Return and Volatility Dynamics in the Spot and Futures Markets in Australia: An Intervention Analysis in a Bivariate EGARCH-X Framework

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This article provides evidence of linkages between the equity market and the index futures market in Australia, where the futures market has experienced a major structural event due to the futures contract respecification. A bivariate Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) model is developed that includes a cointegrating residual as an explanatory variable for both the conditional mean and the conditional variance. The conditional mean returns from both markets are influenced by the long-run equilibrium relationship, and these markets are informationally linked through the second moments. The crossmarket spillovers exhibit asymmetric behavior in that the volatility responses to past standardized innovations are different for market

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advances and market retreats. An intervention analysis shows that some of the parameters describing the return-generating process have shifted after the contract respecification by the futures exchange. Jrl Fut Mark 21:833–850, 2001

INTRODUCTION

The analysis of security return characteristics is an important area of research for several reasons. For example, models of contingent claims require an understanding of the underlying asset return. Distributional assumptions are also needed for portfolio selection models and equilibrium asset pricing models (e.g., Choudhry, 1997; Koutmos & Tucker, 1996). Research interest in this area involving equity indexes increased with the increasing use of index futures contracts. Pliska and Shalen (1991) examined the effects of regulation, particularly tight margins and position limits, on trading activity and the volatility of return in the futures markets. Pericli and Koutmos (1997), however, investigated the impact of index futures and options contracts on the volatility of the underlying spot market.

The equity index futures market has affected the nature of trading in the underlying equity market. Silber (1985) concluded that the futures market performs the main functions of risk transfer and price discovery. According to Kawaller, Koch, and Koch (1987), the volume of equity transactions may be linked to the futures activity. This may induce unwanted influence on the equity prices. The futures market not only provides an important vehicle for price discovery but also offers an alternative way to take equity positions. Kawaller et al. specifically examined the empirical relationship between the Standard & Poor's (S&P) 500 futures and the S&P 500 index in terms of price changes, with one providing guidance for the price movement in the other. Fortune (1989) also suggested that, particularly in the case of equities, the nature of information in the futures is an important influence on the prices and returns on the underlying asset. Stoll and Whaley (1990) suggested that the lower transaction costs and the easier short position taking in the futures market may be the reason for it being the price leader. Chan (1992) further investigated this line of reasoning to establish the price-leading role of the futures market.

Information transmission and the volatility spillover between the spot and futures markets is another area of interesting research. Engle, Ito, and Lin (1990) analyzed the spillover effect (meteor shower) in explaining the spot currency movement. Iihara, Kato, and Tokunaga

(1996) reported a spillover effect mainly from the futures market to the spot market in the case of the Nikkei Stock Average Index. The multivariate econometric technique normally employed by researchers to capture information transmission and spillover effect account for conditional heteroscedasticity through Generalized Autoregressive Conditional Heteroskedasticity (GARCH) (or some variation of it) specification. Flemming, Kirby, and Ostdiek (1998) recently proposed an alternative approach to account for the linkages between the spot and futures markets. Their speculative trading model suggests strong volatility linkages between these markets due to common information that affects expectations in both markets. Crossmarket hedging causes information spillover. These linkages are measured in a stochastic volatility framework that is estimated with a generalized method of moments.

Another issue that becomes important in the joint modeling of more than one variable is the long-run relationship. Several financial time series are known to exhibit nonstationarity when analyzed individually, but they jointly maintain a stable relationship. Such a cointegrating relationship between the spot and futures market has been investigated in the Engle and Granger (1987) framework by several researchers, including Doukas and Rahman (1987) and Ghosh (1993). This is called *error-correction representation,* and a deviation from the long-run equilibrium in one period is expected to be corrected in the next period. One important use of futures contracts is in hedging spot positions, and ignoring such a cointegrating relationship may seriously affect the hedging performance. Kroner and Sultan (1993) found improved results in currency hedging when they explicitly modeled time-varying distributions with a bivariate error correction specification with a GARCH error structure. Lee (1994) also reported a better predictive power of the spread between the spot and forward exchange rates. In that study, Lee included the error correction term in the conditional mean and also extended the GARCH model for the conditional variances with error correction terms. According to Lee, the use of short-run disequilibrium as a conditioning variable in the variance equation is appropriate if one expects shocks to the system to propagate through both the first and second moments. This helps in identifying causality in variance with the help of the error correction term.

