Intertemporal Volatility and Price Interactions between Australian and Japanese Spot and Futures Stock Index Markets

AH-BOON SIM
RALF ZURBREUGG*

Previous studies have examined causality within and between different spot and futures markets with a motivation to discover market comovements, price leadership effects, and, more recently, volatility spillovers across markets. However, the empirical framework within which this is accomplished tends not to analyze explicitly foreign spillover effects upon a spot–futures relationship, which may significantly alter the equilibrium between these markets. This will then have a direct impact upon the estimation of dynamic risk adjustments that occur from the interaction between these markets. This article develops a quadvariate simultaneous-equation EC-ARCH model with an emphasis on volatility spillovers as a better alternative methodology to evaluate these relationships from a different perspective. This model is applied to examine the interaction between the Australian

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*Correspondence author, School of Banking and Finance, University of New South Wales, Sydney 2052, Australia.

- *Ah-Boon Sim is an Associate Professor in the School of Banking and Finance at the University of New South Wales, Australia.*
- *Ralf Zurbreugg is a Lecturer in Finance in the School of Banking and Finance at the University of New South Wales, Australia.*

and Japanese spot and futures stock index markets, which allows for an Australian or Japanese futures trader to analyze the impact of foreign cash and futures markets, as well as the local cash market, on the local futures market in a single coherent framework. This type of analysis is not possible using previous paradigms, because they allow the trader only to examine the impact of local cash and foreign futures markets in separate settings. Jrl Fut Mark 19: 523–540, 1999

INTRODUCTION

This study examines the intertemporal effects of foreign stock and futures markets upon domestic spot–futures relationships. The motivation for this is to determine whether foreign stock and futures markets significantly affect domestic spot–futures market interaction and act as vehicles for international price discovery between them. In particular, the objective is to model and analyze the impact of foreign market prices and volatilities (the foreign spillover effects) upon the local spot–futures relationship, which may significantly alter the equilibrium relationships between these markets. Furthermore, because research on the lead–lag relationship between stock and futures markets generally shows a causal relationship to exist from changes in futures prices to changes in the stock index, *marketwide* international spillover effects may be more effectively traced via index futures than stock indices for markets that are internationally integrated. Active traders may find it more relevant to examine international effects via the futures markets as an indicator of how stock indices will change value in the future. Furthermore, for market participants, the addition of encompassing foreign effects upon a spot–futures relationship may significantly improve their dynamic risk adjustment estimations to foreign market influences.

The explanation for the relationship between spot and futures markets can be attributed to the price maintenance of the cost-of-carry relation[1] for any pair of continuous trading and efficient futures and stock markets. Departures from the cost-of-carry relation are found in earlier studies, and it is conjectured that these deviations may represent significant evidence that suggests futures markets vehicles for price discovery within the corresponding stock markets. One primary reason for this is that futures markets tend to have fewer trading constraints[2] than the

[1] $F_t = S_t e^{(r-d)(T-t)}$; where r is the interest rate and d is the dividend yield.

[2] Trading rules may inhibit short sells, incur higher transaction/commission costs, lead to disadvantageous settlement procedures, increase costs for small trades, imply less anonymity/transparency in trading, and so forth—all of which can deter investors from trading and thereby limit liquidity in markets.

primary markets, rendering futures markets potentially more informationally efficient than their underlying primary markets. Fama (1991) argues that informational efficiency implies asset prices that reflect pricing information up to the point at which the marginal costs from acting upon new information outweigh the marginal gains.[3] In futures markets, trading costs are generally lower than for the primary markets—and they also tend to have more liquidity. Stoll and Whaley (1990) consider these two factors to play a vital role in explaining the systematic evidence that futures markets tend to exhibit price leadership effects over stock markets. Stoll and Whaley (1990) examine intraday price changes from S&P 500 and MM stock index and futures contracts for serial correlation via an ARMA(p,q) process. These authors notice that the futures markets lead the stock indices on average by 5 minutes. One other important explanation relates to Chan's (1992) evidence on the impact of marketwide and firm-specific news events upon a spot–futures relationship.[4] Chan hypothesizes marketwide information, being systematic in nature, would feed through the futures markets before entering the primary market, although the impact of firm-specific news events would not necessarily have the same effect, because it is diversifiable, hence not necessarily affecting futures index contracts. Further research by Anthony (1988) and Miller (1990) also suggests investors prefer trading in the derivative markets rather than the stock markets, because of market frictions such as transaction costs and capital requirements.[5]

There is also significant evidence of futures price leadership in equities outside United States markets. By examining the lead–lag relationship between stock index prices and index futures contracts within an ARMA (p,q) framework, Grünbichler, Longstaff, and Schwartz (1994) note futures price leadership for the German DAX index futures contract. Similar results are also obtained by Shyy, Vijayraghavan, and Scott-Quinn (1996) for the French CAC index futures contract. All the studies note price leadership for periods up to 20 minutes.

