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Is Being a Super-Power More Important Than Being Your Close Neighbor? A Study of What Moves the Australian Stock Market

Heng Chen,[a] Russell Smyth[b] and Wing-Keung Wong[c]

Abstract This paper employs a Fractionally Integrated Vector Error Correction Model (FIVECM) to examine the return transmission between the Australian and New Zealand stock markets and between the Australian and United States stock markets. We augment the FIVECM with a multivariate GARCH model. In so doing, the first and second moments spillover between stock market indices are simultaneously revealed. Our empirical results suggest that the Australian stock market has stronger ties with the United States stock market than with the New Zealand stock market. We conclude that stock market movements in the United States, as the world's economic superpower, are more important to the Australian stock market than stock market movements in New Zealand, Australia's closest neighbor.

JEL Classification: F36; G15

Keywords: Fractionally Integrated Vector Error Correction Model; Multivariate GARCH

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I. Introduction

A large number of studies have examined integration between the world's stock markets. In an era of increasing globalization, where there are substantial capital flows across countries, integration between world stock markets has important practical relevance for investors since greater financial integration implies reduced opportunities for international portfolio diversification. Integration between world capital markets is also an important issue for financial policy makers since co-movements between markets can result in contagion effects where investors incorporate price changes in other markets into their trading decisions in an effort to form a complete information set, meaning that errors in one market may be transmitted to other markets. Such contagion effects have been exacerbated by major events which have affected world stock price indices in recent decades such as the 1987 stock market crash and Asian financial crisis (1997-98).

The objective of this paper is to examine the dynamic relationship between the Australian stock market and New Zealand and United States stock markets. In addition to the United States being the world's leading market, the Australian economy is heavily dependent on the United States. Along with Japan, the United States is Australia's most important trading partner and largest source of inward foreign direct investment. The importance of the United States to Australia as a trading partner and source of foreign direct investment is expected to increase with the signing of the Australia-United States Free Trade Agreement (AUSFTA) which came into operation in January 2005. New Zealand is Australia's closest neighbor and is very important to Australia from an economic perspective. Underpinning the investment and trade ties between Australia and New Zealand is the Australia-New Zealand Closer Economic Relations Trade Agreement (ANZCERTA) which came into operation in January 1983. Under the ANZCERTA, all border restrictions on trade in goods and services between Australia and New Zealand including tariffs, quantitative restrictions and anti-dumping provisions between the two countries have been removed. ANZCERTA also provides for removal of impediments to investment flows such as liberalizing government purchasing orders and free movement of labor, although there is no provision for the free movement of capital.

An important determinant of interdependence in stock markets across countries is economic integration in the form of trade and investment flows. The dividend discount model suggests that the current share price equals the present value of future cash flows, which depends on the earnings growth of a company. Earnings growth depends on the macroeconomic conditions of the domestic market as well as the macroeconomic conditions in countries with which a country trades and sources its investment flows (Shamsuddin and Kim, 2003). Interdependence in stock markets may also reflect geographical proximity between countries with economically and geographically closely connected countries, such as Australia and New Zealand, expected to exhibit high levels of market linkages because of the presence of similar investor groups and multi-listed companies (Janakiramanan and Lamba, 1998). The motivation of the paper in focusing on Australia's stock market linkages with New Zealand and the United States is to examine the importance of geographical distance in explaining movements between markets. As the title of the paper suggests, through examining the bilateral relationships between the Australian stock market and the stock markets of New Zealand and the United States, we investigate the relative importance of being the world's economic superpower versus being a close neighbor in influencing the Australian stock market.

A methodological contribution of the study is that instead of using a Vector Error Correction Model (VECM) commonly employed in cointegration studies of this sort, this paper applies a Fractionally Integrated VECM (FIVECM) to examine co-movements of the Australian market with other markets. The advantage of using FIVECM is that it not only reveals the existence of a long-run equilibrium relationship and short-run dynamics among cointegrated variables, but can also account for possible long memory in the cointegration residual series which may otherwise skew the estimation. Conditional heteroskedasticity is often observed in market price and return series due to changing economic conditions over time. Thus, we augment the FIVECM with a GARCH-type model to capture the second moment autocorrelations in the return series. We employ the BEKK (1,1) model proposed by Engle and Kroner (1995) to model the evolution of conditional variances. Since there are no restrictions imposed on the coefficient matrices of conditional mean and conditional variance equations, lead-lag relations in the first and second moments spillover effects are simultaneously revealed in this model.[1]

The remainder of the paper is organized as follows: The existing literature on stock market integration in the Asia-Pacific region is reviewed in Section 2, focusing on studies of integration between the Australian market and other stock markets.

Section 3 provides an overview of the Australian, New Zealand and United States markets as well as trade and investment flows between the three countries. Section 4 describes the data and methodology. Section 5 presents the empirical results and discusses implications of the findings. The final section contains the conclusion.

II. Existing Studies of Stock Market Linkages

The seminal studies of market interdependence and portfolio diversification were Grubel (1968), Granger and Morgenstern (1970) and Levy and Sarnat (1970). Ripley (1973), Lessard (1974), Panto et al (1976) and Hilliard (1979) were other early studies. Most of these studies used correlation analysis to examine short-run linkages between markets. However since the beginning of the 1990s, several studies, of which Kasa (1992) is one of the earliest, have used cointegration methods to examine whether there are long-run benefits from international equity diversification. Whether stock markets are cointegrated carries important implications for portfolio diversification (see Masih and Masih, 1997, 1999). Cointegrated markets imply that there is a common force, such as arbitrage activity, which brings the stock markets together in the long run, meaning that testing for cointegration is a test of the level of arbitrage activity in the long-run. In theory, if stock markets are not cointegrated this implies that arbitrage activity to bring the markets together in the long-run is zero. On the other hand, if stock markets are cointegrated this means that the potential for making supra-normal profits through international diversification in the cointegrated markets is limited in the long run. If markets are not cointegrated, this implies that there is no arbitrage activity to bring the markets together in the long-run. If this is the case, this means that investors can potentially obtain long-run gains through international portfolio diversification.

There is a large literature on capital market integration between the world's major equity markets (see eg. Dickinson, 2000; Tsutsui and Hirayama, 2004). There are also several studies of integration between Asia-Pacific markets or integration between major world equity markets and Asia-Pacific markets. For example, Ng (2002) examined market linkages between Southeast Asian stock markets. There are several studies which consider whether the Japanese and/or United States market is cointegrated with Asia-Pacific markets (see eg Cheung and Mak 1992; Chung and Liu, 1994; Janakiramanan and Lamba, 1998; Pan et al 1999; Sheng and Tu, 2000; Yang *et al.*, 2003).

