effects for these series are given in the next section, where it is shown that such time-varying effects are evident in all the returns series.

The normality of the variables in the 20 markets can be seen from the Jarque-Bera Lagrange multiplier statistics in Table 2. Since the probability of the Jarque-Bera statistics is zero in each case, it can be seen that the returns data for the 20 markets are not normally distributed.

To test the stationarity of the data, this paper uses the ADF test including a drift and a trend, to test the statonarity of the series. The test can modelled as follows:

$$DY_t = \beta_1 + \beta_2 T + \delta Y_{t-1} + \gamma DY_{t-1} + \varepsilon_t \,. \tag{7}$$

The test results for the 20 series are given in Table 3. The table shows that the estimated δ for all returns are less than zero at the 1% level, so that the returns are stationary.

V. EMPIRICAL RESULTS

All estimates are obtained by the EViews 5 econometric software package, using the quasi-maximum likelihood estimation (QMLE) method and both the Marquardt and BHHH algorithms. Similar results were obtained using the RATS 6 econometric software package. The QMLE method is used as the standardized errors are unlikely to be normally distributed, as discussed in the previous section.

The estimated parameters for the AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models are given in Tables 4 and 5, respectively. From Tables 4 and 5, it is clear that not all returns follow an AR(1) process. This may be interpreted as the returns possibly being determined by other variables, such as spillovers from other markets, while displaying GARCH volatility behaviour. From Table 4, the ARCH(1) term is not significant for SGBOND returns, although the GARCH(1) term is significant. From Table 5, the ARCH(1) term is not significant for SGBOND, AUSSTOCK and SGDNZD, but the corresponding GARCH(1) terms are significant. Therefore, the results reported above show that all series exhibit time-varying conditional volatility, which can be successfully modelled using the GARCH(1,1) and GJR(1,1) models. Asymmetric behaviour is found to be significant for NZBOND, AUSSTOCK, JAPSTOCK, USSTOCK and USDNZD.

In order to check the structural properties of the univariate models, the second moment and log-moment conditions are evaluated for both the AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models. Ling and McAleer (2003) showed that the QMLE for GARCH(r,s) is consistent if the second moment regularity condition is satisfied. Jeantheau (1988) showed that the weaker log-moment regularity condition, given by

$$E(\log(\alpha_1\eta_t^2 + \beta_1)) < 0, \qquad (6)$$

is sufficient for the QMLE to be consistent for the GARCH(1,1) model.

The second moment condition, namely $\alpha_1 + \frac{\gamma_1}{2} + \beta_1 < 1$, is sufficient for consistency and asymptotic normality of the QMLE for GJR(1,1). Moreover, McAleer et al. (2007) established the log-moment regularity condition for the GJR(1,1) model, namely

$$E(\log((\alpha_1 + \gamma_1 I(\eta_t))\eta_t^2 + \beta_1)) < 0, \qquad (7)$$

and showed that it is sufficient for the consistency and asymptotic normality of the QMLE for GJR(1,1). Table 6 provides the results of the second moment and log-moment conditions for the GARCH(1,1) and GJR(1,1) models for all returns series.

Regarding the regularity conditions of the AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models, both the second moment and log-moment conditions are satisfied for all returns, which suggest that the empirical estimates are statistically valid for these series. Thus, the AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models provide accurate measures of the conditional volatility in each of the series.

After demonstrating the statistical adequacy of the AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models, we can extend them to their multivariate counterparts, namely the VARMA(1,1)-GARCH(1,1) and VARMA(1,1)-AGARCH(1,1) models, respectively. As some returns exhibit asymmetric patterns in the conditional variances, and the VARMA(1,1)-GARCH(1,1) estimates are similar to those of the VARMA(1,1)-AGARCH(1,1) estimates, despite the significance of the asymmetric terms, only the VARMA(1,1)-

AGARCH(1,1) estimates will be presented. The VARMA(1,1)-GARCH(1,1) estimates are available from the authors upon request.

Data analysis using the VARMA(1,1)-AGARCH(1,1) model is conducted for five countries, as described above. Groupings of models will be examined, where each group of models contains two countries, namely two stock and bond indices and the exchange rates between a country pair. As five countries are investigated, there are ten models to be estimated in total. In estimating the VARMA(1,1)-AGARCH(1,1) model for the 20 variables, some of the equations have to be estimated using the BHHH algorithm, other than the default Marquardt algorithm in the EViews 5 econometric software package. All sample range from 30/9/1998 to 12/5/2006, giving 1986 observations for each series. However, the Japan-New Zealand case reached convergence only when the sample was reduced to 30/10/1998 to 12/5/2006.

The estimates of the conditional means and conditional variances of the VARMA(1,1)-AGARCH(1,1) model are given in Tables 9.a to 18.b. A summary of the mean and volatility spillovers, together with their signs, are given in Tables 7 and 8, respectively. From the analysis of the mean spillovers, there is evidence of international spillovers from every market to all other markets. Thus, international mean spillovers are evident for bond to bond, bond to exchange rates, bond to stock, exchange rates to bond, exchange rates to stock, stock to bond, stock to exchange rates, and stock to stock markets. The signs of the spillovers within individual markets, namely from one bond market to another and from one stock market to another, are all positive, while the rest are a mixture of positive and negative effects. Spillovers from bond to bond markets, and from stock to stock markets, which are evident in 19 cases, are dominated by the USA, followed by Singapore.

International mean spillovers across markets, namely from bond to stock markets and from stock to bond markets, are evident in only five cases, and is dominated by USA. Therefore, international mean spillovers in individual markets are more common than across markets, and are dominated by the USA. In addition, domestic mean spillovers are evident only in one case, namely from AUSSTOCK to AUSBOND.

There is also strong evidence of mean spillovers from exchange rates to both stock and bond markets, and from both stock and bond markets to exchange rates. The spillovers are generally of the same magnitude, and the signs are mixed.

Volatility spillovers consist of short and long run persistence. The short run persistence of shocks to index *i* in the same market is given by $\hat{\alpha}_i + \frac{1}{2}\hat{\gamma}_i$, where $\hat{\alpha}_i$ is the estimated short run persistence of positive shocks and $\hat{\alpha}_i + \hat{\gamma}_i$ is the estimated short run persistence of negative shocks. The estimated long run persistence of shocks to index *i* in the same market is given by $\hat{\alpha}_i + \frac{1}{2}\hat{\gamma}_i + \hat{\beta}_i$. Tables 9.b to 18.b show that all markets are influenced by their own long run persistence, but some are not influenced by their own short run persistence.