There has also recently been a growth in interest for examining higher moment dependencies between spot and futures markets. Interest regarding the impact of volatility spillovers from one market to another has arisen primarily because of the realization that speculative price

[3]The original conception of informational efficiency can be traced back to the late 1970s from research on asset pricing variability, such as Grossman and Stiglitz (1976).

[4]Marketwide news events are characterized by the event affecting a broad section of security prices on a financial market rather than specific firms.

[5]All purchases of stocks on a stock market must be paid for within a short time-frame, depending upon when settlement dates occur in the exchange. This is in direct contrast with futures contracts, in which the investor maintains margin accounts.

changes are interwoven with higher moment dependencies (see Bollerslev, Chou, & Kroner, 1992), because volatility interaction can be a good measure for the quantity of informational flow between markets (see Ross, 1989; Kyle, 1985). Furthermore, by not accounting for time variation within the second moments, previous studies utilizing ARMA (p,q) processes may suffer from model misspecification, because mean return coefficient estimates will not have accounted explicitly for possible time-varying volatility and volatility interaction between the markets (see Chan, Chan, & Karolyi, 1991; Tauchen & Pitts, 1983).

The examination of price innovations (volatility) between markets can also provide evidence for whether price leadership from futures markets truly exists. If this is the case, one would expect past futures price innovations to affect contemporaneous stock index volatility, but not vice versa. To explicate this, research has focused upon accounting for the presence of conditional heteroskedasticity within time series. The reason for this phenomenon is that most financial data usually exhibit volatility clustering, perhaps due to increased uncertainty from new information arrival and the time delay in traders adjusting to it. Engle, Ito, and Lin (1990) account for this by modeling asset returns via an autoregressive conditional heteroskedastic (ARCH) process.

Another benefit from modeling time series data via ARCH or the more parsimonious generalized ARCH (GARCH) approach, which allows the variances to be a conditional function of past variances and squared error residuals, is that data that have leptokurtic distributions can be more readily accommodated.[6] Chan, Chan, and Karolyi (1991) was the first article to apply a GARCH process to examine spot–futures interaction. These authors note that for the S&P 500 stock index and stock index futures markets, intraday trading is characterized by persistent and predictable volatility patterns arising from both the futures and stock markets; these results are robust in the presence of asynchronous trading in the stock market. The conclusion was that volatility spillovers are bidirectional in nature, arising from and affecting both spot and futures markets. Hence the conjecture that price leadership exists only in futures markets is not supported.

Research by Koutmos and Tucker (1996) suggests that daily price innovations arising from the S&P 500 index futures has an asymmetric effect upon the S&P 500 index. By applying an exponential GARCH approach, these authors note that bad news increases volatility more than good news does. As well, these authors do not note significant volatility

[6]See Baillie and Bollerslev (1989).

spillovers from the cash market to the futures market, contrary to observations by Chan, Chan, and Karolyi (1991). One other recent study employing conditional heteroskedastic processes to ensure time-variation within the second moments is Iihara, Kato, and Tokunaga (1996), which examines intraday trading behavior from the Nikkei Stock Average spot–futures relationship. These authors also note that futures markets are vehicles for price discovery in the cash markets, although they observe that this role has diminished since the Japanese Ministry of Finance imposed stricter regulations upon futures trading, thus limiting the scope of benefits from trading in the futures market before the cash market.

As a means of complimenting and extending the above literature to accommodate the extra consideration of examining foreign market influences, this article applies a quadvariate conditional heteroskedastic model wherein the cointegrative relationship between the markets is also incorporated explicitly. In particular, the model applied herein is utilized to examine the relationship between two markets that for part of the trading day are open simultaneously and are of comparatively different sizes in terms of both market capitalization and global importance—namely the Japanese and Australian markets. Specifically, this study provides an analysis to consider whether foreign spot and futures markets do affect domestic spot and futures markets in both price changes and underlying price volatility. There is currently very little research that examines this possible effect—particularly with regard to examining dynamic volatility structures—despite its potential importance. Evidence from Gannon (1998), when examining S&P 500 index futures volatility spillover effects upon the Australian and Hong Kong markets, suggests domestic spot–futures relationships may indeed by highly susceptible to foreign market influences. Furthermore, the importance in analyzing both the first and second moments lies within their economic interpretation in the context of the fundamental principles of financial theory—namely, risks and returns. Under the assumption of constant volatilities, which postulates a stable risk structure, only conditional mean reactions can be tested. When this assumption is relaxed to allow for time-varying volatilities, many additional relationships can be analyzed. For example, foreign market influences may well affect the level of uncertainty (volatility) within a market, but not have any significant impact in changing price levels; this impies that only risk of the asset can be dependent on foreign influences. On the other hand, prices may be significantly affected by foreign price movements, but not volatility. The significance of these observations for the market participant is that in the first case the importance of the foreign markets is in their impact upon risk exposure in the domestic market, whereas in the second case it will be due to the opportunity for diversification and ability to forecast price movements. Ultimately, the relationship that exists between a domestic and foreign market will be a function of the economic, political, and financial relationship the markets have with one another. Hence, inasmuch as this article examines the interaction between the Japanese and Australian markets, one would expect a unidirectional relationship to emerge—that is, from the Japanese markets' feeding information to the Australian markets—given the relative size and importance of the Japanese capital markets and Australian dependence on the Japanese economy.