Most studies which have tested for long-run relationships between markets have typically used either the Johansen (1988) or Gregory and Hansen (1996) methods of cointegration. Fernandez-Serrano and Sosvilla-Rivero (2001, 2003) examined stock market integration between the Japanese market and Asia Pacific markets and United States market and Latin American markets respectively using the Johansen (1988) and Gregory and Hansen (1996) approaches to cointegration and found more evidence of cointegration allowing for a structural shift in the cointegrating vector. Huang et al (2000) examined whether there is a long-run relationship between the stock markets of the United States, Japan and the South China Growth Triangle using the Gregory and Hansen (1996) method and found that the only markets among these which are cointegrated are Shanghai and Shenzhen. Siklos and Ng

(2001) considered whether stock markets in the Asia-Pacific region are integrated with each other and with the United States and Japan using the Gregory and Hansen (1996) approach to testing for cointegration and found that the 1987 stock market crash and 1991 Gulf War were turning points in the degree of integration.

While the majority of research on market linkages is concentrated on the North American, European and Asian markets there are several studies examining market linkages with the Australasian stock markets. Allen and McDonald (1995) examined whether the Australian stock market is cointegrated with fifteen major world stock markets through applying the Engle and Granger (1987) and Johansen (1988) methods to monthly data over the period 1970 to 1992. These authors found that the Australian market is pairwise-cointegrated with the Canadian, Hong Kong and United Kingdom stock markets, but none of the other markets. Masih and Masih (2001) examined stock market linkages between the Australian market and the markets of Hong Kong, South Korea, Singapore and Taiwan applying the Johansen (1988) method to monthly data for the period 1982 to 1994 and found that the Australian market is cointegrated with these Asian markets. Shamsuddin and Kim (2003) examined whether the Australian market is integrated with the Japanese and United States markets using weekly data from January 1991 to May 2001. Their findings suggested that there was a stable long-run relationship between the Australian market and each of these two major equity markets prior to the Asian financial crisis, but the relationship disappeared in the post crisis period.

Roca (1999) examined equity market linkages between Australia and its major trading partners. No cointegration was found between Australia and the other markets. Narayan and Smyth (2004) examined stock market integration between the Australian equity market and the equity markets of the G7 economies applying both the Johansen (1988) and Gregory and Hansen (1996) approaches to cointegration. That study found some evidence of a pairwise long-run relationship between the Australian stock market and the stock markets of Canada, Italy and Japan, but the Australian equity market was found to be not pairwise-cointegrated with the French, German or United States stock markets. Narayan and Smyth (2005) examined whether the New Zealand stock market is integrated with the Australian stock market and the stock markets of the G7 economies using both the Johansen (1988) and Gregory and Hansen (1996) methods. The Johansen (1988) method suggested there is no long-run relationship between the New Zealand stock market and any of the other markets, while the Gregory and Hansen (1996) method found that the New Zealand and United States stock markets are cointegrated, but there is no long-run relationship between the New Zealand market and any of the other markets[2].

III. Overview of the Markets and Bilateral Trade and Investment Flows

Table 1 provides an overview of Australian, New Zealand and United States capital markets. In terms of market capitalization, value traded and average size of companies listed, the United States is the largest capital market in the world. Australia ranks just outside the top 10 in terms of market capitalization (11th) and value traded (12th) while New Zealand is ranked in the mid-20s in terms of these measures. In terms of the average size of listed companies the Australian and New Zealand stock markets are smaller than if the other indicators are used. In 2003 Australia ranked 26th among world stock markets in terms of the average size of listed companies, while New Zealand ranked 44th. The basic point that emerges from Table 1 is that on all measures the Australian and New Zealand capital markets are much smaller than the United States capital market and that the Australian capital market is larger than the New Zealand capital market.

Insert Table 1

Since the ANZCERTA came into effect in January 1983, bilateral trade in goods between Australia and New Zealand has expanded at an average annual growth rate of 10 per cent. Based on trade in goods and services, in 2004 New Zealand was Australia's fifth largest export market, accounting for seven per cent of Australia's exports and providing the seventh largest source of imports (DFAT, 2005). In 2003, overall New Zealand was Australia's fifth largest trading partner accounting for 5.7 per cent of Australia's trade (DFAT, 2004). In 2004 Australia was New Zealand's major trading partner, providing 23 per cent of its merchandise imports and taking 21 per cent of its exports (DFAT, 2005). In 2003 bilateral investment flows between Australia and New Zealand were AUD56.7 billion. New Zealand is the seventh largest source of inward investment into Australia (AUD19.6 billion) and Australia is the largest investor in New Zealand (AUD 37.1 billion). Over half of Australia's total investment in New Zealand is foreign direct investment, reflecting a high level of economic integration (DFAT, 2005).

In 2003-04 Australia exported goods and services worth AUD13.9 billion to the United States, making the United States the second largest destination for Australian exports following Japan. In 2003-04 Australia imported goods and services worth AUD26.1 billion from the United States, making the United States Australia's largest source for imports (DFAT, 2005a). Overall, in 2003 the United States was Australia's largest trading partner, accounting for 13.6 per cent of Australia's trade (DFAT, 2004). The United States is the largest source of foreign direct investment in Australia (valued at AUD 70.9 billion in 2003). Australia was the tenth largest direct investor in the United States in 2003, with investment totaling AUD 78.9 billion (DFAT, 2005a).

IV. Data and Methodology

Data

The study employs weekly data for the period January 1, 1990 through March 30, 2005, giving 796 observations. The stock price indices are the ASX All Ordinaries for Australia, All Shares Index for New Zealand and the S&P 500 for the United States. All data are from Datastream. Instead of using high frequency data like daily price and return series, this paper employs weekly data because non-synchronous trading time between Australian (New Zealand) and US markets cause the return series from two markets do not overlap each other. The non-synchronous trading time is very likely to bias correlation structure and spillover effect among series involved. However, weekly data could dramatically alleviate the biases[3]. To avoid the so called 'day-of-the-week effect' which suggests that the stock market is more volatile on Mondays and Fridays, we follow Lo and MacKinlay (1988) to use the

Wednesday indices. We base our study on this time period because the world's economy has been growing steadily since 1990, although the growth has been interrupted by periodic events such as the Gulf wars (1991, 2003), Mexican crisis (1994), Asian financial crisis (1997-1998), the bursting of the IT bubble (2001) and September 11 terrorist attacks in the United States (2001).