There is also evidence of international volatility spillovers from every market to all other markets. This means that volatility spillovers are evident from bond to bond, bond to exchange rates, bond to stock, exchange rates to bond, exchange rates to stock, stock to bond, stock to exchange rates, and stock to stock markets. The signs of spillovers from one stock to another stock market are all positive, while the remaining spillover effects are of mixed signs. As distinct from the case of mean spillovers discussed above, bond-to-bond and stock-to-stock market spillovers are not dominated by a single country.

International volatility spillovers across markets (from bond to stock markets and from stock to bond markets) are also evident. The spillovers across markets are as strong as those within an individual market, namely from bond to bond markets and from stock to stock markets. Even though there is no dominating country, the USA remains the strongest country with regard to cross-country influences.

Domestic volatility spillovers are also evident in several cases, namely from NZBOND to NZSTOCK, USBOND to USSTOCK, USSTOCK to USBOND, JAPSTOCK to JAPBOND, and SGSTOCK to SGBOND.

There is also strong evidence of volatility spillovers from exchange rates to both stock and bond markets, and from both stock and bond markets to exchange rates. The spillovers are of similar magnitude, and the signs are mixed.

Asymmetry, as indicated by the significance of $\hat{\gamma}$, is evident in the cases of JAPBOND, JAPSTOCK, AUSSTOCK, NZBOND, SGSTOCK, SGDNZD, USDNZD, and USSTOCK. In total, 8 of 20 variables, namely 5 bond indices, 5 stock indices and 10 exchange rates, with significant asymmetric effects, which supports the use of the VARMA(1,1)-AGARCH(1,1) model.

VI. CONCLUSIONS

The paper investigated the mean and volatility spillovers across bond, stock and foreign exchange rate markets in Australia, Japan, New Zealand, Singapore and USA. The VARMA(1,1)-AGARCH(1,1) model of McAleer et al. (2009) was estimated for the variables as it allows the own short and long run persistence to behave asymmetrically. Modelling the interactions across country pairs from among the five countries resulted in ten models in total, with each model having two stock indices, two bond indices, and exchange rates of the corresponding countries.

From the analysis of the mean spillovers, there was evidence of international spillovers from each market to all other markets. The signs of the spillovers within individual markets, namely from one bond market to another and from one stock market to another, were all positive, while the remainder had a mixture of signs. International mean spillovers across markets were evident in only a few cases. Therefore, it can be concluded that international mean spillovers in individual markets are more common than across markets. Such spillovers were dominated by the USA, followed by Singapore. Domestic mean spillovers were evident in only one case, namely from AUSSTOCK to AUSBOND. There was also strong evidence of mean spillovers from exchange rates to both stock and bond markets, and from both stock and bond markets to exchange rates. The spillovers were generally of the same magnitude, and the signs were mixed.

There was evidence of international volatility spillovers from each market to all other markets. The signs of the spillovers from one stock market to another were all positive, while the other spillover effects were a mixture of positive and negative signs. As distinct from the case of mean spillovers, bond-to-bond and stock-to-stock market volatility spillovers were not dominated by a single country. International volatility spillovers across markets, namely from bond to stock markets and from stock to bond markets, were also evident. The spillovers across markets were found to be as strong as those within individual markets, namely from bond to bond markets and from stock to stock markets. While there was no dominant country, the USA was the strongest country influencing the other countries. All countries, except Australia, experienced domestic volatility spillovers, either from stock to bond markets or the reverse. There was also strong evidence of volatility spillovers from exchange rates to both stock and bond markets, and from stock and bond markets to exchange rates. The spillovers were of the same magnitude, with mixed signs. Asymmetry was evident in 8 of 20 cases, thereby supporting the use of the VARMA(1,1)-AGARCH(1,1) model.

The multivariate models assumed that the conditional correlations were constant. As suggested in da Veiga and McAleer (2005), however, the conditional correlations between S&P 500 and Nikkei 225 were typically not constant, so that future research might consider using models that consider time-varying conditional correlations, such as the VCC model of Tse and Tsui (2002), the DCC model of Engle (2002), or the GARCC model of McAleer et al. (2008).

As SGSTOCK and S&P 500 are non-synchronous, while SGSTOCK and Nikkei 225 are synchronous, future research might also consider modelling such returns using sequential and joint estimation methods. This would provide a check of the robustness of the empirical results presented in this paper.