PRELIMINARY DATA ANALYSIS

The data used in this study are obtained from three different sources spanning a period from 24 July 1997 to 24 October 1997.[7] Minute by minute All Ordinaries (All-Ords) index prices are obtained from SIRCA.[8] Transactions data for SPI futures contracts on the All-Ords are from the Sydney Futures Exchange, and minute by minute transactions data for the Nikkei 300 stock index and futures contracts are from Nihon Keizai Shimbun, Inc. For the indices, both are valued weighted and, in the case of the All-Ords, it accounts for over 95% of the market value of all Australian stocks. The Nikkei 300 was chosen over the better-known Nikkei 225, because the component securities that comprise the Nikkei 300 are selected from highly liquid, capitalized stocks. This particular selection reduces the chances of thinly traded high-priced stocks manipulating the index, as could be the case with the Nikkei 225, which is price weighted. A further problem for indices that have a number of stocks that are not traded frequently is that they may seem to move without actual trades taking place. This is due to the existence of special indication quotes, which are made by the Saitori to aid trade in stocks that have not moved or have large order imbalances. These indication quotes are used to calculate index prices, which can in turn influence the derivative markets without an actual trade taking place.

For futures contracts, prices of contracts with the nearest expiration date are used until ten working days prior to their termination. Taking prices from contracts closest to expiration will potentially limit only the most actively traded contracts to be recorded, because these contracts tend to trade more frequently, hence mitigating infrequent-trading prob-

[7]This period was chosen for having a large degree of futures trading in both markets—plus Australian daylight saving time not being in effect (daylight saving starts on 26 October 1997).
[8]Security Industry Research Centre for Asia-Pacific.

lems. Furthermore, all the futures contracts on the indices have similar delivery months.[9] This scheme thus avoids the potential effect of econometric irregularities that arise from the the tendency of futures prices to become more volatile around expiration dates. If expiration dates are not similar, then explicit consideration of termination dates would need to be incorporated into any analysis in order to account for excess volatility within futures markets for which contracts are expiring.

The data are also sorted to account for the differential in trading hours between the Australian and Japanese markets. Market prices are used only in instances where all four markets are open simultaneously. Furthermore, to account for potential stale opening prices and the time difference for nontrading periods from the opening prices of both morning and afternoon sessions, the first five minutes of trading are also excluded. Therefore, for the sample period, prices are examined between 0905–1100 and 1305–1500 (Tokyo time). From this series the data are partitioned into ten-minute intervals, and rates of return,[10] r_t, are calculated such that $r_t = 1000 * \ln (p_t/p_{t-1})$ where p_t is the price at time t.

There is no incorporation of foreign exchange (FX) rate effects when calculating returns in both countries, because it results in additional volatility arising from the FX markets that may be unrelated to volatility within the stock and futures markets. Furthermore, it can also be argued that currency hedging on the forward markets can mitigate pure currency risk and thereby not require the incorporation of FX changes within domestic prices.[11]

Table I presents summary statistics for all series under discussion. Without exception, all series reject the Jarque-Bera null hypothesis of normality, which infers excess skewness and/or kurtosis within the distributions. This inference is supported by the observation that all series contain excess kurtosis[12] and are highly negatively skewed. As a test of whether the rejection of normality may have also arisen due to intertemporal moment dependencies, Ljung-Box statistics are reported. In all cases, there is evidence to substantiate the presence of both linear and nonlinear intertemporal dependencies, the latter being predominantly larger and suggestive of the existence of conditional heteroskedasticity. Finally, to test for cointegration between the four markets, an OLS regression on the long-run relationship between the markets is calculated

[9]SPI futures contracts (based on the All-Ords) and Nikkei 300 futures contracts both have quarterly expiration cycles with delivery months being March, June, September, and December.