Insert Fig. 1

The normalized indices (starting value for each index is set as 100) shown in Figure 1 suggest that the S&P 500 index is more volatile than the other two indices. The most striking feature of the S&P 500 index is its continuous growth from early 1991 through early 2000 when it reached a peak and then fell following the collapse of the IT bubble and subsequent terrorist attack in September 2001. In contrast, the growth in the Australian stock market is gradual and stable, and we cannot detect any apparent growth pattern in the New Zealand stock market, except after the middle of 2003, when the three markets all started moving up until the end of the sample period. This is also confirmed by summary statistics of the data which are shown in Table 2 in which AU_t is the log of the weekly index of the ASX All Ordinaries, NZ_t the log of the weekly index of the All Shares Index, and SP_t is the log of the S&P 500 index. In Table 2 'LCL Mean' is the 95 per cent Lower Confidence Limit for the mean and 'UCL Mean' is the corresponding Upper Confidence Limit for the mean. The standard deviation for the S&P 500 index is 0.487 which is higher than the standard deviation for the ASX All Ordinaries and All Shares indices, showing the higher variability in the United States stock market.

Insert Table 2

Methodology

To establish the existence of cointegration between the stock price indices, we employ a Granger two-step procedure. In the first step, we fit the following dynamic ordinary least squares (DOLS) model to the pairs of stock price indices:

$$y_{1t} = \alpha + \beta y_{2t} + \sum_{j=-p}^{p} \omega_j' \Delta y_{2t-j} + \eta_t \ . \qquad (1)$$

Here y_{1t}, y_{2t} are pairs of stock indices involving AU_t, NZ_t and SP_t. The estimate $\hat{\beta}$ is shown by Stock and Watson (1993) to be super-consistent as well as efficient. The estimated cointegrating residual ($\hat{z}_t$) can be constructed as follows:

$$\hat{z}_t = y_{1t} - \hat{\beta}\ y_{2t} \ . \qquad (2)$$

In the second step, we test for long memory, applying an R/S test to the $\hat{z}_t$ series. If the cointegrating residual follows a long memory (I(d), -0.5<d<0.5) process, y_{1t}, y_{2t} are fractionally cointegrated and we proceed to fit an autoregressive fractionally integrated moving average (ARFIMA) model to each residual series of the form:

$$\Psi(B)^{-1}\Phi(B)(1-B)^d\ \hat{z}_t = a_t \ . \qquad (3)$$

Here, $\Psi(B)$ and $\Phi(B)$ represent MA and AR polynomials, B is a backward shift operator and $\{a_t\}$ is an *i.i.d.* noise series, which will be interpreted as the disequilibrium error in the error correction model below. Once a long-run relationship among the variables is established, Engle and Granger (1987) show that a Vector Error Correction Model (VECM) is an appropriate method to model the long-run as well as short-run dynamics among the cointegrated variables. We expand the VECM to a FIVECM by accounting for fractional integration in the $\hat{z}_t$ series using the ARFIMA model as set out in Equation (3). Following Granger (1986), the bivariate FIVECM can be depicted in the following form:

$$\begin{aligned}\Delta y_{1t} &= c_1 + \alpha_1[(1-B)^d - (1-B)]\hat{z}_t + \sum_{i=1}^{m}\phi_{11}^i \Delta y_{1t-i} + \sum_{i=1}^{m}\phi_{12}^i \Delta y_{2t-i} + \varepsilon_{1t} \\ \Delta y_{2t} &= c_2 + \alpha_2[(1-B)^d - (1-B)]\hat{z}_t + \sum_{i=1}^{m}\phi_{21}^i \Delta y_{1t-i} + \sum_{i=1}^{m}\phi_{22}^i \Delta y_{2t-i} + \varepsilon_{2t}\end{aligned}. \quad (4)$$

Here $\Delta y_t = \left(\Delta y_{1t,} \Delta y_{2t}\right)'$ is the differenced series vector or return vector of $(\Delta AU_t, \Delta SP_t)'$ or $(\Delta AU_t, \Delta NZ_t)'$, and $\hat{z}_{t-1}$ is estimated from Equation (1) fitted to respective stock index vectors. Note that we employ the VAR(*m*) structure for the VECM model, in particular *m*=1 in this study and $\varepsilon_t = \left(\varepsilon_{1t}, \varepsilon_{2t}\right)'$ is the error vector. The coefficients $\alpha = \left(\alpha_1, \alpha_2\right)'$ capture the reaction of the series when they deviate from the long-run equilibrium, while the magnitudes of the $\alpha_i{}'s$ represent the speed of the adjustment. The lagged terms in Equation (4) account for the AR structure of the Δy_t series, while their coefficients reflect the return transmissions between different stock markets.

Because it is often observed that the conditional volatilities of financial return series exhibit time varying characteristics, we employ a multivariate GARCH (MGARCH) model to capture the heteroskedasticity in the series. In other words, we model the conditional mean and conditional variance of the return series simultaneously.

To do so, let $\sum_t \equiv \text{cov}_{t-1}(\varepsilon_t) \equiv \begin{pmatrix} \sigma_t^{11} & \sigma_t^{12} \\ \sigma_t^{21} & \sigma_t^{22} \end{pmatrix}$ denote the variance-covariance matrix of ε_t conditional on past information. The most general and flexible MGARCH model is the BEKK model proposed by Engle and Kroner (1995) in the form:

$$\sum_t = A_0 A_0' + \sum_{i=1}^{p} A_i (\varepsilon_{t-i} \varepsilon_{t-i}') A_i' + \sum_{j=1}^{q} B_j \sum_{t-j} B_j' \ . \qquad (5)$$

Here A_0 is a lower triangular matrix, $A_i's$ and $B_j's$ are unrestricted coefficient matrices and $\sum_t$ is symmetric and positive semi-definite. Usually allowing p=1 and q=1 suffices for modeling volatility in financial time series. With this formulation, the dynamics of $\sum_t$ are fully displayed in the sense that the dynamics of the conditional variance as well as the conditional covariance are modeled directly, thereby allowing for volatility spillovers across series to be observed. The volatility spillover effect is indicated by the off-diagonal entries of coefficient matrices A_1 and B_1. This can be clearly seen from the expansion of BEKK(1,1) into individual dynamic equations:

$$\begin{aligned}
\sigma_t^{11} &= \left(A_0^{11}\right)^2 + \left[A_1^{11}\varepsilon_{1t-1} + A_1^{12}\varepsilon_{2t-1}\right]^2 + \left[\left(B_1^{11}\right)^2 \sigma_{t-1}^{11} + 2B_1^{12}B_1^{11}\sigma_{t-1}^{12} + \left(B_1^{12}\right)^2 \sigma_{t-1}^{22}\right] \\
\sigma_t^{22} &= \left(A_0^{21}\right)^2 + \left(A_0^{22}\right)^2 + \left[A_1^{21}\varepsilon_{1t-1} + A_1^{22}\varepsilon_{2t-1}\right]^2 + \left[\left(B_1^{21}\right)^2 \sigma_{t-1}^{11} + 2B_1^{21}B_1^{22}\sigma_{t-1}^{21} + \left(B_1^{22}\right)^2 \sigma_{t-1}^{22}\right] \\
\sigma_t^{12} &= A_0^{11}A_0^{21} + A_1^{11}A_1^{21}\varepsilon^2{}_{1t-1} + (A_1^{11}A_1^{22} + A_1^{12}A_1^{21})\varepsilon_{1t-1}\varepsilon_{2t-1} + A_1^{12}A_1^{22}\varepsilon^2{}_{2t-1} + B_1^{11}B_1^{21}\sigma_{t-1}^{11} + \\
&\left(B_1^{12}B_1^{21} + B_1^{11}B_1^{22}\right)\sigma_{t-1}^{12} + B_1^{12}B_1^{22}\sigma_{t-1}^{22}.
\end{aligned} \qquad (6)$$