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Appendix

Figure 1: Daily Returns for All Series

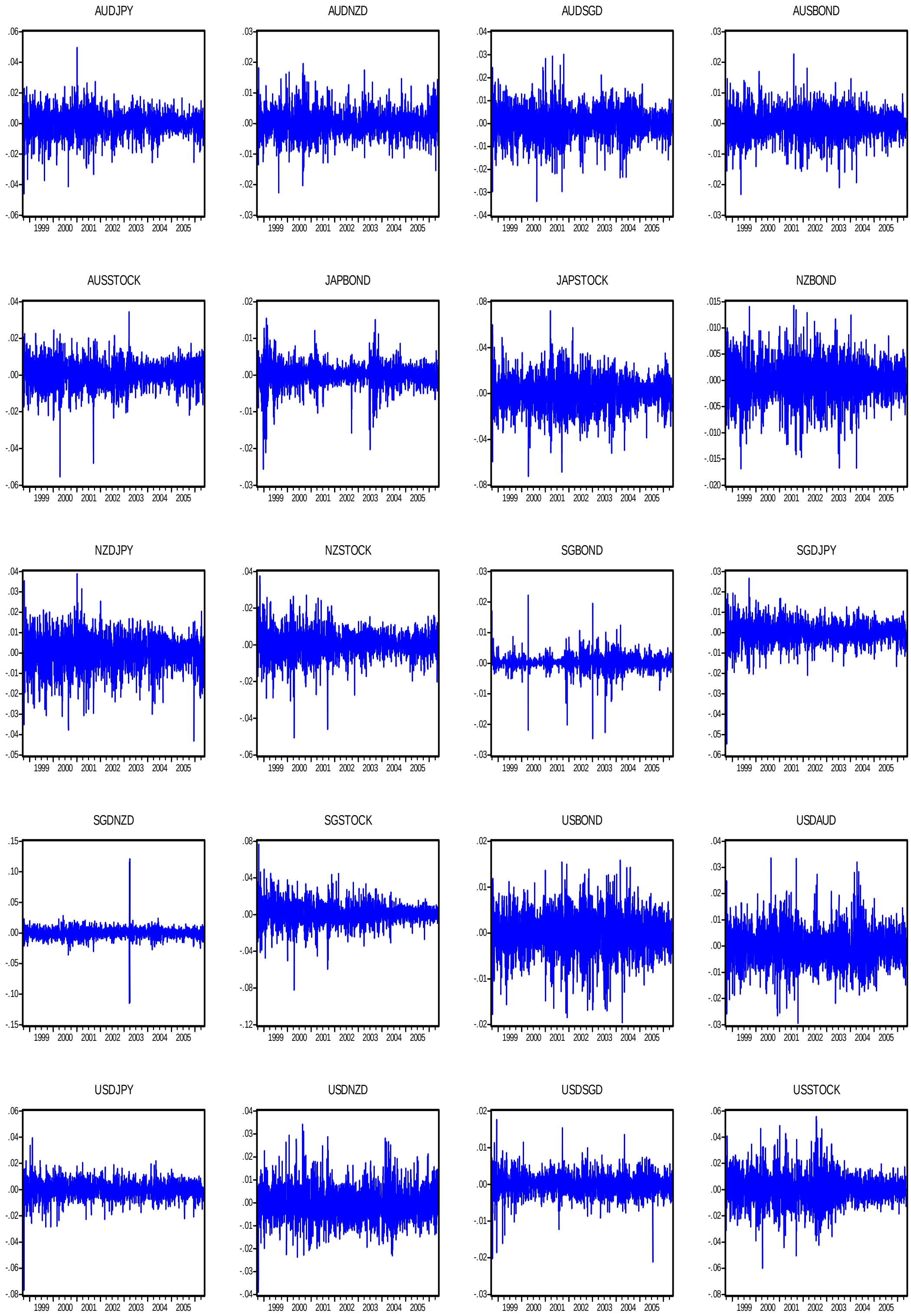

Table 1: Summary of Variable Names

Variable	Index Names	Variable Names
Australian Bond	AU Benchmark 10 Year Govt. Index	AUSBOND
Japanese Bond	JP Benchmark 10 Year Govt. Index	JAPBOND
New Zealand Bond	NZ Benchmark 10 Year Govt. Index	NZBOND
Singaporean Bond	Sg Gov. Bond Long Term Index	SGBOND
US Bond	US Benchmark 10 Year Govt. Index	USBOND
Australian Stock	S&P ASX 200 Price Index	AUSSTOCK
Japanese Stock	Nikkei 225 Stock Average Price Index	JAPSTOCK
New Zealand stock	NZX ALL Price Index	NZSTOCK
Singaporean Stock	Singapore Straits Time Price Index	SGSTOCK
US Stock	S&P 500 Composite Price Index	USSTOCK
Australia – Japan ER	-	AUDJPY
Australia – New Zealand ER	-	AUDNZD
Australia – Singapore ER	-	AUDSGD
Australia – USA ER	-	USDAUD
Japan – New Zealand ER	-	NZDJPY
Japan – Singapore ER	-	SGDJY
Japan – USA ER	-	USDJPY
New Zealand – Singapore ER	-	SGDNZD
New Zealand – USA ER	-	USDNZD
Singapore – USA ER	-	USDSGD

Note: ER = Exchange Rates.

Table 2: Jarque-Bera and Its Probability for the Returns

Returns	Jarque-Bera	Probability
AUSBOND	189.4	0
JAPBOND	4716.4	0
NZBOND	151.5	0
SGBOND	30155	0
USBOND	151.3	0
AUSSTOCK	1437.4	0
JAPSTOCK	237	0
NZSTOCK	1445.3	0
SGSTOCK	1325.5	0
USSTOCK	403.7	0
AUDJPY	768.3	0
AUDNZD	465.7	0
AUDSGD	339.2	0
NZDJPY	4402.5	0
SGDJY	310994.8	0
SGDNZD	9902.1	0
USDAUD	318.2	0
USDJPY	247.6	0
USDNZD	236.2	0
USDSGD	2552.3	0

Table 3: ADF Test of a Unit Root in the Returns

Variable Names	Coefficients	t-statistic	Probability
AUSBOND	-1.0276	-45.8023	0
JAPBOND	-0.9893	-44.0918	0
NZBOND	-1.0354	-46.1477	0
SGBOND	-0.9735	-43.8456	0
USBOND	-0.9510	-42.4695	0
AUSSTOCK	-1.0193	-45.4151	0
JAPSTOCK	-1.0333	-46.0874	0
NZSTOCK	-0.9503	-42.3883	0
SGSTOCK	-0.9611	-42.8456	0
USSTOCK	-1.0183	-45.4378	0
AUDJPY	-1.0171	-45.3085	0
AUDNZD	-1.0016	-44.5813	0
AUDSGD	-1.0796	-48.2386	0
NZDJPY	-0.9815	-43.7179	0
SGDJPY	-0.9229	-41.2164	0
SGDNZD	-1.3534	-41.4816	0
USDAUD	-1.0308	-45.9233	0
USDJPY	-0.9818	-43.7941	0
USDNZD	-0.9955	-44.3424	0
USDSGD	-1.0393	-46.3969	0

Note: All estimates of δ are significantly less than 0 at the 1% level.

