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Cross Country Mean and Volatility Spillover Effects of Food Prices: Evidence for Asia and Pacific

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This paper examines cross country mean and volatility spillover effects of food prices across selected Asian and Pacific countries namely Australia, New Zealand, South Korea, Singapore, Hong Kong, Taiwan, India and Thailand. The principal method of analysis is a set of component GARCH-type models of conditional variance. Mean and volatility spillover effects of food prices are examined across a full (1995-2010) sample and two subsamples (1995-2001 and 2002-2010), using daily food price indices. Main findings of the study are as follows: (1) there is no strong evidence of cross country mean spillover effects of food prices across all samples, (2) the recent subsample of sharp rise of food prices shows more evidence of mean spillover effects than the early subsample, (3) evidence of volatility spillover effects is stronger than mean spillover effects, (4) mixed evidence of volatility spillover effects is reported and (5) no exact direction of spillover effects between exporters and importers is evident; rather mixed evidence of spillover from exporter to importer, exporter to exporter, importer to exporter and geographical proximity can be documented.

Keywords: Food Prices, mean, volatility, Spillover, CGARCH Modelling

1. Introduction

Concern over the degree of commodity price fluctuations or volatility has attracted increasing attention in recent economic and financial literature and has been recognised as one of the more important economic phenomena in recent years (Engle, 1982). The importance of understanding commodity price movement is now well documented. For example, Pindyck (2004) pointed out that changes in commodity prices can influence the total cost of production as well as the opportunity cost of producing commodities currently rather than later. Apergis and Rezitis (2003a) noted down that price volatility leads both producers and consumers to uncertainty and risk and thus volatility of commodity prices has been studied to a certain extent. In the same line, It has also been argued that price volatility reduces welfare and competition by increasing consumer search costs (Zheng et al., 2008). It is believed that price returns spill over and it is well documented in the literature of financial economics especially in terms of asset prices. However, food price volatility using daily food price indices in the fashion of financial assets is still an area in which little empirical attention

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has been paid. Since food prices are getting popular positions in the portfolio of fund managers of food futures and options, it appears worthwhile to devote effort to examine spillover effects of food prices with extended GARCH models particularly with Component GARCH (CGARCH) models in the context of some countries of Asia and Pacific namely Australia, New Zealand, South Korea, Singapore, Hong Kong, Taiwan, India and Thailand. Hence, the objective of this paper is to assess cross country mean and volatility spillover effects of food price returns, expecting to add to the scarce literature on food price volatility.

The next section of the paper provides an overview of relevant literature; section 3 delineates food export and import scenarios of countries covered by the study; section 4 discusses the data used for our analysis; the methodology used to carry out the analysis is provided in section 5; empirical findings of the study along with discussions are presented in section 6, whereas section 7 of the paper summarises the main results of the study and draws relevant conclusions with limitation of the study.

2. Literature Review

Commodity prices in general are volatile and in particular agricultural commodity prices are renowned for their continuously volatile nature (Newbery, 1989) and also deserve much attention from policymakers. Kroner et al. (1993) reported that commodity prices are one of the most volatile of all international prices. It has been emphasized that continuous volatility causes concern for governments, traders, producers and consumers. Large fluctuations in prices can have a destabilizing effect on the real exchange rates of countries and a prolonged volatile environment makes it difficult to extract exact price signals from the market which leads to inefficient allocation of resources and also volatility can attract speculative activities (FAO Food Outlook, November 2007). There is no consensus whether agricultural commodity price volatility increased over time or not, for example, Gilbert and Morgan (2010) have shown that recent food price volatility is not the highest rather in the past volatility was even higher.