Because the error correction term is based on a long-run relationship between the two variables of interest, this may be subject to some major events or structural break. Therefore, cointegration analysis in the Engle and Granger (1987) framework has to account for such events. The analysis in this article is based on the successful index futures contract (SPI) in the Australian market trading on the Sydney Futures

Exchange (SFE). This futures contract is written on the Australian All Ordinaries Share Price index (AOI), which is a market value-weighted index that represents about 80% of the total capitalization of the Australian stock exchange. The SFE rescaled this contract on October 11, 1993 by reducing the multiplier from $100 to $25. The Chicago Mercantile Exchange increased the multiplier for S&P 500 futures contracts from $200 to $500 in 1984. According to the SFE, the purpose of this respecification of the SPI contract was to increase access to the market by potential traders. However, whether this action was successful with respect to other criteria is a matter of separate research. The increased access was noticeable from the fact that the average daily trading volume rose by 36% from the pre-event period to the postevent period. This daily average has been computed from February 2, 1993 to October 11, 1993 as the pre-event sample and from October 12, 1993 to February 28, 1994 as the postevent sample.

At the same time, October 11, 1993, the initial margin was reduced from $6,000 to $1,500, and the exchange fees of $1.17 per contract were removed. However, on November 18, 1993, the initial margin was increased to $2,000, and exchange fees of $1.00 per contract were introduced again on March 1, 1994. These changes around the time of contract respecification provide sufficient justification to focus on this as a major event and study its impact on the conditional return distribution. To establish the cointegrating relationship between the spot (AOI) and futures contracts (SPI), the impact of this event must be accounted for.

Iihara et al. (1996) also examined the impact of bidirectional information flow in the Japanese cash and futures market after the introduction of stricter measures in futures market transactions. They reported a lessening of volatility spillover from the futures to cash markets with intraday data following the event date. They did not account for any asymmetric responses to past innovations in their model. Abhyankar (1995) also documented (with intraday data from the U.K. market) the impact of lower transaction costs in the futures market and in the spot market. The author reported in a linear regression framework the leading role of the futures market and did not find any clear pattern in the lead–lag relationship in the volatility.

The main research questions pursued in this article relate to the following:

- Linkages between the spot (AOI) and futures contracts (SPI) through the second moment and in the presence of a long-run relationship subject to a regime shift.

- Relative asymmetry, that is, whether good news (market advances) and bad news (market retreats) affect the volatility differently.
- Shifts in the parameters describing the correlation between AOI and SPI, volatility spillover, relative asymmetry, and the persistence in volatility after the intervention by the SFE.

This study adopts a bivariate Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) framework for modeling the returns from AOI and SPI jointly. This EGARCH model makes it possible to investigate the asymmetric effect mentioned. Bae and Karolyi (1994) also stressed this asymmetric effect in the context of national stock market returns. The asymmetric effect may also be examined with the extensions of the GARCH models suggested by Kroner and Ng (1998) for multivariate systems. Although their model appears to perform better than several standard multivariate GARCH approaches, it is not clear that it has any advantage over the bivariate EGARCH framework adopted here. Besides, the Kroner and Ng framework would require more parameters to be estimated for the bivariate system studied in this article. Furthermore, the bivariate EGARCH model is quite popular in modeling spot–futures interaction, as can be seen from another recent application in Tse (1999).

The error correction term is used in the conditional mean equation to impose the long-run equilibrium relationship. The conditional volatility equation in the EGARCH model is augmented with the error correction term, and following Lee (1994), we may refer to it as the EGARCH-X model. To estimate the cointegrating vector, we test the two series for unit roots in the presence of a major structural event such as the SPI contract respecification. We achieve this by following the method of Zivot and Andrews (1992), which specifically addresses such a situation. Similarly, the cointegrating relationship is examined with the modification of Gregory and Hansen (1996), which revises the Engle and Granger (1987) model to explicitly account for a possible regime shift. Finally, to examine whether the parameters of the return-generating process shift after the futures contract respecification, we define and estimate interventions. These are discussed in detail later in the third section on methodology. The next section discusses the data set used in this study and the preliminary statistics, whereas the fourth section analyzes the empirical results before the conclusion in the fifth section.