Table 4: Univariate AR(1)-GARCH(1,1) Estimates

Variable	C	AR(1)	ω	α	β
AUSBOND	0	-0.015	0	**0.014**	**0.984**
JAPBOND	0	0.009	0	**0.107**	**0.884**
NZBOND	0	-0.01	0	**0.03**	**0.965**
SGBOND	**0**	**0.126**	0	0.154	**0.801**
USBOND	0	0.043	0	**0.036**	**0.952**
AUSSTOCK	**0.001**	0	**0**	**0.071**	**0.91**
JAPSTOCK	0	-0.001	**0**	**0.07**	**0.916**
NZSTOCK	**0**	**0.071**	**0**	**0.071**	**0.916**
SGSTOCK	**0.001**	0.032	**0**	**0.074**	**0.923**
USSTOCK	0	-0.031	**0**	**0.055**	**0.941**
AUDJPY	0	0.013	**0**	**0.044**	**0.948**
AUDNZD	0	0.02	**0**	**0.04**	**0.937**
AUDZGD	0	**-0.047**	**0**	**0.038**	**0.955**
NZDJPY	0	0.031	**0**	**0.047**	**0.943**
SGDJPY	0	0.01	**0**	**0.045**	**0.937**
SGDNZD	0	-0.035	**0**	**0.099**	**0.719**
USDAUD	0	-0.023	**0**	**0.037**	**0.95**
USDJPY	0	-0.023	**0**	**0.017**	**0.963**
USDNZD	0	0.008	**0**	**0.034**	**0.923**
USDSGD	0	-0.024	0	**0.032**	**0.947**

Notes:
1. The entries are estimates for each parameter.
2. C and AR(1) denote the constant and the own one-period lagged returns.
3. Entries in **bold** are significant at the 5% level.

Table 5: Univariate AR(1)-GJR(1,1) Estimates

Variable	C	AR(1)	ω	α	γ	β
AUSBOND	0	-0.015	0	**0.016**	-0.003	**0.984**
JAPBOND	0	0.018	**0**	**0.067**	0.073	**0.879**
NZBOND	0	-0.008	0	**0.043**	**-0.026**	**0.968**
SGBOND	**0**	**0.128**	0	0.149	0.011	**0.8**
USBOND	0	0.041	0	**0.043**	-0.015	**0.955**
AUSSTOCK	**0**	0.001	**0**	0.002	**0.116**	**0.916**
JAPSTOCK	0	0.002	**0**	**0.04**	**0.064**	**0.909**
NZSTOCK	**0**	**0.071**	**0**	**0.055**	0.025	**0.919**
SGSTOCK	**0.001**	0.035	**0**	**0.055**	0.036	**0.924**
USSTOCK	0	-0.022	**0**	**-0.017**	**0.118**	**0.953**
AUDJPY	0	0.013	**0**	**0.044**	-0.001	**0.948**
AUDNZD	0	0.023	**0**	**0.047**	-0.023	**0.94**
AUDSGD	0	**-0.046**	**0**	**0.031**	0.012	**0.955**
NZDJPY	0	0.03	**0**	**0.049**	-0.004	**0.944**
SGDJPY	0	0.011	**0**	**0.041**	0.01	**0.934**
SGDNZD	0	-0.028	0	0.037	0.192	**0.583**
USDAUD	0	-0.023	0	**0.04**	-0.007	**0.95**
USDJPY	0	-0.023	**0**	**0.018**	-0.003	**0.964**
USDNZD	0	0.006	**0**	**0.051**	**-0.041**	**0.917**
USDSGD	0	-0.023	0	**0.038**	-0.01	**0.944**

Notes:

1. The entries are estimates for each parameter.
2. C and AR(1) denote the constant and the own one-period lagged returns.
3. Entries in **bold** are significant at the 5% level.

Table 6: Second Moment and Log Moment Conditions for the AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) Models

	GARCH(1,1)		GJR(1,1)	
Variable	Second Moment	Log Moment	Second Moment	Log Moment
AUSBOND	0.998	-0.002	0.998	-0.002
JAPBOND	0.991	-0.024	0.982	-0.032
NZBOND	0.995	-0.006	0.998	-0.004
SGBOND	0.955	-0.101	0.955	-0.101
USBOND	0.988	-0.013	0.991	-0.011
AUDJPY	0.991	-0.012	0.991	-0.011
AUDNZD	0.977	-0.025	0.976	-0.026
AUDSGD	0.993	-0.009	0.992	-0.010
NZDJPY	0.991	-0.012	0.991	-0.012
SGDJPY	0.982	-0.021	0.980	-0.023
SGDNZD	0.818	-0.228	0.715	-0.393
USDAUD	0.987	-0.015	0.986	-0.016
USDJPY	0.980	-0.021	0.981	-0.020
USDNZD	0.957	-0.046	0.947	-0.055
USDSGD	0.979	-0.023	0.978	-0.025
AUSSTOCK	0.981	-0.026	0.976	-0.031
JAPSTOCK	0.986	-0.020	0.981	-0.026
NZSTOCK	0.987	-0.019	0.987	-0.019
SGSTOCK	0.997	-0.010	0.996	-0.011
USSTOCK	0.995	-0.008	0.995	-0.011

Table 7: Summary of Mean Spillovers and Their Signs

Exchange Rates to Bond	**Sign**	**Bond to Stock**	**Sign**
NZJPY to JAPBOND	-	AUSBOND to NZSTOCK	-
USDJPY to JAPBOND	+	SGBOND to AUSSTOCK	+
USDJPY to USBOND	+	USBOND to AUSSTOCK	+
USDNZD to USBOND	+		
USDSGD to SGBOND	-	**Stock to Bond**	
USDSGD to USBOND	+	AUSSTOCK to AUSBOND *	+
		USSTOCK to AUSBOND	-
Exchange Rates to Stock		USSTOCK to NZBOND	-
NZDJPY to JAPSTOCK	+		
SGDJPY to JAPSTOCK	+	**Stock to Exchange Rates**	
USDJPY to JAPSTOCK	-	USSTOCK to USDAUD	-
SGDNZD to NZSTOCK	-	NZSTOCK to NZDJPY	+
USDNZD to NZSTOCK	+	JAPSTOCK to SGDJPY	-
USDSGD to USSTOCK	-	SGSTOCK to SGDJPY	+
		USSTOCK to USDJPY	-
Bond to Bond		NZSTOCK to SGDNZD	+
AUSBOND to NZBOND	+	NZSTOCK to USDNZD	-
USBOND to AUSBOND	+	USSTOCK to USDNZD	-
NZBOND to JAPBOND	+	USSTOCK to USDSGD	-
SGBOND to JAPBOND	+		
SUBOND to JAPBOND	+	**Stock to Stock**	
SGBOND to NZBOND	+	AUSSTOCK to NZSTOCK	+
USBOND to NZBOND	+	SGSTOCK to AUSSTOCK	+
USBOND to SGBOND	+	USSTOCK to AUSSTOCK	+
		JAPSTOCK to NZSTOCK	+
Bond to Exchange Rates		SGSTOCK to JAPSTOCK	+
AUSBOND to AUDJPY	-	USSTOCK to JAPSTOCK	+
AUSBOND to AUDSGD	-	SGSTOCK to NZSTOCK	+
SGBOND to AUDSGD	+	USSTOCK to NZSTOCK	+
USBOND to USDAUD	+	USSTOCK to SGSTOCK	+
JAPBOND to NZDJPY	+		
NZBOND to NZDJPY	-		
JAPBOND to SGDJPY	+		
SGBOND to SGDJPY	-		
JAPBOND to USDJPY	+		
USBOND to USDJPY	-		
USBOND to USDSGD	-		
USBOND to USDAUD	-		