Historic food prices show significant ups and down. A large body of studies exist to document the causes and consequences of food price booms. The recent food price spike was explained from different angles such as supply shocks (Hossain, 2007; ESCAP, 2008), demand shock (OECD, 2008), oil and metal price hike (Radetzki, 2006; Heady and Fan, 2008; Xiadong et al., 2009), chronic depreciation of US dollars against major currencies (Heady and Fan, 2008; Abbott et al., 2009) and increased demand for bio-fuel (Heady and Fan, 2008; Rosegrant et al., 2008; Mitchell, 2008). Along with these mainstream macroeconomic factors, the index based agricultural futures market attracted much attention for being one of the factors of the food price boom (Robles et al., 2009; Gilbert, 2010). Gilbert (2010) pin-pointed that the agricultural futures market is one of the major channels through which macroeconomic and monetary factors created the 2007-08 food price rises. Food commodity price futures are also gaining popularity like other financial funds. From 2005 to 2006, the average monthly volumes of futures for wheat and maize grew by more than 60 percent and those for rice by 40 percent (Robles et al., 2009).

Volatility modelling is popular in financial economics. Financial variables such as stock price, interest rate and exchange rates are being modelled frequently by using financial econometrics models especially ARCH classes of models (Blair et al., 2001; Dewachter 1996; Maneschiold 2004; Wei C., 2009). Recently energy prices have also been studied using the technique of Financial Econometrics, for example, Regnier (2007) has shown that the common view regarding energy price volatility is true. That is, testing a long span of data, it has been shown that energy prices are more volatile than other commodity prices. Narayan and Narayan (2007) have documented mixed evidence concerning oil price shocks' volatility. However, only a few studies are available in the field of commodity price volatility in general and food price volatility modelling in particular. Valadkhani et al. (2005) studied Australia's export price volatility by using ARCH-GARCH models and provided evidence that Australia's export prices vary with world prices significantly.

Mean and volatility spillover effects were studied in a considerable extent in the field of finance (Ng, 2000; Christiansen, 2007). Not many studies on spillover effects in general and on cross country spillovers in particular are available in the literature. Apergis and Rezitis (2003a) examined volatility spillover effects from macroeconomic fundamentals to relative food price volatility in Greece by using GARCH models. They reported that the volatility of relative food prices shows a positive and significant impact on its own volatility in the case of Greece. In another paper (2003b) using similar GARCH models, they pointed out that agricultural input and retail food prices exert positive and significant effects on the volatility of agricultural output prices and also output prices have significant positive effects on its own volatility in Greece. Shaun (2010) reported low frequency volatility such as U.S inflation and exchange rate as two of the determinants of rising food price volatility since 1990s with a framework of spline-GARCH models with monthly food commodity data. Price volatility spillover effects in US catfish markets have been studied by Buguk et al. (2003). They used univariate EGARCH models to check volatility spillover and provided evidence of volatility spillovers in agricultural markets. Zheng and colleagues (2008) studied time varying volatility of US food consumer prices using Exponential G However, till date low attention has been paid for studying food price returns in the fashion of financial assets.

However, as stated earlier, to date not many studies have focused on the cross country spillover effects of food prices, especially in the Asia-pacific region. Therefore, it is worthwhile to investigate the spillover effects of food prices under the framework of component generalized autoregressive conditional heteroskedasticity (CGARCH) family models in the context of the countries covered by the study.

3. Food Export-Import Status

We selected 8 different countries of Asia and Pacific based on food import and export criteria. Australia, New Zealand, Thailand and India are major food exporters while South Korea, Singapore, Hong Kong and Taiwan are net food importers and there exists considerable economic integration among them. As of 2008-09, top four food export items of Australia include meat, grains, dairy products and wine. Korea, Taiwan, Singapore and Hong Kong ranked third, fifth, sixth and seventh export destination of Australia respectively for meat export. Major food exporter countries also possesses on the top list except India. New Zealand and Thailand ranked as eighteenth and twenty seventh. As cereal export destination of Australia except Hong Kong all other countries are among top twenty five countries. For dairy and poultry products also these countries are among the top export destinations of Australia. Meat, fish and dairy products are on the top of New Zealand food export items for 2009. For all these products Australia, Korea, Singapore, Taiwan, Hong Kong are among the major trade partners including Thailand and India among minor partners. Hong Kong, Singapore, Australia and Taiwan are among the major rice export partners of Thailand. Korea, Singapore, Hong Kong and Taiwan are among the top fish export partners of Thailand. India also has considerable trade relationship with these countries regarding export of food items such as dairy products, fruits, vegetables and cereals. Export import statistics of these countries support that there is strong trade relationship of agricultural products among these countries.