[10]If no futures contract is traded on the 10th minute for each interval, the nearest price is taken instead.

[11]See Eun and Resnik (1988) and Cheung and Ho (1990) for further discussion.

[12]The level of kurtosis for a normal distribution is 3.

TABLE I

Preliminary Statistics

	Stock Index		*Stock Index Futures*	
	All-Ords	*Nikkei 300*	*SPI*	*Nikkei 300*
Mean	−0.0379	−0.0466	−0.1037	−0.1057
Std. Dev.	2.2495	2.5439	2.8156	2.9087
Skewness	−8.4352	−3.5699	−5.7193	−6.4704
Kurtosis	167.0258	55.5341	98.6148	126.5230
Jarque-Bera	1402504	144991	478333	795693
Qx (21)	32.3541[a]	20.8925[a]	22.8755[a]	16.8261[a]
Qxx (21)	47.8680[a]	37.5028[a]	29.0136	35.4208[a]
ADF (prices	−0.9384	−0.9388	−0.8477	1.0360
ADF (returns)	−16.1886[a]	−16.5801[a]	−16.1174[a]	−16.4933[a]
Cointegration	−18.9110[a]	−26.5317[a]	−18.3849[a]	−25.9817[a]

Notes: *Qx* (21) and *Qxx* (21) are Ljung-Box test statistics for the null hypothesis of no serial correlation of up to the 21st order in returns and squared returns respectively. 21 lags are incorporated, as this will measure serial dependence up to a full working month. The Jarque-Bera statistic, under the null-hypothesis, tests where a series is normally distributed by examining the last two moments. Its statistic is distributed as χ^2 with two degrees of freedom. The ADF statistics are Augmented Dicke-Fuller tests for the null of nonstationarity, all incorporating four lags. The critical value of −4.18 (at the 5% significance level) for the presence of cointegration is obtained from Engle and Yoo (1987).
[a]Indicates rejection of the null hypothesis at the 5% level.

to obtain series of white noise disturbances. The long-run relationship between prices are modeled as being dependent upon previous lagged prices in all markets, $i(i = 1,2,3,4)$:

$$\ln P_{i,t} = \eta_i + \sum_{j=1}^{4} \varphi_{ij} \ln P_{j,t-1} + z_{i,t} \tag{1}$$

where $z_{i,t}$ is the white noise disturbance.

Thereafter, the Dickey and Fuller (1979, 1981) formulation for unit root tests is conducted on the disturbances, where $e_{i,t}$ is the error term for the ith market, such that

$$\Delta z_{i,t} = \theta z_{i,t-1} + e_{i,t} \tag{2}$$

Thus, if the null hypothesis of $\theta = 0$ is true, the four market series are said not to be cointegrated. These results, along with Augmented Dickey-Fuller (1981) unit root test statistics, are reported in Table I, indicating all markets are cointegrated with each other and are nonstationary in prices.

METHODOLOGY

In this article, we consider an extension of the ARCH family of conditional heteroskedastic processes, which incorporates an error-correction term to account for any long term relationship between the markets. Specifically, a quadvariate autoregressive conditional heteroskedastic regression is applied within a cointegrative framework, which will be referred to as an EC-ARCH process (see Lee, 1994). Given the presence of cointegration, conditional heteroskedasticity, and the desire to analyze the time-varying properties of the first and second moments, a number of ARCH-class models are considered; however, in terms of their relative performance in robustness and log-likelihood ratio tests, EC-ARCH(1) performs the best. In particular, no consistent lagged variance effects are noted (GARCH). This observation may be due to an increase in noise and short-lived intraday volatility components, which can create highly variable results when used to detect longer-term volatility structures. Andersen and Bollerslev (1997) and Andersen and Bollerslev (1998) examine this issue in depth when they discuss modeling high-frequency data with conditional heteroskedastic processes. The EC-ARCH model applied herein is also found to be consistent over different subsamples of the data, as well as conforming with most of the results obtained from a regression in which daily returns are examined.[13]

The conditional mean equations specify returns in one market as a function of lagged returns from its own and all other markets. However, to account for any possible long-run relationship between the four markets, a cointegrative parameter is also included. Granger (1981, 1983) suggests the use of an error-correction term within the mean equations. This employment of an error-correction term may be considered as a prediction equation of the cointegrated series, because it is an expectation of the first difference of a series given a specific price series. Within a conditional heteroskedastic framework, Lee (1994) discusses the importance of the inclusion of an error-correction term for both the conditional variance and mean equations to account for a potential feature within these cointegrated series—that feature being a possible relationship existing between a disequilibrium in market prices and the degree of uncertainty (conditional variances) observed in the short-run. To actually forecast the cointegrated variables, we use a two-step estimation procedure introduced by Engle and Granger (1987). This procedure first involves obtaining the estimated values of $z_{i,t}$, which are the residuals of the cointegrating regression of all markets taken together, with the ith market price as the dependent variable. Once calculated, the lagged val-

[13]Although results are not necessarily comparable with daily data, they can shed light upon general long-term relationships that may exist. Results from the daily return regressions are not provided in this paper but can be requested from the authors.

ues of these residuals, $z_{i,t-1}$, are used for each series in the mean equations, substituting cross-equation constraints as an error-correction term.