DATA AND PRELIMINARY STATISTICS

The spot equity market data used are from the main market index on the Australian Stock Exchange, that is, the All Ordinaries Index (AOI) and the futures contract (SPI) on this index traded on the SFE. Only the near-quarter-month-maturity futures contract is used because this is the most liquid one. The data set covers the 10-year period from January 1989 to December 1998 and represents the daily settlement prices. The total number of observations in the sample is 2,534. The futures contract respecification date (October 11, 1993) is close to the midpoint of this sample.

The upper panel of Table I reports the basic statistics of the spot and futures return series created from the first differences of the log price series. It presents the statistics for both the preintervention and postintervention periods. Of the three quantities reported there, the kurtosis appears to have changed significantly for both return series after the intervention date. Although the statistical significance of the differences is not established here, it is taken up later when the significance of the parameters after the regime shift are considered. The upper panel also shows the Ljung–Box statistics for the return series, the squared return series, and the preintervention and postintervention dates. It is clear that there is no linear dependence, and this is in contrast to the finding by Koutmos and Tucker (1996), who dealt with S&P 500 data.

TABLE I

Descriptive Statistics of the Returns

	M (Pre)	*M (Post)*	*Var. (Post)*	*Var. (Post)*	*Kurtosis (Pre)*	*Kurtosis (Post)*
Spot index (AOI)	0.0260	0.0248	0.0067	0.0073	10.31	6.67
Index futures (SPI)	0.0274	0.0243	0.0119	0.0113	10.78	3.22
	SK (Pre)	*SK (Post)*				
Spot index (AOI)	−0.9092	−0.4102				
Index futures (SPI)	−0.8094	−0.0801				
	LB (Pre)	*LB (Post)*	*LB^2 (Pre)*	*LB^2 (Post)*		
Spot index (AOI)	0.178	0.161	0.000	0.000		
Index futures (SPI)	0.172	0.307	0.004	0.000		
Percentage of Equal Correlation between AOI and SPI for Various Sample Windows						
	50	100	200	300	500	600
	100	100	100	87.50	100	75.0

Note. Pre and post refer to the statistics before October 11, 1993 and after that date when the SPI futures contract specification was changed. The sample period covers January 1989 to December 1998, and the total number of observations is 2,534. SK refers to skewness. LB refers to *p* values for the Ljung–Box statistic with returns for 10 lags, and LB^2 refers to *p* values for the Ljung–Box statistic with squared returns for 10 lags. The equality of correlations is tested with the procedure described in Jenrich (1970) between successive samples of different sizes at the 5% level of significance. Returns are calculated as first differences of the log of the variables. Var. stands for variance.

There is substantial nonlinear dependence, however. If this nonlinear dependence is due to volatility clustering, the bivariate model developed in the next section should adequately address this. The lower panel of Table I reports the result of the formal test of the stability of the correlations between these two return series. This is done according to the method suggested by Jenrich (1970) by the calculation of the correlations between adjacent samples of various lengths. This test has a χ^2 distribution with the degrees of freedom $p(p - 1)/2$, where p is the dimension of the correlation matrix. The test statistic is given by the following equation:

$$\chi^2 = \frac{1}{2}\mathrm{tr}(Z^2) - \mathrm{diag}'(Z)S^{-1}\mathrm{diag}(Z) \qquad (1)$$

where

$$\overline{R} \equiv (\bar{r}_{ij}) = (n_1R_1 + n_2R_2)/(n_1 + n_2)$$

$$S = (\delta_{ij} + \bar{r}_{ij}\bar{r}^{ij})$$

$$c = \frac{n_1n_2}{(n_1 + n_2)}$$

and

$$Z = c^{0.5}\overline{R}^{-1}(R_1 - R_2)$$

In this expression, tr is the trace of the matrix, and diag implies diagonal elements of the matrix. R_1 and R_2 are sample correlation matrices of two successive samples of size n_1 and n_2, respectively, and δ_{ij} is the Kronecker delta (it is 0 when $i = j$ and 1 otherwise).

The entries in the lower panel of Table I indicate the percentage of times the correlations between successive samples of the given size are tested equal at the 5% significance level. It tends to support the fact that the correlations between these two return series have remained relatively stable over the entire sample period. This observation helps to define the covariance matrix of the bivariate model taken up in the next section. Kaplanis (1988) reported that the correlation matrices are relatively more stable than the covariance matrices. However, whether there is any change in the correlation due to regime shift occurring on October 11, 1993 is to be detected by an intervention analysis described in the next section.