Furthermore, countries considered here are also member of some regional and trade associations. ASEAN-Australia-New Zealand free trade agreement (FTA) went into operation from 1 January 2010. An FTA between Australia and Thailand went into force in January 2005, FTA between Australia and Singapore has already been signed. A negotiation of Australia-India FTA is going on. Singapore-New Zealand and Thailand-New Zealand FTAs went into force in 2001 and 2005 respectively. An FTA between India and Thailand has been signed in 2004 (Park, 2009).

4. Data and their Statistical Properties

We use 4000 daily observations of food producers' price indices for Australia, New Zealand, South Korea, Singapore, Hong Kong, Taiwan, India and Thailand provided by DataStream Advance for the period 2 January 1995 to 30 April 2010. Returns of food prices for every variable are computed by using standard continuously computed logarithm technique as follows where P_t is the daily price of current time t:

$$R_t = \ln(\frac{P_t}{P_{t-1}}) \qquad (1)$$

Table 1 displays summary statistics for each series. Large unconditional standard deviations of each series indicate high volatility of food prices, although the unconditional standard deviations for each return series show that net food importing countries returns are more volatile than those for net food exporting countries which asserts that net food importing countries are largely affected by food price changes (Braun, 2008). For the price series, only New Zealand data show negative skewness implying the distribution has a long left tail, whereas all other series have positive skewness implying long right tails. On the other hand, the world, Australia and Korean series show negative skewness meaning long left tails while other returns series show long right tails. The values of Kurtosis for all series are high (close to 3 or higher) except the price series of New Zealand, Korea and Singapore, implying that distributions are relatively peaked rather than normal. The Jarque-Bera tests reject the null hypothesis of normality at 1 and 5 percent levels of significance. In support of J-B test, we also plot theoretical Quantile-Quantile as shown in Figures 3 and 4. None of the plots exhibit good fit of the distribution of observations. The graphs show that both positive and negative large shocks create non-normal distribution of the series for both price and returns. Hence, the samples appropriately contain financial characteristics such as volatility clustering, long tails and leptokurtosis.

In addition to the above, unit root tests results are also presented in Table 1. In levels, all the food price series appear non-stationary, however, they appear stationary in first differences, implying all series are integrated of order 1, denoted I (1). This suggests using the returns for estimating the GARCH models for examining conditional volatility over the time period selected. Figures 1 and 2 show the plots of food prices and their returns. In the returns graphs, it is clearly visible that there is evidence of volatility clustering for the return series of all individual countries. Figure 1 shows that since 2002 there was a sharp rises in food prices (Mitchell, 2008) of each country and therefore we divide total time period into two subsamples ranging from 1995 to 2001 and 2002 to 2010 for the purpose of estimation. By dividing into two subsamples we can distinguish whether there is any significant difference between high rise and non-high rise period of food prices.