To incorporate volatility spillover effects, squared error residuals from all four markets are included within the conditional variance equations, whereas conditional covariance processes are a function of a constant unconditional covariance term and multiplicative cross-error terms. Also, for both conditional variances and covariances, error-correction terms are incorporated to allow for any potential relationship between a short-term pricing disequilibrium and uncertainty in the cointegrated system. Therefore, for all four markets,[14] the conditional regression equations are specified as follows:

$$r_{i,t} = \phi_{i0} + \sum_{j=1}^{4} \phi_{ij} r_{j,t-1} + \omega_i z_{i,t-1} + \varepsilon_{i,t} \tag{3}$$

where $\varepsilon_t = (\varepsilon_{1,t}, \varepsilon_{2,t}, \varepsilon_{3,t}, \varepsilon_{4,t})'$ and $\varepsilon_t \sim N(0,H_t)$. The diagonal elements of $H_t = \{h_{ij,t}\}$ are:

$$h_{i,t} = \alpha_{i0} + \sum_{j=1}^{4} \alpha_{ij} \varepsilon^2_{i,t-1} + \gamma_i z^2_{i,t-1} \tag{4}$$

The covariances are defined as:

$$h_{ij,t} = \alpha_{ij0} + \alpha_{ij} \varepsilon_{i,t-1} \varepsilon_{j,t-1} + \gamma_{ij} z_{i,t-1} z_{j,t-1} \tag{5}$$

Maximum likelihood (ML) is used to estimate the model parameters and the logarithm of the likelihood function is specified as:

$$L(\Theta) = -\frac{n}{2} \ln(2\pi) - \frac{1}{2} \ln|\mathrm{H}_t| - \frac{1}{2} \varepsilon'_t H_t^{-1} \varepsilon_t \tag{6}$$

where Θ is the parameter vector to be estimated, ε_t is a $1 \times n$ vector of residuals at time t, n is the number of simultaneous equations, and H_t is the conditional variance–covariance matrix. Furthermore, a number of algorithms are employed to obtain consistent parameter estimates and standard errors of the asymptotic H_t; however, the Berndt, Hall, Hall, and Hausman (1974) utilization of numerical derivatives to maximize $L(\Theta)$ was of most consistent use.

EMPIRICAL RESULTS

One important consideration that must be raised is the possibility that the degree of multicolinearity within the regression may have weakened

[14]All-Ords, SPI, Nikkei 300 cash and Nikkei 300 futures.

the t-tests for the coefficients as the coefficient estimates become less efficient. This generally gives rise to larger standard errors and, hence, smaller t-statistics. When modeling the conditional mean return equations to contain lagged returns of its own and all other markets, there will be the potential for introducing a higher degree of multicolinearity among these lagged market returns. This should be taken into consideration when one evaluates the parameter estimates of the model, which are reported in Table II.

To determine the improvement in fit from modeling the markets within a quadvariate framework, a number of specification tests are carried out. First, the significance of the results for the error-correction term in the mean equations of the returns series highlight the importance of accounting for cointegration within the model. It is significant at the 5% level for the two futures markets and the Nikkei 300 index, although it is not significant for the Australian cash index. One would expect this latter estimate to be significant, given that the presence of cointegration among the four financial markets has been established at the 5% level. A plausible explanation for this discrepancy is the presence of multicolinearity in the quadvariate simultaneous EC-ARCH model, which does not affect the earlier cointegration test results. However, to appreciate the importance of still including all of the cointegrative parameters, a logarithm of likelihood ratio test is carried out by examining the difference between the current model and by estimating the quadvariate simultaneous ARCH model—which does not have the error-correction terms in the mean equations. The estimated logarithm of likelihood function values for the restricted model (with 4 restrictions) is -9684.61, whereas the corresponding value for the unrestricted model is -9599.63, thus yielding a difference of 84.98. The critical value of a chi-square distribution with 4 degrees of freedom is 13.3767 at the 1% level of significance, and the estimated test statistic is 169.96, thus establishing that the cointegrative model is a better model and that failure to include the error-correction terms will result in model mis-specification bias and hence lead to inconsistent parameter estimates.