The above equation system is more complicated than a univariate GARCH model because of interactions among the two conditional variances and residuals. The time-varying correlation coefficient can be obtained from the conditional variances and covariances after the model is estimated. Since there are no restrictions on the coefficients, estimation of the BEKK model involves more computation than other MGARCH models. The stationarity condition for the volatility series in a BEKK (1,1) model is that the eigenvalues of matrix $A_1 \otimes A_1 + B_1 \otimes B_1$ are all less than unity in modulus.[4] By estimating jointly the FIVECM-BEKK model the coefficient estimates are more efficient and the relationship among the series are delineated more accurately.

V. Empirical Results

Modeling cointegration

Before modeling cointegration, it is necessary to establish the stationarity properties of the stock price indices. To test for stationarity we applied the Augmented Dickey Fuller and Phillips-Perron unit root tests to the logarithmic values of AU_t, NZ_t and SP_t. The results are presented in Table 3. All the indices are found to be integrated of order one using both tests. This finding is consistent with the results of previous studies which have applied unit root tests to examine the random walk properties of stock price indices in developed markets (see e.g. Narayan and Smyth, 2006).

Insert Table 3

Next, we test for long-run relationships between pairs of stock price indices $(AU_t, SP_t)'$ and $(AU_t, NZ_t)'$ by fitting the DOLS model in Equation (1) with lag length *p=2*. The estimated model coefficients are presented in Table 4. The results suggest that the estimated $\hat{\beta}$ for the two regression models are highly significant. In order to confirm the existence of a long-run relationship between the series in each pair, we test the stationarity of the cointegration residuals. We construct the $\hat{z}_t$ series following Equation (2) for each pair of series using the estimated cointegrating coefficient $\hat{\beta}$ from the corresponding DOLS model. These constructed disequilibrium error series are denoted as z_{sp}^{au} and z_{nz}^{au} respectively (where the superscript stands for the dependent variable and the subscript for the independent variable). The R/S test for long memory is applied to these two residual series. The results, presented in Table 5, confirm that the residual series are fractionally integrated processes. Therefore, we proceed to fit an ARFIMA model to each of the series. The choice of the ARFIMA order is based on examination of the ACF and PACF of the residual series.[5] The fitted results are shown in Table 6.

Insert Tables 4-6

It is noteworthy that all the estimated values of *d* in the two ARFIMA models fall into the range $-0.5 < d < 0.5$, and estimated coefficients for the AR terms also produce two stationary series, although the serial correlations of the two series are persistent. In particular, the two *d*-values are less than 0.5, thus, we conclude that the two pairs of stock markets are fractionally cointegrated with each other. The implications for investors is that there is no potential for long-run portfolio gains through investing in the Australian stock market and the equity markets of New Zealand and the United States. This result differs from Allen and McDonald (1995), Roca (1999) and Narayan and Smyth (2004) who found that there was no long-run relationship between the Australian and United States stock markets and that there was thus potential for portfolio diversification.

Empirical results for the Australian and United States stock markets

Once a long-run relationship between the respective stock market indices has been established, we proceed to fit a FIVECM augmented by a MGARCH model. We fit a FIVECM-BEKK(1,1) model to the two pairs of differenced indices in logs, i.e. a pair of indices for the ASX All Ordinaries and S&P 500 and a pair of indices for the ASX All Ordinaries and All Shares Index of New Zealand. The variable sequence was $\left(\Delta AU_t, \Delta SP_t\right)'$ or $\left(\Delta AU_t, \Delta NZ_t\right)'$ for the FIVECM and BEKK cases, while an AR(1) structure was employed in the FIVECM. We assumed a multivariate Gaussian distribution for the error series of both VECM-BEKK (1,1) models. The coefficients for FIVECM-BEKK(1,1) fitted on $\left(\Delta AU_t, \Delta SP_t\right)'$ are given in Table 7.

Insert Table 7

To interpret the results in Table 7, we first focus on the conditional mean equation. C(i), i=1,2 are the constant terms in the conditional mean equation, AR(i, j, k), i=1, j=1,2, k=1,2, stand for the AR term coefficients, and α_i , i=1,2, represents the adjustment speed parameter α_i in the FIVECM in Equation (4). From the *t*-value, both C(1) and C(2) are statistically significant, which implies that the long-run unconditional means of the ASX All Ordinaries return series, ΔAU_t , and S&P 500 index return series, ΔSP_t, are positive. The significant AR(1;1,1) and AR(1;2,2) terms verify the serial dependence in the index returns, ΔAU_t and ΔSP_t, though it is not strong. The AR(1;2,1) term is not significant, while the AR(1;1,2) is highly significant. This implies that there is a unidirectional return transmission from the United States market to the Australian market, or the United States stock market Granger-causes[6] the Australian stock market in one period. It is somewhat surprising that the two adjustment speed parameter estimates are not significant. This implies that the two index series do not move back to long-run equilibrium when they deviate from it. This is an issue which deserves further investigation.

Second, for the conditional variance equation, A(i, j) denoting the elements of the constant matrix A_0, ARCH(1;i,j) and GARCH(1;i,j) are the elements of the ARCH and GARCH coefficient matrices A_1 and B_1 respectively. It appears from the results that GARCH modeling is appropriate for our data set. All the elements of the constant matrix are positive, although only A(1,1) is highly statistically significant and A(2,1) is marginally significant at 10 per cent. This fact shows that the unconditional variances of the two stock indices are not zero as illustrated in Figure 2. Most strikingly, all the elements of the ARCH and GARCH matrices are highly significant, except GARCH(1;2,1) which is significant at around 2 per cent. The diagonal coefficient estimates show that the ARCH and GARCH effects are substantial in both index return series. This can also be verified by inspecting the autocorrelation function of the squared return series. The significant off-diagonal coefficients reveal that there are feedback relations between the volatilities of the two stock return series, indicating there are information transmissions between the two markets. Thus, shocks to the United States market will be reflected in the Australian market at a later date and vice versa. These off-diagonal estimates also indicate that the time varying correlation coefficients between the two series are determined by lagged values of volatilities and residuals respectively.