Note: * = domestic spillovers.

Table 8: Summary of Volatility Spillovers and Their Signs

Exchange Rates to Bond	**Sign**	**Bond to Stock**	**Sign**
AUDJPY to AUSBOND (S,L)	- , +	SGBOND to SGSTOCK (L)	-
AUDSGD to SGBOND (S,L)	- , -	AUSBOND to SGSTOCK (L)	+
USDAUD to AUSBOND (S)	-	USBOND to AUSSTOCK (S)	+
USDNZD to NZBONDS, (S,L)	+ , -	AUSBOND to USSTOCK (L)	+
USDSGD to USBOND (L)	+	NZBOND to NZSTOCK* (S,L)	+ , -
		NZBOND to SGSTOCK (L)	+
Exchange Rates to Stock		USBOND to NZSTOCK (L)	-
AUDNZD to NZSTOCK (L)	+	USBOND to USSTOCK* (S,L)	- , +
AUDSGD to SGSTOCK (L)	+		
USDAUD to AUSSTOCK (S)	-	**Stock to Bond**	
SGDJPY to SGSTOCK (S,L)	- , +	JAPSTOCK to JAPBOND* (S)	-
SGDNZD to NZSTOCK (S)	-	AUSSTOCK to AUSBOND* (S,L)	+ , +
		USSTOCK to AUSBOND (L)	+
Bond to Bond		JAPSTOCK to NZBOND (S)	+
NZBOND to AUSBOND (S)	+	JAPSTOCK to JAPBOND*(L)	-
AUSBOND to NZBOND (L)	-	USSTOCK to USBOND* (S,L)	+ , +
AUSBOND to SGBOND (S)	+	SGSTOCK to SGBOND* (L)	-
USBOND to AUSBOND (S,L)	+ , +	NZSTOCK to USBOND (L)	-
JAPBOND to SGBOND (S)	-	USSTOCK to SGBOND (S)	-
NZBOND to SGBOND (L)	+	USSTOCK to USBOND* (S)	-
USBOND to NZBOND (S,L)	+ , +		
SGBOND to USBOND (S,L)	+ , -	**Stock to Exchange Rates**	
		SGSTOCK to AUDSGD (S)	+
Bond to Exchange Rates		JAPSTOCK to SGDJPY (L)	-
USBOND to USDAUD (L)	-	JAPSTOCK to USDJPY (L)	-
SGBOND to SGDJPY (L)	-	NZSTOCK to USDNZD (S,L)	- , +
USBOND to USDJPY (S)	-	USSTOCK to USDNZD (L)	+
USBOND to USDSGD (L)	+	USSTOCK to USDSGD (S,L)	+ , -
		Stock to Stock	
		AUSSTOCK to NZSTOCK (S)	+
		SGSTOCK to AUSSTOCK (S)	+
		USSTOCK to JAPSTOCK (S)	+
		SGSTOCK to NZSTOCK (S)	+
		NZSTOCK to SGSTOCK (L)	+
		USSTOCK to SGSTOCK (L)	+

Note: S = short persistence, L = long persistence, and * = domestic spillovers.

Notes on Tables 9.a to 18.b.:

1. The entries are estimates for each parameter.
2. C and MA denote constant and Moving Average.
3. Entries in **bold** are significant at the 5% level.

Table 9.a: VARMA-AGARCH: Conditional Mean for Australia-Japan

Return	C	MA(1)	AUDJPY(-1)	AUSBOND(-1)	AUSSTOCK(-1)	JAPBOND(-1)	JAPSTOCK(-1)
AUDJPY	0.000	**0.747**	**-0.769**	**-0.154**	0.049	0.145	-0.001
AUSBOND	0.000	-0.488	0.002	0.454	-0.006	0.009	-0.003
AUSSTOCK	0.000	0.002	0.011	-0.011	-0.024	0.022	0.025
JAPBOND	0.000	-0.306	0.014	0.032	-0.002	0.292	-0.007
JAPSTOCK	0.000	0.248	0.001	-0.086	0.124	-0.067	-0.277

Table 9.b: VARMA-AGARCH: Conditional Variance for Australia-Japan

Variance	ω	α_{AUDJPY}	$\alpha_{AUSBOND}$	$\alpha_{AUSSTOCK}$	$\alpha_{JAPBOND}$	$\alpha_{JAPSTOCK}$	γ	β_{AUDJPY}	$\beta_{AUSBOND}$	$\beta_{AUSSTOCK}$	$\beta_{JAPBOND}$	$\beta_{JAPSTOCK}$
AUDJPY	0.000	**0.047**	0.009	-0.009	0.002	0.004	-0.007	**0.937**	0.011	0.012	0.008	-0.002
AUSBOND	0.000	**-0.002**	-0.008	-0.002	0.000	0.001	0.008	**0.002**	**1.001**	0.004	-0.002	-0.001
AUSSTOCK	**0.000**	0.008	-0.003	**0.111**	-0.053	-0.001	0.129	-0.002	-0.037	**0.450**	-0.043	-0.007
JAPBOND	**0.000**	0.001	0.000	0.000	0.047	**-0.002**	**0.078**	0.002	0.000	0.000	**0.889**	0.001
JAPSTOCK	0.000	-0.028	0.017	0.055	-0.175	0.036	**0.060**	0.057	0.193	-0.056	0.269	**0.895**