Table 1: Statistical Properties of Data

Prices	AUSFP	NZFP	KORFP	SINFP	HKFP	TWNFP	INFP	THFP
Mean	976.7134	451.266	385.7578	474.174	168.941	284.359	1078.308	550.576
Median	895.3350	483.450	333.6900	418.970	116.650	234.690	899.3050	561.640
Maximum	1905.49	744.57	871.13	1007.11	625.34	695.64	2989.23	1190.86
Minimum	477.210	206.460	124.310	117.190	33.390	116.250	254.140	176.560
Std. Dev.	363.048	129.657	180.137	218.316	132.946	135.559	630.132	171.329
Skewness	0.63647	-0.24493	0.59562	0.52627	1.46040	0.86664	0.83363	0.37046
Kurtosis	2.31378	1.86426	2.09315	1.98832	4.45968	2.67396	2.95978	3.35085
J-B	348.547	254.978	373.571	355.224	1776.97	518.426	463.562	112.012
Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADFL (prob)	0.5574	0.4467	0.5817	0.8510	0.9998	0.5963	0.9843	0.9667
ADFFD(prob)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Obs.	4000	4000	4000	4000	4000	4000	4000	4000
Returns	RAUSFP	RNZFP	RKORFP	RSINFP	RHKFP	RTWNFP	RINFP	RTHFP
Mean	0.00015	-6.78E-06	0.000261	0.00012	0.00045	0.00021	0.00045	0.00017
Median	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Maximum	0.10508	0.21383	0.12514	0.15767	0.15568	0.15838	0.13291	0.16875
Minimum	-0.11389	-0.19674	-0.14811	-0.13523	-0.15054	-0.08981	-0.08622	-0.15808
Std. Dev.	0.01230	0.01603	0.02322	0.01932	0.02093	0.02257	0.01565	0.01861
Skewness	-0.045	0.078	-0.069	0.254	0.113	0.111	0.393	0.023
Kurtosis	11.0713	23.4145	7.71010	9.48634	9.26574	5.00237	8.14859	11.8719
J-B	10856.4	69445.3	3699.7	7053.6	6550.1	676.3	4520.2	13115.6
Prob.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
ADFL (prob)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Obs.	3999	3999	3999	3999	3999	3999	3999	3999