Insert Figure 2

Overall, the unidirectional return transmission and bidirectional volatility spillover shown by the estimated results underscore the close relationship between the Australian and United States stock markets. The strong influence of the United States stock market on the Australian stock market is expected, since the former is the largest stock market based in the most influential economy in the world. The United States is the most important trading partner and export destination for almost all the countries in the world, including Australia. The information flow from the Australian stock market to the United States stock market may be attributed to the strengthening economic and political ties between the countries, indicating the growing importance of Australia on the international stage.

Insert Figure 3 and Table 8

To view the time varying characteristics of correlation between the two return series, Figure 3 shows the evolution of the correlation coefficient. There is no obvious trend in the time-varying conditional correlation, although the correlation remains positive all the time; indeed, the mean of the correlation over the sample period is 0.5166. This high positive correlation of the two stock markets over time could provide some evidence for the significant estimates of the fitted FIVECM-BEKK model. The relevant model diagnostics are listed in Table 8. Three test statistics and *p*-

values are shown. All the tests were applied to the two individual residual series separately. Specifically, the Shapiro-Wilk Normality tests were conducted for the two residual series; Ljung-Box tests for white noise were applied to standardized residuals and the same tests were applied to the squared standardized residuals to test for serial correlation in the second moments of the residuals. The number of lags employed in the two Ljung-Box tests were 12, thus the test statistics follow the Chi-square distribution with 12 degree of freedom. Since all the *p*-values are larger than conventional levels in Table 7, we can conclude that the fitted model is successful in capturing the dynamics in the first as well as second moments of the stock market indices. Finally, the eigenvalues of $\hat{A}_1 \otimes \hat{A}_1 + \hat{B}_1 \otimes \hat{B}_1$ ($\hat{A}_1$ and $\hat{B}_1$ are estimated ARCH and GARCH coefficient matrices respectively) are 0.9884; 0.9478; 0.9301 and 0.8947, all of which are less than unity. Therefore, we can conclude that the conditional volatilities of the two stock indices are stationary.

Empirical results for the Australian and New Zealand stock markets

Table 9 shows the coefficient estimates for the FIVECM-BEKK(1,1) model fitted on $(\Delta AU_t, \Delta NZ_t)'$, representing the Australian and New Zealand markets. The close relationship between the Australian and New Zealand stock markets is evident in Table 9. First, the significant C(1) indicates that the long-run mean of ΔAU_t is not zero, whereas the non-significant C(2) (*p*-value is 0.145) suggests the probable zero long-run return of the New Zealand stock index, ΔNZ_t. Note that the AR(1;2,2) is greater than unity, but the eigenvalues of the AR coefficient matrix are 0.9637 and -0.0025 which are less than unity, satisfying the stationarity condition of the VAR(1) model. The only significant cross term, AR(1;2,1), signifies the unidirectional return transmission from the Australian market to the New Zealand market, i.e., the Australian market leads the New Zealand market. The significant and positive value of α_2 implies that the All Shares Index of New Zealand , NZ_t adjusts toward the long-run equilibrium when it drifts away, and the close-to-one magnitude of α_2 (0.9686) implies that most of the deviation is corrected in one period which is one week. While α_1 does not have the expected sign, it is not significant. Thus, the response of the stock market indices to disequilibrium is unilateral.

Insert Table 9

The estimates for the conditional variance equation show a simpler interaction between the volatilities of the Australian and New Zealand stock markets than that between the Australian and United States markets. Two positive and significant elements of the constant matrix, A(1,1) and A(2,1), signify nonzero unconditional variances of the two stock market indices as illustrated by Figure 4. The highly significant diagonal estimates of ARCH and GARCH coefficient matrices show the time varying features of the second moments are not negligible. More importantly, the ARCH(1;2,1) and GARCH(1;2,1) estimates are significant at around 4%. This finding depicts a unidirectional information transmission from the Australian stock market to the New Zealand stock market. Shocks to the Australian stock market lead those of the New Zealand stock market, but not vice versa. This result can also be observed in Figure 4, in which the large volatility of the ASX All Ordinaries occurs first followed by some larger volatility on the All Shares Index. Hence, both return transmission and volatility spillover between the index return series, $(\Delta au_t, \Delta nz_t)'$, are unidirectional, running from the Australian market to New Zealand market. This finding underpins the dominant position of the Australian stock market vis-à-vis the New Zealand stock market in bilateral relations between the two markets and is consistent with the relative size and importance of the two economies.

Insert Fig. 4

The fitted conditional correlation between ΔAU_t and ΔNZ_t as shown in Figure 5, suggests a similar pattern to that between ΔAU_t and ΔSP_t in Figure 3 and it is positive over the whole sample span. The mean value of the conditional correlation between ΔAU_t and ΔNZ_t is 0.5309 which is slightly higher than 0.5166, its counterpart between ΔAU_t and ΔSP_t. The minimum conditional correlation between ΔAU_t and ΔNZ_t is 0.3235 which is much larger than that between ΔAU_t and ΔSP_t which is 0.1231. These comparisons show that the correlation between ΔAU_t and ΔNZ_t is stronger than that between ΔAU_t and ΔSP_t in terms of the conditional correlation coefficients.

Insert Figure 5

The model diagnostics for FIVECM-BEKK on $(\Delta AU_t, \Delta NZ_t)'$ as listed in Table 10 indicate that our model is adequate in capturing the dynamics of the conditional means and conditional variances of the two index return series. The four eigenvalues of $\hat{A}_1 \otimes \hat{A}_1 + \hat{B}_1 \otimes \hat{B}_1$ for this model are 0.9632, 0.9355; 0.9313 and 0.9046, all of which are less than unity. This result indicates that the conditional volatilities of the ASX All Ordinaries Index and New Zealand All Shares Index are stationary.

Insert Table 10

VI. Conclusion

This paper has employed the FIVECM to investigate the long-run bilateral relationship between the Australian and United States stock markets and between the Australian and New Zealand stock markets. Specifically, applying the Engle and Granger (1987) two-step procedure to estimating and constructing the cointegrating variable and subsequently fitting an ARFIMA model to the resulting cointegrating variable, this paper has set up a FIVECM in the general VAR framework which allows examination of lead-lag relations among the stock market return series. Further, by augmenting the FIVECM with a MGARCH model (specifically BEKK), the dynamic dependence and lead-lag relations in the second moment of the stock market returns have also been captured.