Table 10.a: VARMA-AGARCH: Conditional Mean for Australia-New Zealand

Return	C	MA(1)	AUDNZD(-1)	AUSBOND(-1)	AUSSTOCK(-1)	NZBOND(-1)	NZSTOCK(-1)
AUDNZD	0.000	0.011	0.002	-0.066	0.000	0.022	0.010
AUSBOND	0.000	-0.141	0.023	0.107	-0.021	0.015	0.012
AUSSTOCK	0.000	**-0.679**	0.011	-0.039	**0.685**	0.050	-0.023
NZBOND	0.000	**-0.835**	0.010	**0.116**	0.002	**0.686**	-0.003
NZSTOCK	0.000	-0.153	-0.008	**-0.116**	**0.082**	0.099	0.208

Table 10.b: VARMA-AGARCH: Conditional Variance for Australia-New Zealand

Variance	ω	α_{AUDNZD}	$\alpha_{AUSBOND}$	$\alpha_{AUSSTOCK}$	α_{NZBOND}	$\alpha_{NZSTOCK}$	γ	β_{AUDNZD}	$\beta_{AUSBOND}$	$\beta_{AUSSTOCK}$	β_{NZBOND}	$\beta_{NZSTOCK}$
AUDNZD	**0.000**	**0.140**	0.000	0.000	0.010	0.000	0.030	**0.540**	-0.040	0.000	-0.010	-0.010
AUSBOND	0.000	0.000	-0.010	**0.000**	**0.020**	0.000	-0.010	0.000	**1.000**	**0.010**	0.000	0.000
AUSSTOCK	0.000	0.000	0.010	-0.020	-0.020	0.000	**0.140**	0.050	0.040	**0.890**	-0.060	0.030
NZBOND	0.000	0.000	0.000	0.000	**0.010**	0.000	**-0.020**	0.000	**-0.010**	0.000	**1.000**	0.000
NZSTOCK	0.000	0.010	0.060	**0.040**	0.000	**0.070**	0.020	**0.180**	-0.050	-0.030	0.030	**0.850**

Table 11.a: VARMA-AGARCH: Conditional Mean for Australia-Singapore

Return	C	MA(1)	AUDSGD(-1)	AUSBOND(-1)	AUSSTOCK(-1)	SGBOND(-1)	SGSTOCK(-1)
AUDSGD	0.000	**-0.545**	**0.485**	**-0.170**	0.034	**0.165**	**0.025**
AUSBOND	0.000	-0.180	-0.023	0.118	-0.003	**0.145**	-0.013
AUSSTOCK	**0.001**	**0.628**	-0.011	-0.011	**-0.633**	**0.109**	**0.036**
SGBOND	**0.000**	0.106	-0.002	0.002	0.012	0.033	-0.004
SGSTOCK	0.000	**-0.636**	0.050	0.004	0.036	-0.056	**0.658**

Table 11.b: VARMA-AGARCH: Conditional Variance for Australia-Singapore

Variance	ω	α_{AUDSGD}	$\alpha_{AUSBOND}$	$\alpha_{AUSSTOCK}$	α_{SGBOND}	$\alpha_{SGSTOCK}$	γ	β_{AUDSGD}	$\beta_{AUSBOND}$	$\beta_{AUSSTOCK}$	β_{SGBOND}	$\beta_{SGSTOCK}$
AUDSGD	**0.000**	**0.025**	-0.007	-0.004	0.009	**0.005**	0.016	**0.948**	0.002	-0.004	-0.010	-0.001
AUSBOND	0.000	-0.001	0.004	-0.004	0.013	0.001	0.007	0.003	**0.990**	**0.006**	-0.015	-0.002
AUSSTOCK	**0.000**	-0.003	-0.008	-0.015	0.030	**0.008**	**0.119**	0.000	0.004	**0.918**	-0.068	-0.004
SGBOND	**0.000**	**-0.001**	**0.010**	-0.001	**0.170**	0.000	0.007	**-0.009**	0.007	0.000	**0.780**	0.001
SGSTOCK	**0.000**	-0.031	0.006	0.017	0.409	0.042	**0.065**	**0.073**	**0.385**	0.028	-0.435	**0.862**

Table 12.a: VARMA-AGARCH: Conditional Mean for Australia-USA

Return	C	MA(1)	USDAUD	AUSBOND(-1)	AUSSTOCK(-1)	USBOND(-1)	USSTOCK(-1)
USDAUD	0.000	**-0.730**	**0.704**	**0.195**	-0.021	**-0.181**	**-0.051**
AUSBOND	0.000	**-0.123**	0.005	-0.048	**0.020**	**0.683**	**-0.032**
AUSSTOCK	**0.000**	**-0.176**	-0.006	0.018	**0.081**	**0.111**	**0.321**
USBOND	0.000	0.044	0.004	-0.017	-0.011	0.000	0.006
USSTOCK	0.000	**0.731**	-0.034	0.006	0.004	**0.074**	**-0.738**

Table 12.b: VARMA-AGARCH: Conditional Variance for Australia-USA

Variance	ω	α_{USDAUD}	$\alpha_{AUSBOND}$	$\alpha_{AUSSTOCK}$	α_{USBOND}	$\alpha_{USSTOCK}$	γ	β_{USDAUD}	$\beta_{AUSBOND}$	$\beta_{AUSSTOCK}$	β_{USBOND}	$\beta_{USSTOCK}$
USDAUD	**0.000**	**0.029**	-0.005	0.000	0.024	0.004	-0.001	**0.954**	0.023	-0.005	**-0.054**	-0.004
AUSBOND	**0.000**	**-0.005**	**0.147**	-0.003	**0.069**	0.004	-0.046	-0.002	**0.231**	**-0.019**	**0.171**	**0.018**
AUSSTOCK	**0.000**	**-0.011**	0.009	0.030	**-0.021**	**0.009**	0.046	0.013	0.006	**0.888**	-0.021	-0.003
USBOND	**0.000**	-0.002	0.006	-0.002	0.028	0.002	-0.002	0.003	0.002	-0.002	**0.945**	-0.001
USSTOCK	0.000	-0.004	0.001	0.011	-0.056	**-0.030**	**0.132**	-0.001	**0.144**	0.000	0.018	**0.949**