The existence of a unit root in many financial time series is well documented in the literature. The researchers generally apply the augmented

Dickey–Fuller (ADF) test based on the results of Dickey and Fuller (1979). The test is described by the following equation:

$$\Delta y_t = \alpha + \beta t + (\rho - 1)y_{t-1} + \sum_{i=1}^{k-1} \theta_i \Delta y_{t-i} + w_t \qquad (2)$$

where Δ indicates the first difference of the series, the second term on the right represents a trend variable, and w_t is a white-noise term. The lag length k is chosen on the basis of the Akaike information criterion. The null hypothesis is $H_0:\rho = 1$ and y_t is said to have a unit root if the null hypothesis cannot be rejected. If the sample period contains major world events or, as in this case, a major structural event of the futures contract respecification, it has to be taken into account; otherwise, a proper conclusion cannot be reached. Zivot and Andrew (1992) suggested an alternative to Equation 2:

$$\Delta y_t = \alpha + \beta t + (\rho - 1)y_{t-1} + \gamma D_t(\lambda) + \sum_{i=1}^{k-1} \theta_i \Delta y_{t-1} + w_t \qquad (3)$$

where $D_t(\lambda)$ is equal to 1 for $T > \lambda T$ and is otherwise zero and λ is equal to T_B/T. T is the sample size, and T_B is the point at which structural break occurs. In this study, λ is 0.477. Table II reports the result of this unit root test along with the appropriate critical values, and it is clear that the null hypothesis of the unit root cannot be rejected.

The next step is to investigate the cointegrating property in the presence of a structural break. Gregory and Hanson's (1996) method in this context is a two-step process. First, we estimate the following regression:

$$y_{1t} = \alpha + \beta t + \gamma D_t(\lambda) + \theta_1 y_{2t} + e_t \qquad (4)$$

where y_1 and y_2 represent the two $I(1)$ series. The second step is to test e_t for $I(0)$ with the ADF test. If e_t is $I(0)$, the two series are said to be

TABLE II

Unit Root (Zivot and Andrew) and Cointegration (Gregory and Hansen) Tests

Zivot and Andrew Unit Root Test		*Gregory and Hansen Cointegration Test*	
AOI	*SPI*	*AOI on SPI*	*SPI on AOI*
−2.57	−2.85	−9.65	−9.48

Note. The Zivot and Andrew unit root test incorporates an adjustment for the structural break and is described in the text. The structural break parameter is $\lambda = 0.477$ for the data set being examined. The critical values for $\lambda = 0.4$ and 0.5 are −3.94 and −3.96, respectively, at the 5% level. The Gregory and Hansen cointegration test also incorporates the structural break and applies a traditional augmented Dickey–Fuller test to the cointegrating residual. Critical values are provided in Zivot and Andrews (1992) and Gregory and Hansen (1996).

cointegrated. It is this cointegrating residual that was used by Koutmos and Tucker (1996), although the cointegrating vector in their case was (1, −1). Similarly, Choudhry (1997) used Johansen's (1988) method to identify the cointegrating vector. There was, however, no need for a structural break to be taken into account in these two studies. From the results of the Gregory and Hansen test reported in Table II, the hypothesis that these two return series are cointegrated cannot be rejected.

BIVARIATE EGARCH-X MODEL

The asymmetric impact of news on the volatility transmission is now well documented, such as in Bae and Karolyi (1994). This together with the observed volatility clustering in equity returns and the futures returns can be modeled in a bivariate EGARCH framework. The bivariate modeling approach is well suited for the analysis of the return series, AOI and SPI, particularly because these two are shown to be cointegrated. The inferences drawn from the estimated parameters will be more precise because the bivariate model uses information from both markets simultaneously (Choudhry, 1997).

As the error correction term for the two cointegrated series has important predictive power, according to Lee (1994), the conditional mean equation is augmented by the lagged error correction term to capture this predictive ability. Lee also suggested that the lagged squared error correction term might also have important predictive power for the conditional covariance matrix. The bivariate EGARCH model is, therefore, extended appropriately to incorporate this fact. The significance of the estimated parameters, however, will determine how important the error correction terms are in explaining the propagation of shocks through the first and second moments.