The estimation results confirm our conjecture that there are fractional cointegration relationships between the Australian and United States markets, as well as between the Australian and New Zealand markets. This finding implies that investors cannot make long-run portfolio diversification gains through investing in the Australian stock market and the New Zealand and United States stock markets. Finding that the Australian market is pairwise-cointegrated with the New Zealand and United States stock markets, however, does not preclude the possibility that investors could arbitrage profits through investing in the Australian market and New Zealand and United States markets in the short term. It is also worth emphasizing that finding cointegration does not necessarily imply anything about market efficiency. There is a unidirectional return transmission from the United States market to the Australian market, while volatility spillovers between the two markets are bidirectional. However, neither AU_t nor SP_t adjusts in response to the disequilibrium error. This is an issue which deserves further examination. The relationship between the Australian and New Zealand stock markets is dominated by the behavior of the Australian stock index. Specifically, both return and volatility transmissions run unilaterally from the Australian market to the New Zealand market.

To sum up, our results suggest that what occurs in the New Zealand market does not influence the Australian market. However, what happens in the United States market does contribute to the evolution of the Australian market, and the Australian market also has some impact on the United States market, even if that impact is restricted to shocks spillover. Therefore, from this perspective, the United States as the world's superpower seems to be more important to the Australian market than is its close neighbor, New Zealand. There are at least two avenues for future research. First, this paper only exploits the stock market indices and their differenced series from the three markets studied; incorporating other relevant exogenous variables into the model may shed some additional light on the results. Second, our finding that New Zealand has less influence on the Australian market than the United States may not be surprising given the relative small size of the New Zealand economy. A future study could look at how the New Zealand market is affected by the Australian and United States markets. In this setting, geographic proximity may play a bigger role.

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Table 1. Average company size, market capitalization, turnover ratios and value traded in NZ, Australian and United States markets, 2003.

	Turnover Ratios (Percent)		Market Capitalization ($US Million, End of Period Levels)		Value Traded ($US Million, End of Period Levels)		Average Company Size ($US Millions)	
New Zealand	38.3	38th	33.052	24th	10,481	22nd	210.5	44th
Australia	76.5	24th	585,475	11th	369,845	12th	416.7	26th
USA	122.8	9th	14,266,266	1st	15,547,431	1st	2694.3	1st

Notes: Rankings for average company size and turnover ratios are world rankings. Rankings for market capitalization and value traded are for developed markets as classified by Standard and Poors (2004).

Source: Standard and Poors (2004, pp. 22, 25, 29, 32)

Table 2. Descriptive statistics

Statistics	AU_t	NZ_t	SP_t
Min:	7.0938	5.9644	5.6996
Mean:	7.7822	6.5444	6.6014
Max:	8.3499	6.9636	7.3189
Total N:	796	796	796
Std Dev.:	0.3034	0.1993	0.4870
LCL Mean:	7.7611	6.5306	6.5675
UCL Mean:	7.8033	6.5583	6.6353
Skewness:	-0.3308	-0.8536	-0.2277
Kurtosis:	-1.1068	0.1916	-1.4670

Notes: Stock price indices are the ASX All Ordinaries (Australia) AU_t , All Shares Index (New Zealand) NZ_t and the S&P 500 (United States) SP_t. Kurtosis, computed with S-PLUS, is excess kurtosis.

Table 3. Unit root tests

Test / Index	Augmented Dickey-Fuller (ADF)		Phillips-Perron (PP)	
	t-statistic	*p*-value	*t*-statistic	*p*-value
AU_t	-3.029	0.125	1.808	0.9834
NZ_t	-2.537	0.3101	0.5264	0.8294
SP_t	2.097	0.9918	1.989	0.9893

Notes: The stock price indices are the ASX All Ordinaries for Australia AU_t , All Shares Index for New Zealand NZ_t and the S&P 500 for the United States SP_t. The ADF test applied on AU_t and NZ_t employ a constant and trend, the lag length is 1 for AU_t and 3 for NZ_t . The ADF test for SP_t does not employ a constant and trend and the lag length is 2. The lag length selection for the ADF test is determined using the data dependent procedure of Ng and Perron (1995). The corresponding PP tests have the same structure without lag terms, using Bartlett window with bandwidth 6.

Table 4. DOLS model estimates, dependent variable is “ AU_t ”

Statistics / Estimates	SP_t		NZ_t	
	Value	P-value	Value	P-value
α	3.9164	0.0000	-0.4522	0.0264
$\hat{\beta}_2$	0.5858	0.0000	1.2583	0.0000
$\hat{\omega}_{-2}$	-0.2191	0.1876	0.5228	0.0845
$\hat{\omega}_{-1}$	-0.2500	0.1347	0.5823	0.0545
$\hat{\omega}_0$	-0.4208	0.0117	-0.2108	0.4869
$\hat{\omega}_1$	-0.2835	0.0888	-0.2374	0.4344
$\hat{\omega}_2$	-0.2467	0.1363	-0.2484	0.4132

Notes: The fitted model is DOLS as per Equation (1) in the text.

Table 5. Stationarity tests on cointegration residuals

Test / Index	Range Over Standard Deviation (R/S) test	
	Test statistic	P-value
z_{sp}^{au}	3.0971	<0.01
z_{nz}^{au}	4.3751	<0.01

Notes: The residual series were constructed using Equation (2) based on the corresponding DOLS model in table 4. The bandwidth used in R/S test is calculated according to $4(N/100)^{1/4}$ where N is sample size.

Table 6. ARFIMA fitting results

Estimates / Parameters	z_{sp}^{au}		z_{nz}^{au}	
	Value	*p*-value	Value	*p*-value
D	-0.0597	0.0442	-0.0556	0.0706
AR(1)	0.9969	0.0000	0.9943	0.0000

Notes: Series z_{sp}^{au} and z_{nz}^{au} are constructed with Equation (2), using the estimate $\hat{\beta}$ obtained from the DOLS models in Table 4. Selection of AR (lag) terms is based on examination of ACF and PACF.

Table7. Estimated coefficients for FIVECM-BEKK(1,1) fitted on $\left(\Delta AU_t, \Delta SP_t\right)'$.

Parameters	Value	Std. Error	*t*-value	Pr(>|t|)
C(1)	0.0020	0.0006	3.5073	0.0002
C(2)	0.0026	0.0007	3.8249	0.0001
AR(1;1,1)	-0.0982	0.0463	-2.1216	0.0171
AR(1;2,1)	-0.0416	0.0464	-0.8964	0.1852
AR(1;1,2)	0.1074	0.0302	3.5641	0.0002
AR(1;2,2)	-0.1180	0.0412	-2.867	0.0021
α_1	0.0004	0.0268	0.0145	0.4942
α_2	-0.0228	0.0317	-0.7174	0.2367
A(1,1)	0.0050	0.0010	4.7843	0.0000
A(2,1)	0.0015	0.0011	1.3405	0.0902
A(2,2)	0.0007	0.0035	0.2084	0.4175
ARCH(1;1,1)	0.3855	0.0436	8.8353	0.0000
ARCH(1;2,1)	0.1751	0.0534	3.2806	0.0005
ARCH(1;1,2)	-0.0950	0.0366	-2.5960	0.0048
ARCH(1;2,2)	0.1964	0.0418	4.7002	0.0000
GARCH(1;1,1)	0.8632	0.0377	22.920	0.0000
GARCH(1;2,1)	-0.0823	0.0403	-2.0444	0.0206
GARCH(1;1,2)	0.0444	0.0173	2.5735	0.0051
GARCH(1;2,2)	0.9866	0.0188	52.580	0.0000

Notes: Since the differenced series of logarithmic indices are modeled, the actual sample size used in estimation is 793.The estimated model is FIVECM-BEKK(1,1) (Equation systems (4) + (6)); the dependent variable is ΔAU_t; The number of lags in the two Ljung-Box tests are 12, thus the test statistics follow a Chi-square distribution with 12 degrees of freedom.