Table 13.a: VARMA-AGARCH: Conditional Mean for Japan-New Zealand

Return	C	MA(1)	NZDJPY(-1)	JAPBOND(-1)	JAPSTOCK(-1)	NZBOND(-1)	NZSTOCK(-1)
NZDJPY	0.000	**-0.752**	**0.741**	**0.079**	0.001	**-0.110**	**0.076**
JAPBOND	0.000	**-0.558**	**0.016**	**0.536**	-0.008	**0.029**	0.001
JAPSTOCK	0.000	**0.413**	**0.071**	-0.082	**-0.420**	-0.119	0.065
NZBOND	0.000	0.227	0.006	0.051	-0.009	-0.247	0.001
NZSTOCK	0.000	**0.504**	-0.007	0.014	**0.027**	0.025	**-0.440**

Table 13.b: VARMA-AGARCH: Conditional Variance for Japan-New Zealand

Variance	ω	α_{NZDJPY}	$\alpha_{JAPBOND}$	$\alpha_{JAPSTOCK}$	α_{NZBOND}	$\alpha_{NZSTOCK}$	γ	β_{NZDJPY}	$\beta_{JAPBOND}$	$\beta_{JAPSTOCK}$	β_{NZBOND}	$\beta_{NZSTOCK}$
NZDJPY	0.000	**0.042**	0.034	-0.002	0.022	0.017	-0.004	**0.940**	-0.032	0.004	-0.011	-0.006
JAPBOND	0.000	0.000	0.043	0.001	0.005	-0.001	**0.078**	0.003	**0.895**	**-0.001**	0.000	0.001
JAPSTOCK	0.000	-0.014	-0.209	0.037	-0.052	0.020	**0.068**	0.046	0.251	**0.885**	0.443	0.005
NZBOND	0.000	0.000	-0.003	**0.001**	**0.027**	0.001	**-0.024**	-0.001	0.007	-0.001	**0.980**	-0.001
NZSTOCK	**0.000**	-0.005	0.020	-0.002	**0.069**	**0.055**	0.040	0.019	-0.025	0.001	**-0.095**	**0.895**

Table 14.a: VARMA-AGARCH: Conditional Mean for Japan-Singapore

Return	C	MA(1)	SGDJPY(-1)	JAPBOND(-1)	JAPSTOCK(-1)	SGBOND(-1)	SGSTOCK(-1)
SGDJPY	0.000	**-0.917**	**0.910**	**0.056**	**-0.011**	**-0.059**	**0.008**
JAPBOND	0.000	-0.333	-0.012	0.313	-0.007	**0.049**	0.000
JAPSTOCK	0.000	-0.161	**0.106**	-0.044	0.111	-0.108	**0.120**
SGBOND	0.000	0.006	-0.014	0.023	0.000	0.021	-0.006
SGSTOCK	0.000	**-0.474**	0.002	0.095	-0.021	-0.094	**0.523**

Table 14.b: VARMA-AGARCH: Conditional Variance for Japan-Singapore

Variance	ω	α_{SGDJPY}	$\alpha_{JAPBOND}$	$\alpha_{JAPSTOCK}$	α_{SGBOND}	$\alpha_{SGSTOCK}$	γ	β_{SGDJPY}	$\beta_{JAPBOND}$	$\beta_{JAPSTOCK}$	β_{SGBOND}	$\beta_{SGSTOCK}$
SGDJPY	**0.000**	**0.036**	0.008	0.002	0.015	0.002	0.010	**0.914**	0.005	**-0.004**	**-0.034**	0.002
JAPBOND	**0.000**	0.001	0.060	0.001	0.001	0.000	0.065	0.003	**0.884**	**-0.001**	0.000	0.000
JAPSTOCK	**0.000**	-0.009	-0.143	0.030	0.378	0.010	**0.070**	-0.028	0.286	**0.906**	-0.318	0.002
SGBOND	**0.000**	0.000	**-0.009**	-0.001	**0.151**	0.001	0.050	-0.003	-0.005	-0.002	**0.600**	0.000
SGSTOCK	**0.000**	**-0.064**	-0.128	0.000	0.039	**0.054**	**0.095**	**0.181**	0.261	0.001	0.091	**0.870**

Table 15.a: VARMA-AGARCH: Conditional Mean for Japan-USA

Return	C	MA(1)	USDJPY(-1)	JAPBOND(-1)	JAPSTOCK(-1)	USBOND(-1)	USSTOCK(-1)
USDJPY	0.000	**-0.636**	**0.607**	**0.088**	-0.015	**-0.131**	**-0.033**
JAPBOND	0.000	-0.243	**-0.021**	0.231	-0.005	**0.062**	-0.006
JAPSTOCK	0.000	**-0.256**	**0.109**	-0.017	**0.178**	-0.062	**0.442**
USBOND	0.000	-0.265	**0.040**	-0.048	0.000	0.306	-0.002
USSTOCK	0.000	**0.684**	**-0.050**	0.002	0.004	0.062	**-0.692**

Table 15.b: VARMA-AGARCH: Conditional Variance for Japan-USA

Variance	ω	α_{USDJPY}	$\alpha_{JAPBOND}$	$\alpha_{JAPSTOCK}$	α_{USBOND}	$\alpha_{USSTOCK}$	γ	β_{USDJPY}	$\beta_{JAPBOND}$	$\beta_{JAPSTOCK}$	β_{USBOND}	$\beta_{USSTOCK}$
USDJPY	**0.000**	0.012	0.023	0.002	**-0.026**	0.005	0.009	**0.921**	0.018	**-0.006**	0.030	0.000
JAPBOND	**0.000**	0.000	0.040	0.000	0.003	0.000	**0.084**	0.002	**0.895**	-0.001	-0.003	0.001
JAPSTOCK	0.000	-0.008	-0.069	**0.032**	-0.034	**0.040**	**0.051**	-0.025	0.192	**0.911**	0.164	-0.024
USBOND	**0.000**	-0.002	0.008	0.000	-0.010	**0.003**	0.014	0.000	-0.005	0.000	**0.999**	**-0.003**
USSTOCK	0.000	-0.003	-0.019	0.001	-0.038	**-0.026**	**0.125**	0.014	0.040	-0.003	0.057	**0.959**