Let R_{it}, $i = 1,2$ ($1 =$ AOI, $2 =$ SPI) be the return for market i at time t. Ω_{t-1} is the information set at time $t-1$. μ_{it}, σ and $\sigma_{i,j,t}$ are the conditional mean, conditional variance, and conditional covariance ($i \neq j$), respectively. ε_{it} ($\equiv R_{it} - \mu_{it}$) is the innovation, and $z_{it} = \varepsilon_{it}/\sigma_{it}$ is the standardized innovation. The EGARCH model for the bivariate system incorporating the effect of the error correction term (e_t) from Equation 4 and the volatility linkages between the two markets is given by

$$R_{it} = \beta_{i0} + \beta_{i1}e_{t-1} + \varepsilon_{it} \tag{5a}$$

for $i = 1,2$ and

$$\begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \Bigg| \Omega_{t-1} \sim N(0, \Sigma_t) \tag{5b}$$

The diagonal elements of the (2×2) conditional covariance matrix (Σ_t) are defined as

$$\ln(\sigma_{it}^2) = \alpha_{i0} + \alpha_{i1} f_1(z_{1,t-1}) + \alpha_{i2} f_2(z_{2,t-1}) + \gamma_i \ln(\sigma_{i,t-1}^2) + \theta_i \ln(e_{t-1}^2) \tag{6}$$

for $i = 1,2$ and

$$f_1(z_{1,t-1}) = |z_{1,t-1}| - E(|z_{1,t-1}|) + \delta_1 z_{1,t-1} \tag{7a}$$

$$f_2(z_{2,t-1}) = |z_{2,t-1}| - E(|z_{2,t-1}|) + \delta_2 z_{2,t-1} \tag{7b}$$

With reference to the evidence presented earlier regarding the stability of correlations between the two series (ρ_{ij}), the covariance term is defined as

$$\sigma_{i,j,t} = \rho_{ij} \sigma_{it} \sigma_{jt}, \quad (i \neq j) \tag{8}$$

In the conditional variance Equation 6, the parameter α_0 represents the logarithm of the unconditional variance of the return process assumed to be constant. The parameter γ determines the influence of the past conditional volatility on the current conditional volatility. For the conditional volatility process to be stationary, $|\gamma_i| < 1$ is required. The persistence of volatility may also be quantified by an examination of the half-life (HL):

$$\text{HL} = \frac{\ln(0.5)}{\ln|\gamma_i|} \tag{9}$$

which indicates the time period required for the shocks to reduce to one-half their original size.

The functions $f_1(z_1, t)$ and $f_2(z_2, t)$, defined by Equations 7a and 7b, respectively, generate sequences of zero mean, an identically and independently distributed random variable by construction, and allow past standardized innovations to have an asymmetric effect. The first two terms measure the size effect, and the third term measures the sign effect. If δ is negative, a negative realization of z_t will increase volatility by more than a positive realization of equal magnitude. Similarly, if the past absolute value of z_t is greater than its expected value, the current volatility will rise. However, because Equations 7a and 7b enter the conditional volatility expression Equation 6 after being multiplied by α_{1i} and α_{2i}, the sign effect may enhance or reduce the size effect depending on the sign of these parameters. If α_{ii} is positive and δ_i is negative, a negative innovation in the previous period will lead to higher conditional volatility in the current period compared with a negative innovation in the previous period. This is called the *leverage effect* and is documented by Black (1976) and Nelson (1991) among others. Similarly, the crossmarket volatility linkage effects are controlled by the parameters α_{12} and α_{21}. For example, α_{12} represents the impact of standardized innovation in the futures market (SPI) on the spot market (AOI), and α_{21} represents the impact in the opposite case. Thus, if α_{12} is positive and δ_2 is negative, a retreat (negative innovation) in the futures market will be followed by higher spot market volatility than in the case of a futures market advance (positive innovation). The asymmetric effect of standardized innovations on volatility may be measured by derivatives from Equations 7a and 7b:

$$\partial f_i(z_{it})/\partial z_{it} = \begin{Bmatrix} 1 + \delta_i & z_i > 0 \\ -1 + \delta_i & z_i < 0 \end{Bmatrix} \tag{10}$$

Relative asymmetry may be defined as $|-1 + \delta_i|/(1 + \delta_i)$. This quantity is greater than, equal to, or less than 1 for negative asymmetry, symmetry, and positive asymmetry, respectively.