A similar test is also performed on the usefulness and inclusion of the squared error-correction terms in modeling the variance equations in the system, showing no better fit at the 5% level. This should, however, be expected, because none of the coefficients are significant, and most of the t-statistics are less than 1—which suggests that these coefficients can be omitted from the model as being irrelevant. Actually doing so changes the rest of the parameter results insignificantly.

TABLE II

Maximum Likelihood Estimates

Coefficient	Stock Index: *All-Ords (AOD)*	Stock Index: *Nikkei 300 (NC)*	Stock Index Futures: *SPI*	Stock Index Futures: *Nikkei 300 (NF)*				
Levels and Causality Among Returns								
ϕ_0 (constant)	−0.0965	−0.1093	−0.0928	−0.1095				
	(0.0943)	(0.1168)	(0.0926)	(0.1223)				
ϕ_1 ($R_{AOD,t-1}$)	−0.0592	−0.0256	0.2811[a]	0.0072				
	(0.0696)	(0.0729)	(0.0515)	(0.0778)				
ϕ_2 ($R_{SPI,t-1}$)	0.0735	−0.0794	−0.1504[a]	−0.0907				
	(0.0520)	(0.0852)	(0.0554)	(0.0845)				
ϕ_3 ($R_{NC,t-1}$)	0.1714[a]	−0.0559	0.1047[c]	0.2936[a]				
	(0.0633)	(0.0734)	(0.0598)	(0.0846)				
ϕ_4 ($R_{NF,t-1}$)	−0.1872[a]	0.2167[a]	−0.1427[b]	−0.0522				
	(0.0642)	(0.0832)	(0.0613)	(0.0844)				
ω_i ($Z_{i,t-1}$)	−0.0210	−0.1006[a]	−0.0561[b]	−0.1094[a]				
	(0.0249)	(0.0392)	(0.0219)	(0.0379)				
Variances and Volatility Spillovers					Covariances	α_{ij0} (constant)	α_{ij} ($\varepsilon_{i,t-1}\varepsilon_{j,t-1}$)	γ_{ij} ($Z_{i,t-1}\ Z_{j,t-1}$)
α_{i0} (constant)	6.2817[a]	7.7894[a]	4.1394[a]	8.1522[a]	*NC↔NF*	7.2501[a]	0.0073	−0.0076
	(0.1776)	(0.2037)	(0.1174)	(0.2576)		(0.2095)	(0.1076)	(0.0094)
α_{AOD} ($e^2_{AOD,t-1}$)	0.0155	−0.0048	0.0207	0.0028	*AOD↔SPI*	4.3060[a]	0.0778[a]	−0.0029
	(0.0122)	(0.0101)	(0.0186)	(0.0091)		(0.1300)	(0.0224)	(0.0037)
α_{SPI} ($\varepsilon^2_{SPI,t-1}$)	0.0670[a]	0.0182	0.0711[b]	−0.0113	*NC↔AOD*	3.3679[a]	0.0023	−0.0075
	(0.0119)	(0.0135)	(0.0286)	(0.0195)		(0.1375)	(0.0126)	(0.0089)
α_{NC} ($\varepsilon^2_{NC,t-1}$)	−0.0021	0.0192	−0.0169[c]	0.00269	*NC↔SPI*	3.5076[a]	−0.0033	0.0034
	(0.0140)	(0.0135)	(0.0099)	(0.0131)		(0.0971)	(0.0185)	(0.0677)
α_{NF} ($\varepsilon^2_{NF,t-1}$)	−0.0040	0.0337[a]	0.0291[a]	0.0172	*NF↔AOD*	3.7627[a]	0.0040	0.0082
	(0.0143)	(0.0166)	(0.0087)	(0.0183)		(0.1491)	(0.0146)	(0.0079)
γ_i ($Z^2_{i,t-1}$)	0.0045	0.0064	0.0048	0.0043	*NF↔SPI*	3.8947[a]	0.0297	−0.0083
	(0.0051)	(0.0085)	(0.0036)	(0.0098)		(0.1033)	(0.0228)	(0.0082)
Diagnotstics								
$Qx(21)^d$ $\varepsilon_{i,t}/\sqrt{h_{ii,t}}$	19.5	20.8	17.1	10.6				
$Qxx(21)^d$ $\varepsilon^2_{i,t}/h_{ii,t}$	8.1	10.9	7.8	12.1				

Notes: [a]indicates significance at the 1% level. [b]at the 5% level, and [c] at the 10% significance level. [d]$Qx(21)$ and $Qxx(21)$ are Ljung-Box test statistics for serial correlation of up to the 21st order in standardized residuals and squared standardized residuals respectively. The 5% critical value is 32.6705.