Table 8. Model diagnostic statistics for $\left(\Delta AU_t, \Delta SP_t\right)'$

Test / Series	Normality test (Shapiro-Wilk)		White noise test (Ljung-Box)		GARCH effect test (Ljung-Box)	
	statistic	*p*-value	statistic	*p*-value	statistic	*p*-value
ΔAU_t	0.9882	0.7988	6.854	0.8671	19.30	0.0817
ΔSP_t	0.9895	0.9082	13.606	0.3265	10.28	0.5918

Table 9. Estimated results for FIVECM-BEKK(1,1) fitted on $(\Delta AU_t, \Delta NZ_t)'$

Parameters	Value	Std. Error	*t*-value	Pr(>|t|)
C(1)	0.0015	0.0006	2.5811	0.0050
C(2)	0.0008	0.0008	1.0603	0.1447
AR(1;1,1)	-0.2184	0.2649	-0.8245	0.2049
AR(1;2,1)	-0.8552	0.3376	-2.5328	0.0057
AR(1;1,2)	0.2985	0.3323	0.8984	0.1846
AR(1;2,2)	1.1797	0.4221	2.7947	0.0027
α_1	0.2312	0.2642	0.8750	0.1909
α_2	0.9686	0.3316	2.9206	0.0018
A(1,1)	0.0058	0.0014	4.0880	0.0000
A(2,1)	0.0032	0.0013	2.3920	0.0085
A(2,2)	0.0002	0.0429	0.0035	0.4986
ARCH(1;1,1)	0.2866	0.0578	4.9574	0.0000
ARCH(1;2,1)	0.1737	0.0562	3.0883	0.0010
ARCH(1;1,2)	-0.0037	0.0411	-0.0905	0.4640
ARCH(1;2,2)	0.1834	0.0450	4.0779	0.0000
GARCH(1;1,1)	0.8772	0.0554	15.817	0.0000
GARCH(1;2,1)	-0.1152	0.0667	-1.7262	0.0423
GARCH(1;1,2)	0.0284	0.0314	0.9054	0.1828
GARCH(1;2,2)	0.9971	0.0375	26.610	0.0000

Notes: Since the differenced series of logarithmic indices are modeled, the actual sample size used in estimation is 793.The estimated model is FIVECM-BEKK(1,1) (Equation systems (4) + (6)); the dependent variable is ΔAU_t and the number of lags in the two Ljung-Box tests are 12. Thus the test statistics follow a Chi-square distribution with 12 degrees of freedom.

Table 10. Model diagnostic statistics for $(\Delta AU_t, \Delta NZ_t)'$

Test / Series	Normality test (Shapiro-Wilk)		White noise test (Ljung-Box)		GARCH effect test (Ljung-Box)	
	statistic	*p*-value	statistic	*p*-value	statistic	*p*-value
ΔAU_t	0.9920	0.9898	6.004	0.9159	20.16	0.0641
ΔNZ_t	0.9877	0.7304	10.337	0.5864	11.77	0.4641