The parameter θ in Equation 6 captures the effect of the error correction term in influencing the conditional variance in the sense introduced by Lee (1994). The series e_t is obtained from Equation 4, and its logarithm is used simply to be numerically consistent with the specification of the conditional volatility.

The estimation problem is, therefore, to maximize the joint log likelihood function under the distributional assumption made previously. If the sample size is T, the log likelihood function to be maximized with respect to the parameter vector Θ is

$$\mathrm{L}(\Theta) = -T\ln(0.5\pi) - 0.5\sum_{t=1}^{T}\ln|\Sigma_t| - 0.5\sum_{t-1}^{T}\varepsilon_t'\Sigma_t^{-1}\varepsilon_t \tag{11}$$

where $\varepsilon_t = [\varepsilon_{1t}, \varepsilon_{2t}]$ and the parameter vector includes

$$\Theta = [\beta_{i0}, \beta_{i1}, \alpha_{i0}, \alpha_{i1}, \alpha_{i2}, \gamma_i, \theta_i, \delta_i, \rho], \quad i = 1, 2$$

The estimation problem as represented by this maximization objective assumes the constancy of the parameters both before and after intervention by the SFE to respecify the SPI futures contract. To investigate whether this intervention has affected any parameter of interest, such as the contemporaneous correlation between the two markets given by ρ, we define an intervention as follows. A series x_t is generated such that x_t is zero for all $t <$ intervention date, and it is 1 for all $t \geq$ intervention date. The model is reestimated by the introduction of $\rho(1 + \Delta\rho \cdot x_t)$ in place of ρ. Let the new maximized log likelihood function be L(Ψ), where the new parameter vector Ψ contains one additional parameter, $\Delta\rho$. If, for example, $\Delta\rho$ is negative, it implies that the contemporaneous correlation has decreased after the intervention date. A similar interpretation can be made with respect to any other interventions introduced. Other parameters investigated this way include the crossmarket volatility linkages (α_{12}, α_{21}), the sign effect parameters (δ_1, δ_2), and the volatility persistence parameters (γ_1, γ_2).

The statistical significance of the intervention parameters is inferred from the likelihood ratio test (LRT; Amemiya, 1985). This is given by the following quantity:

$$\text{LRT} = 2[L(\Psi) - L(\Theta)] \tag{12}$$

which is distributed as $\chi^2(q)$, where q, the number of degrees of freedom, is equal to the number of extra parameters. For Δp, $q = 1$, and for all the other interventions mentioned previously, which are tested jointly, $q = 2$.

EMPIRICAL RESULTS

The parameters of the bivariate EGARCH-X model are estimated by the numerical maximization of the discussed likelihood function with the algorithm developed by Berndt, Hall, Hall, and Hausman (1974; BHHH in GAUSS$^{\text{TM}}$) without any parameter restriction imposed. These results are presented in Table III. The parameters β_{i1} ($i = 1$ for AOI and $i = 2$ for SPI) are statistically significant, indicating that the error correction term is an important determinant of the conditional mean return in both the spot and futures markets. The signs of these parameters conform to the results in Koutmos and Tucker (1996) for the S&P 500 data. As mentioned there, Kroner and Sultan (1993) also reported similar findings for currency futures. The significance of these parameters suggests the possible use of the cointegrating residual in forming expectations of future returns.

The parameters measuring the effect of the short-run deviations on the conditional variance θ_i ($i = 1,2$) are both positive, and only the one for the spot market is statistically significant. The implication of this

TABLE III

Estimation Results for the Bivariate EGARCH-X Model

Parameters		*AOI*		*SPI*
Mean equations				
β_{i0}		0.0003 (1.50)		0.0003 (1.50)
β_{i1}		−0.1270 (−5.85)		0.0551 (2.03)
Volatility equations				
α_{i0}		−2.0983 (−10.15)		−1.4428 (−12.45)
	α_{11}	−0.0083 (−0.32)	α_{12}	−0.1041 (−4.93)
	α_{12}	0.2544 (9.82)	α_{22}	0.2756 (11.25)
γ_i		0.7687 (34.32)		0.8358 (63.80)
θ_i		0.0118 (2.88)		0.0048 (1.71)
δ_i		−0.2447 (−2.34)		−0.3069 (−5.63)
Correlation				
ρ			0.9128 (351.08)	
Others				
Half-life		2.63		3.86
Relative asymmetry		1.65		1.89