To establish further the importance of using a quadvariate simultaneous EC-ARCH model, EC-ARCH is compared to its bivariate counterpart, with no foreign spillover effects. Two bivariate simultaneous EC-ARCH models are estimated using the Australian and Japanese data, respectively. The estimated logarithm of likelihood function values for the Australian and Japanese bivariate models are -4908.62 and -4978.75, respectively. The sum of these two values is -9887.37, whereas the corresponding value for the quadvariate simultaneous EC-ARCH model is -9599.63, thus yielding a difference of 287.74. The number of parameters estimated in the quadvariate model is 66, and the total number of parameters estimated in the two bivariate models is 38 (19 parameters for each bivariate model), resulting in a difference of 28. The critical values for a chi-square distribution with 28 degrees of freedom are 37.9159, 41.3372, and 48.2782 for 10%, exhibiting 5% and 1% levels of significance, respectively. The estimated logarithm of likelihood ratio test statistic is 575.48 (twice that of 287.74) and is significant at the 1% level; hence the bivariate models have to be rejected in favour of the quadvariate model.

The empirical results reported in Table II are of interest to futures and spot traders in both countries. The results at the 5% significance level suggest that Australian traders should be concerned by developments in the Japanese cash and futures markets—although the same cannot be said for Japanese traders, where developments in the Australian markets are unimportant. Specifically, a market participant trading Nikkei 300 futures need only be concerned about the underlying Japanese cash market (0.2936), whereas a trader trading in the Nikkei 300 cash market has to be concerned about the Nikkei 300 futures market (0.2167) as well as the volatility spillover effect from this market (0.0337). Notably, Australian markets are far more susceptible to Japanese price movements. A SPI futures trader in Australia has to monitor the effects of the Australian stock market (0.2811) as well as the Japanese futures (-0.1427) and spot markets (0.1047), plus the volatility spillover effects from both the Japanese futures (0.0291) and spot markets (-0.0169).[15] The Australian spot trader is slightly better off than his futures counterpart, because he needs only to monitor the effects of the Japanese futures (-0.1872) and spot markets (0.1714) plus the volatility spillover effect from the local futures market (0.0670). Hence these empirical results suggest traders in the Japanese markets need not worry about the impact of and volatility

[15]This negative value indicates that a possible dampening effect arises within the market from periods of high volatility within the Japanese futures market. This phenomenon may be a result of Australian traders' being unsure of how to interpret information disseminated from the Japanese market.

spillover from the Australian markets. For these purposes, the Australian markets reveal little new information that is utilized in setting Japanese prices. This is in direct contrast to traders in the Australian markets, in which changes in the Japanese markets do have a significant effect on both local cash and futures trading. For smaller markets, such as that of Australia, the importance of these results suggests a potential heavy weighting should be given to external (foreign) markets, even when trying to examine a relationship between only local stock index and futures markets.

From a modeling perspective, the results suggest that a simple bivariate model would be adequate for modeling futures and spot market relationships for cases wherein these same markets are large and show little impact from other financial markets—such as the negligible impact the Australian markets have upon Japanese markets. However, for smaller markets and markets in an integrated global financial environment, models that account for foreign effects will outperform their bivariate counterpart. Furthermore, given that mostly all financial markets are globally integrated to some degree, one would therefore also expect them to be cointegrated. If one were not to include this component, model misspecification bias will be induced in the parameter estimates, potentially leading to wrong conclusions on local spot–futures interaction in which these markets are internationally integrated.

The results in Table II are not inconsistent with previous studies on spot–futures market relationships, despite particular differences that appear when examining the size of the parameter coefficients for the mean return equations. For instance, although lagged returns from local futures markets play a larger role in explaining contemporaneous local cash returns, lagged returns from local cash markets also play a larger role in explaining contemporaneous local futures returns. Hence there is evidence of bidirectional causality in market returns. However, in the case of Australia, the Japanese markets also have a far more dominant effect than either the local cash and futures market do. For Australian traders, this may suggest that the Australian futures market is a weak vehicle relative to the Japanese futures market in the price discovery process.

The results also suggest, as a number of previous studies have also indicated, that volatility spillovers are unidirectional from the futures markets to the cash markets. Hence there exists an unique set of information that is inherent in futures prices, and this set of information is transmitted to the cash market from the futures market. Because volatility is a measure of uncertainty, it may be the case that traders use the futures market to discover the new equilibrium price of assets when a significant event occurs. Whereas the mean of this new equilibrium price may be reflected quickly in contemporaneous prices in financial markets, the variations in traders' perceptions may persist over time. From the empirical results, one can hypothesize that these traders' perceptions are formed in the futures markets, perhaps due to cheaper transaction costs and ease of trading, and later conveyed to the underlying cash markets. This results in volatility spillovers from the futures markets to their underlying cash markets, but not vice versa. For the Australian markets, the sequence of volatility spillovers may well first originate from a Japanese futures volatility spillover effect to the Australian futures market, and then a local volatility spillover effect from the Australian futures market to the Australian cash market.