Figure 1. Stock indices of Australia, New Zealand and USA

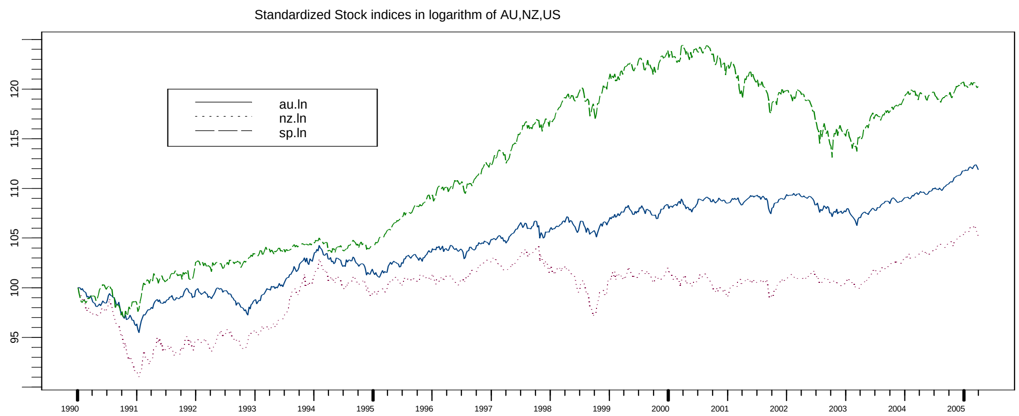


Figure 2. Conditional standard deviations for ΔAU_t and ΔSP_t

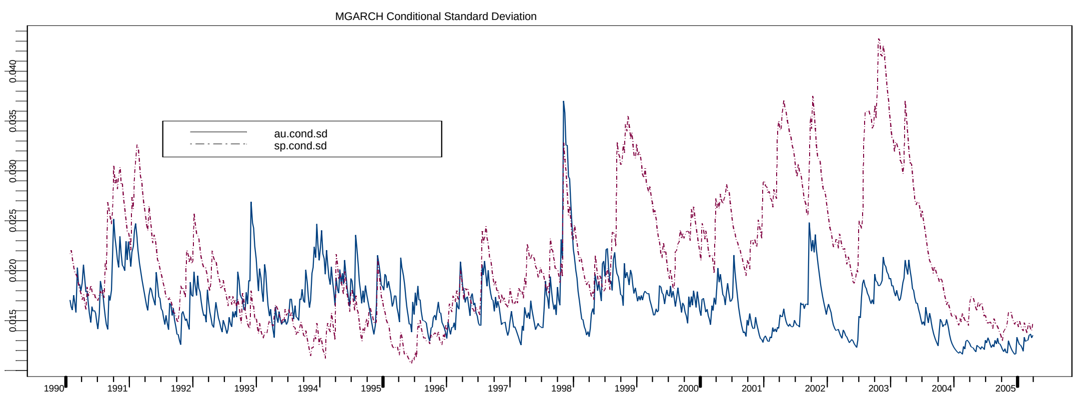


Figure 3. Conditional correlation between return series ΔAU_t and ΔSP_t

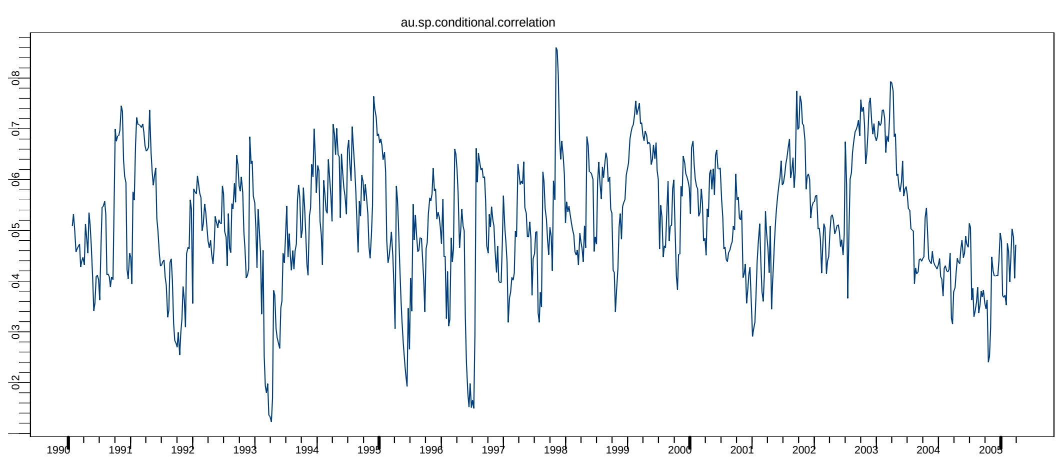


Figure 4. Conditional standard deviations for ΔAU_t and ΔNZ_t

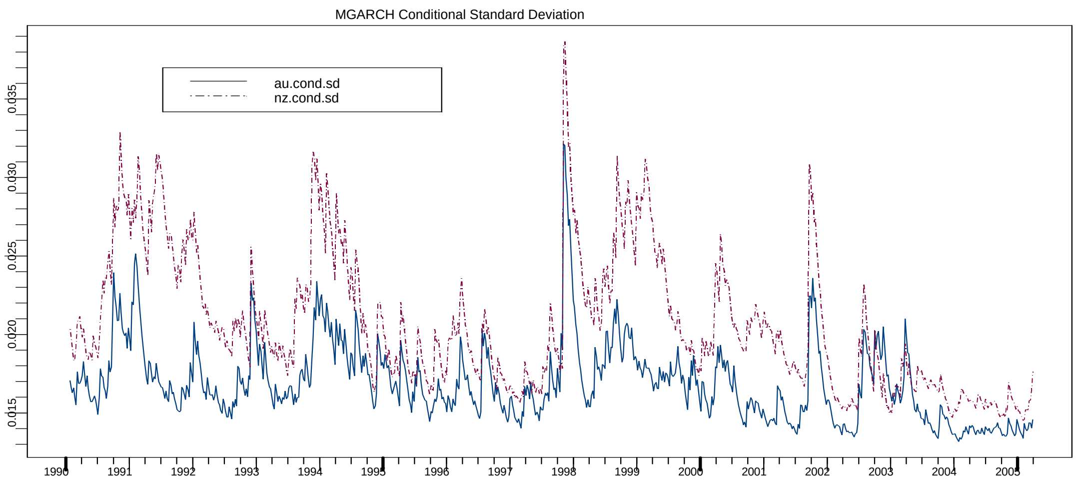
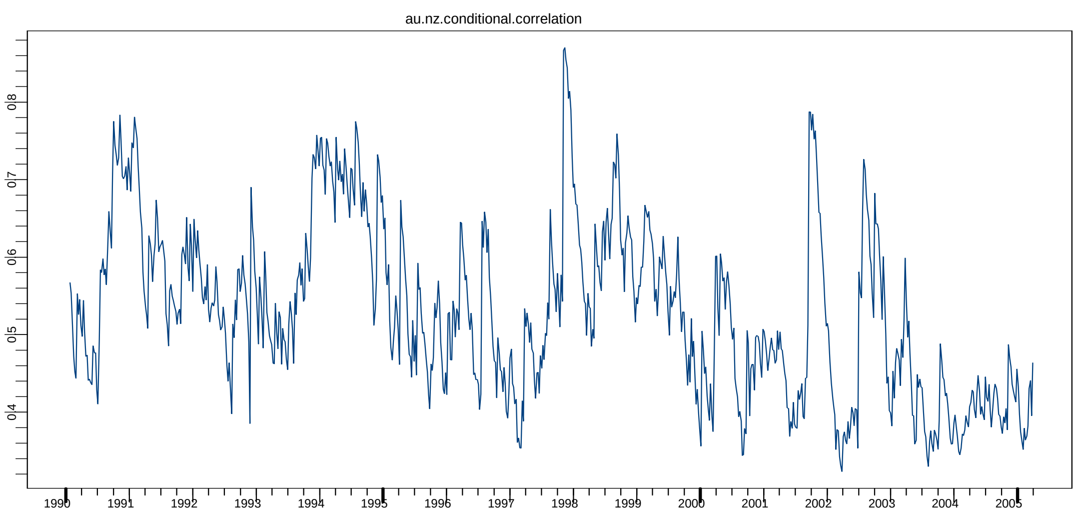


Figure 5. Conditional correlation between return series ΔAU_t and ΔNZ_t



ENDNOTES

[1] Long memory time series models augmented by GARCH have been adopted in the literature to model a variety of economic and financial topics. For example, Baillie et al (1996) analyzed the inflation series of ten countries using a fractionally integrated ARFIMA-GARCH model and Lien and Tse (1999) applied a FIVECM-GARCH(1,1) model to evaluate the performance of futures hedge ratios. Few studies, however, have examined stock market co-movements using a FIVECM-BEKK model.

[2] Besides equity market, cointegration and vector error correction model (VECM) have also been extensively applied to other financial markets, typical of which is foreign exchange market, see Clarida and Taylor (1997) and Manzur et al (1999).

[3] See for example Theodossiou et al (1997) and Ramchand and Susmel (1998).

[4] For conditions for the general BEKK model, see Proposition 2.7 in Engle and Kroner, (1995).

[5] Details are not reported here but are available upon request.

[6] This is another interpretation of coefficients in VAR model due to Granger. That one variable Granger-causes another variable implies that the former variable has forecasting ability for the later variable. FIVECM model in this paper can be viewed as restricted version of general VAR model due to the presence of error correction term. In particular, in our bivariate VAR (FIVECM) model, this implies that the lagged US market return can contribute to the prediction of Australian market return.