Note. The numbers in parentheses indicate *t* statistics. The half-life is defined in the text and represents the time it takes the shock to reduce its impact by one-half. Relative asymmetry is also defined in the text, and this statistic is greater than, equal to, and less than 1 for negative asymmetry, symmetry, and positive asymmetry respectively (i = 1 for AOI and i = 2 for SPI).

finding is that when the futures and spot price difference becomes larger, the conditional volatility of the spot return increases. The magnitudes of these parameters are somewhat higher than those reported by Choudhry (1997), who used a GARCH-X formulation. Besides, Choudhry reported this effect for Australian futures market returns.

The parameters α_{11} and α_{22} capture the impact of our own market lagged standardized innovations of the conditional volatility for AOI and SPI, respectively. Because α_{11} is not statistically significant, the leverage effect in the spot market is not readily apparent. Koutmos and Tucker (1996) pointed out the existence of such an effect in terms of an increased ratio of aggregate debt to equity after a market decline and, hence, higher volatility. The parameter α_{22} is, however, highly significant if there is support for an asymmetric volatility response in the case of futures market returns. This may be understood in term of the price-leading behavior of the futures market and a market decline, thereby resulting in an unfavorable reaction by the participants, leading to a higher conditional volatility. This behavior of the two market returns is summarized by the quantity of relative asymmetry given in Table III.

The persistence in volatility is measured by the parameter γ_i. These values are both significantly less than 1, a condition necessary for the volatility process to be stable. The magnitude of these parameters suggests a strong tendency for the volatility shocks to persist, and it is higher for the futures return. The quantity HL best interprets this result. It takes 3.86 days for the shocks to reduce its impact by half for the futures market return. For the spot market return, it is 2.63 days.

The parameters α_{12} and α_{21} capture the impact of crossmarket standardized innovations for the spot and futures market returns, respectively. These past crossmarket innovations exert an asymmetric influence on conditional volatility. The impact of a market retreat in the futures market on the conditional volatility in the spot market is controlled by $(\alpha_{12} + \alpha_{12}\delta_2)$. Similarly, the impact of a market advance in the futures market is controlled by $(\alpha_{12} - \alpha_{12}\delta_2)$. This asymmetric effect is quantified by relative asymmetry in Table III. As the futures market has a price-leading role, a decline in that market tends to exert more reaction in the spot market than a corresponding rise in that market. Hence, a higher conditional volatility is the result. In contrast to the finding by Koutmos and Tucker (1996), the crosslinkage between the spot and futures markets is significant and is measured by the parameter α_{21}. Because the sign of this parameter is negative, the impact is opposite to that discussed previously between the futures and spot markets. This finding is in general agreement with the findings in Chan, Chan, and Karolyi (1991). In summary, both the spot equity and index futures markets in Australia are informationally linked through the second moment, and this dependence is asymmetric in nature.

The contemporaneous correlation between the index and the index futures is high and statistically significant, and it is time-invariant by construction. This is also expected from the usual pricing relationship connecting the spot and futures markets. However, this does not imply that the conditional covariance is time-invariant. This time-varying nature of the covariance is important and may be exploited in a dynamic hedging environment.

The diagnostic statistics are given in Table IV. They include the 10th-order serial correlation in the level and squared standardized innovations as well as the asymmetry test statistics following Engle and Ng (1993). As suggested in Engle and Ng, the Ljung–Box test may not detect misspecifications due to asymmetric effects. The Ljung–Box statistics indicate the absence of linear and nonlinear dependence in the standardized innovations. The Engle and Ng tests also indicate a reasonable fit of the bivariate EGARCH-X model to the data over the 10-year period.

Table V reports the intervention analysis of the parameters for contemporaneous correlation, volatility spillover, sign effect, and volatility persistence after the date SFE redenominated the SPI futures contract.