To provide a further analysis of this time-varying relationship that the Australian and Japanese markets have with one another, a decomposition of the conditional variances is provided in Table III. The conditional variance of return $i(v_{i,t})$ is decomposed into the sum of the explained conditional variances attributed to the explanatory variables and the conditional error residual variance $(h_{i,t})$. To illustrate, let

$$v_{i,t} = \sum_{j=1}^{4} \phi_{ij}^2 v_{j,t-1} + h_{i,t} \text{ (for } i = 1,2,3,4) \tag{7}$$

then the contribution of the lagged conditional variance of each explanatory variable $(v_{j,t-1})$ to $v_{i,t}$ is defined as:

$$w_{ij,t} = \frac{\phi_{ij}^2 v_{j,t-1}}{v_{i,t}}. \tag{8}$$

These results help to illustrate further the primary importance of foreign futures markets over foreign cash markets in affecting home market conditional variations. From the variance-decomposition results, the Australian SPI futures trader, on average, can only account for 11.5593% of price variation if he focuses only on local effects and misses out on the 4.5212% (28% of average explained variance) in variance due to the Japanese cash and futures markets. On the other hand, a Japanese Nikkei 300 futures trader will on average miss out on only 1.2019% (13% of average explained variance) in variance—which is due to the effects of the Australian cash and futures markets. The difference is even greater for cash traders. In the case of the Australian cash trader, 8.4629% (89% of average explained variance) in variance is due to Japanese effects, whereas for the Japanese cash trader 0.7302% (11.5% of average explained variance) in variance is due to Australian effects. It would seem

TABLE III

Time-Varying Decomposition of Conditional Variances (Percentage Based)

Relative Variation		*Explained by lagged variations in:* *Stock Index*		*Stock Index Futures*				
from:		*NC*	*AOD*	*NF*	*SPI*			
Stock Index						Residuals	*NC*	*AOD*
NC	mean	0.3225	0.0558	5.3087	0.6744	mean	93.6386	90.5036
	s.d.	0.1147	0.0190	1.7606	1.3557	s.d.	2.9513	4.0923
	max.	3.0929	0.3178	42.5917	26.5082	max.	100.0000	100.0000
AOD	mean	3.6640	0.3581	4.7989	0.6755			
	s.d.	1.4815	0.1497	1.9019	1.2470			
	max.	37.3768	3.9941	48.7337	25.3305			
Stock Index Futures						Residuals	*NF*	*SPI*
NF	mean	8.0265	0.4090	0.2789	0.7929	mean	90.4927	83.9177
	s.d.	2.2681	0.1287	0.0761	1.5863	s.d.	3.2600	5.6744
	max.	58.5165	2.2870	1.7018	32.1024	max.	100.0000	100.0000
SPI	mean	1.4942	8.7196	3.0270	2.8397			
	s.d.	0.5382	2.6268	1.0084	3.7552			
	max.	9.2546	20.2202	15.8758	56.2169			

Notes: All minimum values are zero. *AOD* = All-Ords. *NC* = Nikkei 300 cash. *NF* = Nikkei 300 futures.

that by the time information has flowed down to the Australian cash market, a reasonable percentage of the resultant movement can be explained via the effect of foreign market behavior, separate to its own futures market. Subsequently, when one examines the time-varying decomposition of the conditional variances, these results have the strongest implications for the Australian cash trader, followed by the Australian futures trader. Ignoring foreign market behavior can severely limit accurate risk measures of an Australian trader. For the Japanese market, there seems to be little impact from the Australian financial markets—and this would preclude Japanese traders from having to worry about price movements in these markets.

SUMMARY AND CONCLUSION

This study shows that, for markets that are exposed to global financial interaction, a large part of a domestic spot–futures relationship can be determined by foreign market behavior. This will be particularly true for smaller markets that are more heavily dependent upon larger foreign financial centers. For traders active in these markets, significant benefits can arise from analyzing pricing behavior in foreign markets so that they might improve their risk perceptions following changes in these foreign markets. To assume that spot–futures relationships can be explained entirely by their own local market behavior will furthermore limit severely the ability of calculating correct risk adjustments and trading strategies employed by traders. This is shown to be particularly true for futures traders.

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