Figure 1: Daily food price indices 1995-2010

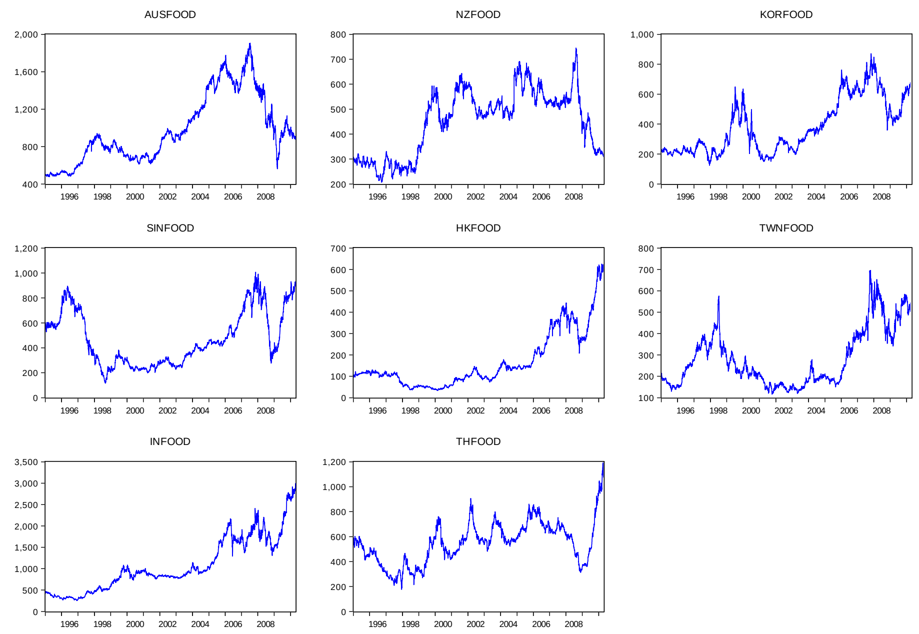


Figure 2: Daily food price returns 1995-2010

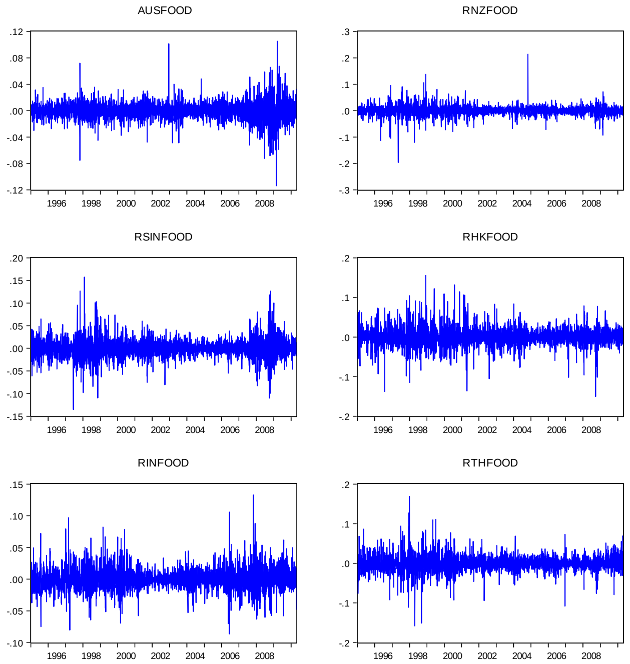


Figure 3: Theoretical Quantile- quantile plot for food prices 1995-2010

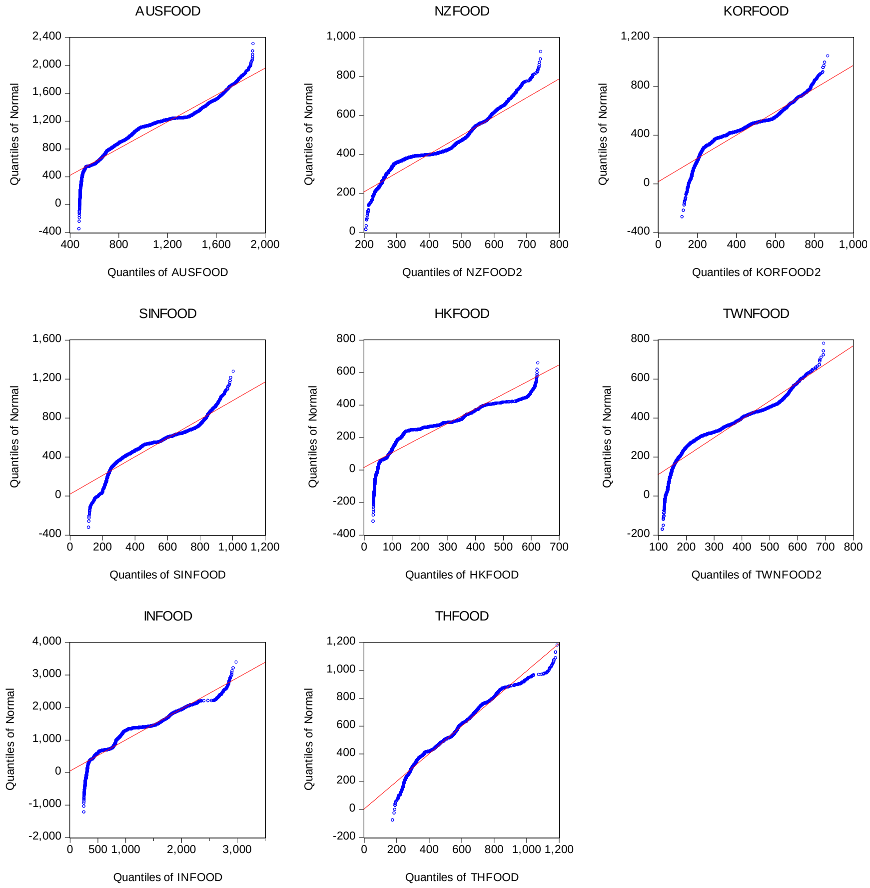
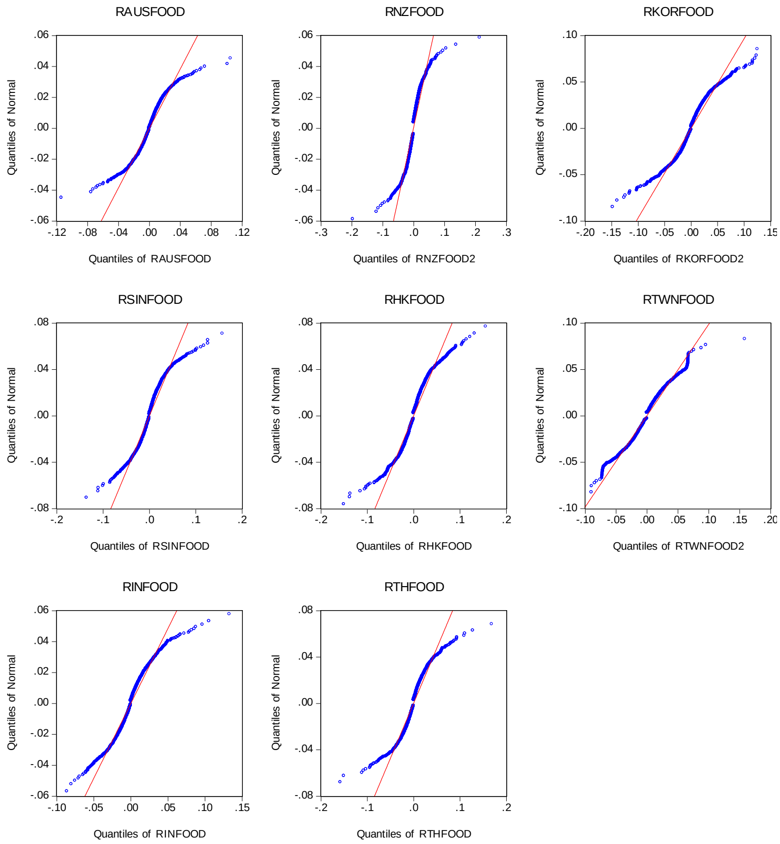