TABLE IV
Diagnostic Tests

	AOI	*SPI*
p values for Ljung–Box Q(10) statistics		
z	0.011	0.825
z^2	0.865	0.693
$z_1 \cdot z_2$	0.913	
p values for Engle and Ng (1993) diagnostic tests		
Sign bias test	0.918	0.967
Negative size bias test	0.972	0.971
Positive size bias test	0.358	0.198
Joint test	0.193	0.038

Note: z represents the standardized residual for the corresponding equation, that is, either AOI or SPI. $z_1 \cdot z_2$ indicates the product of the two standardized residuals.

TABLE V
Likelihood Ratio Test of the Individual Intervention Parameters

	$\Delta\rho$	$\Delta\alpha_{1,2}$	$\Delta\alpha_{2,1}$	$\Delta\delta_1$	$\Delta\delta_2$	$\Delta\gamma_1$	$\Delta\gamma_2$
	0.0378	−0.1699	1.3515	1.23	2.09	0.0070	0.0083
t statistic	7.88	−3.43	1.56	0.70	1.29	4.67	5.93
LR statistic	45.64	23.96		6.69		30.95	
p value	0.000	0.000		0.035		0.000	

Note. The subscripts 1 and 2 refer to the AOI and SPI series, respectively. LR stands for the likelihood ratio as explained in the text. p values are computed from the χ^2 distribution. The degree of freedom is 1 for $\Delta\rho$ and 2 for all the others, which are tested jointly.

With a lower valuation of each futures contract, SFE estimated that the number of transactions had gone up. To the extent this increased trading volume represents more analysis being done by the market participants, the contemporaneous correlation is likely to increase after the intervention date. The highly significant parameter $\Delta\rho$ does indeed show a slight increase in the contemporaneous correlation. In terms of the crosslinkage parameters, $\Delta\alpha_{21}$ is not significant, but $\Delta\alpha_{12}$, representing the impact of past futures market innovations on the spot market return volatility, is significant. The negative sign of $\Delta\alpha_{12}$ indicates that the spillover effect (from the futures market to the spot market) is marginally reduced. Based on the estimated parameters, the fall in the value of α_{12} is only from 0.2544 to 0.2112 (i.e., $\alpha_{12} \cdot \times \Delta\alpha_{12}$) after the intervention date. There are actually two sources affecting this. First, the increased activity in the futures market resulting from the contract respecification may be thought to exert greater influence on the spot market through higher α_{12}.

Second, the other changes brought about by the SFE on November 18, 1993 and again on March 1, 1994 would amount to increasing the transaction costs in the futures market. This would have the opposite effect on α_{12}. Therefore, the estimated $\Delta\alpha_{12}$ represents the resultant effect from these two opposing sources.

Both return series also show slightly increased volatility persistence ($\Delta\gamma_1$, $\Delta\gamma_2$) after the intervention date. If volatility clustering is responsible for unconditional kurtosis, this increased volatility persistence does not offer an adequate explanation for the decreased unconditional kurtosis in both return series. It is also interesting to examine whether the sign effect parameters of past standardized innovations have shifted after the intervention date. Table V suggests that both $\Delta\delta_1$ and $\Delta\delta_2$ are statistically insignificant. Therefore, the SFE intervention has not affected the sign effect component of the asymmetric behavior of the standardized innovations on the conditional volatility.

CONCLUDING REMARKS

This article applies an extended bivariate EGARCH model (EGARCH-X) to capture the dynamic behavior of the joint spot equity and index futures return-generating process. These two markets are cointegrated despite a major structural event of futures contract respecification. The cointegrating residual is not only found to be a significant determinant of the conditional mean return in the bivariate system but also has significant explanatory power for the conditional volatility. The results of this article suggest that the issue of cointegration, in the presence of a structural break, should be addressed appropriately because the conditional distributions are affected by its presence. This may have an important bearing on the dynamic hedging behavior of the futures contract.

The diagnostic tests suggest that the proposed model fit the data over 10-year periods well. Both markets display volatility spillover effects and asymmetric behavior of past standardized innovations on the conditional volatility. The intervention analysis carried out around the date the SFE respecified the index futures contract indicates an increase in contemporaneous correlation between the spot equity and index futures markets. The spillover effect from the futures market to the spot market appears to be slightly reduced after the intervention date. However, both markets display somewhat increased volatility persistence after the intervention. The increased trading that accompanied the futures contract redenomination did not affect the sign effect of the volatility response from the past standardized innovations.

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