Table 16.a: VARMA-AGARCH: Conditional Mean for New Zealand-Singapore

Return	C	MA(1)	SGDNZD(-1)	NZBOND(-1)	NZSTOCK(-1)	SGBOND(-1)	SGSTOCK(-1)
SGDNZD	0.000	**-0.811**	**0.777**	-0.020	**0.049**	0.054	-0.007
NZBOND	0.000	**-0.623**	0.014	**0.564**	0.002	**0.094**	-0.010
NZSTOCK	**0.001**	**0.473**	**-0.023**	0.028	**-0.401**	0.037	**0.046**
SGBOND	**0.000**	0.062	0.009	0.020	0.010	0.073	-0.003
SGSTOCK	0.000	**-0.629**	0.045	0.079	0.047	-0.110	**0.659**

Table 16.b: VARMA-AGARCH: Conditional Variance for New Zealand-Singapore

Variance	ω	α_{SGDNZD}	α_{NZBOND}	$\alpha_{NZSTOCK}$	α_{SGBOND}	$\alpha_{SGSTOCK}$	γ	α_{SGDNZD}	α_{NZBOND}	$\alpha_{NZSTOCK}$	α_{SGBOND}	$\alpha_{SGSTOCK}$
SGDNZD	**0.000**	0.004	0.269	-0.003	0.052	-0.004	**0.089**	**0.845**	-0.242	0.005	0.013	0.011
NZBOND	0.000	0.001	**0.032**	0.001	0.008	0.001	-0.020	-0.001	**0.974**	-0.001	-0.009	-0.001
NZSTOCK	**0.000**	**-0.002**	0.036	**0.068**	0.041	**0.014**	0.025	0.003	**-0.106**	**0.866**	-0.074	0.003
SGBOND	**0.000**	0.000	-0.005	0.005	**0.214**	0.000	0.010	-0.002	**0.023**	0.001	**0.760**	**-0.001**
SGSTOCK	**0.000**	-0.016	-0.087	0.018	0.362	0.033	**0.102**	0.006	**0.699**	**0.095**	-0.305	**0.835**

Table 17.a: VARMA-AGARCH: Conditional Mean for New Zealand-USA

Return	C	MA(1)	USDNZD(-1)	NZBOND(-1)	NZSTOCK(-1)	USBOND(-1)	USSTOCK(-1)
USDNZD	0.000	**-0.855**	**0.836**	0.003	**-0.031**	-0.038	**-0.025**
NZBOND	0.000	**-0.081**	-0.010	-0.047	0.005	**0.552**	**-0.028**
NZSTOCK	**0.000**	0.053	**0.048**	-0.021	0.035	0.018	**0.192**
USBOND	0.000	-0.217	**0.034**	-0.044	-0.005	0.267	0.005
USSTOCK	0.000	0.117	-0.002	-0.042	-0.054	0.068	-0.139

Table 17.b: VARMA-AGARCH: Conditional Variance for New Zealand-USA

Variance	ω	α_{USDNZD}	α_{NZBOND}	$\alpha_{NZSTOCK}$	α_{USBOND}	$\alpha_{USSTOCK}$	γ	α_{USDNZD}	α_{NZBOND}	$\alpha_{NZSTOCK}$	α_{USBOND}	$\alpha_{USSTOCK}$
USDNZD	**0.000**	**0.154**	-0.065	**-0.018**	0.023	0.013	**-0.188**	0.154	0.125	**0.175**	0.071	**-0.041**
NZBOND	**0.000**	**0.010**	**0.150**	0.002	**0.023**	0.003	-0.064	**-0.026**	**0.390**	0.002	**0.113**	0.000
NZSTOCK	0.000	0.002	0.019	**0.066**	0.007	0.001	0.015	-0.005	0.059	**0.891**	**-0.075**	0.003
USBOND	**0.000**	0.000	0.007	0.004	0.018	0.002	0.018	-0.003	0.045	**-0.016**	**0.895**	0.003
USSTOCK	0.000	-0.015	-0.016	0.028	-0.044	**-0.028**	**0.125**	0.011	0.182	-0.027	-0.012	**0.952**

Table 18.a: VARMA-AGARCH: Conditional Mean for Singapore-USA

Return	C	MA(1)	USDSGD(-1)	SGBOND(-1)	SGSTOCK(-1)	USBOND(-1)	USSTOCK(-1)
USDSGD	0.000	-0.311	0.269	0.025	-0.011	**-0.050**	**-0.018**
SGBOND	**0.000**	0.006	**-0.043**	-0.035	0.002	**0.190**	-0.002
SGSTOCK	**0.001**	-0.138	-0.043	-0.050	0.111	-0.084	**0.305**
USBOND	0.000	**-0.514**	**0.086**	-0.025	-0.005	**0.534**	0.002
USSTOCK	0.000	**0.773**	**-0.189**	-0.093	0.020	0.049	**-0.771**

Table 18.b: VARMA-AGARCH: Conditional Variance for Singapore-USA

Variance	ω	α_{USDSGD}	α_{SGBOND}	$\alpha_{SGSTOCK}$	α_{USBOND}	$\alpha_{USSTOCK}$	γ	α_{USDSGD}	α_{SGBOND}	$\alpha_{SGSTOCK}$	α_{USBOND}	$\alpha_{USSTOCK}$
USDSGD	0.000	**0.016**	0.001	0.001	-0.003	**0.001**	-0.009	**0.973**	-0.004	-0.001	**0.007**	**-0.001**
SGBOND	**0.000**	0.000	**0.150**	-0.001	0.004	**-0.002**	0.050	-0.002	**0.597**	-0.001	-0.001	-0.001
SGSTOCK	0.000	-0.050	0.248	**0.064**	0.030	**0.030**	0.037	0.225	**-0.387**	**0.868**	0.127	-0.002
USBOND	**0.000**	0.008	**0.082**	0.001	0.002	**0.002**	0.000	**-0.019**	**-0.111**	-0.001	**0.999**	-0.002
USSTOCK	**0.000**	0.040	0.181	0.016	**-0.081**	**-0.033**	**0.128**	-0.074	-0.220	-0.006	**0.103**	**0.955**