Figure 4: Theoretical Quantile-Quantile plot for food price returns 1995-2010



5. Methodology

Autoregressive Conditional Heteroskedasticity (ARCH) model developed by Engle (1982) and later generalised by Bollerslev (1986) are very popular in analysing financial characteristics of time series data. ARCH/GARCH models got momentum to grow in different dimensions not only for magnitudes but also on the directions to better capture the financial characteristics of assets (Engle, 2001). One of these extended versions of GARCH family models is the Component GARCH (CGARCH) model developed by Engle and Lee (1993). We use this variant of GARCH model in this study due to its superior performance in different aspects. According to Black and McMillan (2004), the CGARCH model decomposes conditional variances into a long run time varying trend component and a short run transitory component, which reverts to the trend following a shock. This model has superiority in terms of capturing both long and short run properties of time series. Christoffersen and colleagues (2008) mention “The component model’s superior performance is partly due to its improved ability to model the smirk and the path of spot volatility, but its most distinctive feature is its ability to model the volatility term structure.”

In component GARCH (CGARCH) models, the constant conditional variance condition of GARCH (1, 1) model is replaced with a time varying component 'q' to capture long run volatility. In general the ARMA (1, 1)-CGARCH (1, 1) model may be written in the following form:

Mean equation:

$$R_t = \beta_1 + \beta_2 R_{t-1} + \beta_3 e_{t-1} + \varepsilon_t \tag{2}$$

$$\varepsilon_t \sim iid(0, h_t)$$

Variance equations:

$$\begin{aligned} q_t &= \gamma_0 + \gamma_1 (q_{t-1} - \gamma_0) + \gamma_2 (e_{t-1}^2 - h_{t-1}) \\ h_t &= q_t + \gamma_3 (e_{t-1}^2 - q_{t-1}) + \gamma_4 (h_{t-1} - q_{t-1}) \end{aligned} \tag{3}$$

Where q_t is the *permanent* component, $(e_{t-1}^2 - h_{t-1})$ serves as the driving force for the time dependent movement of the *permanent* component and $(h_{t-1} - q_{t-1})$ represents the *transitory* component of the conditional variance. The sum of parameters γ_3 and γ_4 measures the *transitory* shock persistence and γ_1 measures the long run persistence derived from the shock to a permanent component given by γ_2.

The objective of this study is to examine whether past information regarding the mean return in one food market affects other markets' current mean return or not, and similarly past information of volatility in one market affects other markets' current volatility or not. The second portion reveals information regarding the 'heat waves' or 'meteor shower' effects of Engle et al. (1990). If the current volatility of one food market, for example Australian food market, is not influenced by past volatilities of other markets, for example New Zealand, South Korea, Singapore, Hong Kong, Taiwan, India and Thailand, we can say that volatility in Australian food market takes an independent path and this is termed as 'heat wave' effects. On the other hand, if current volatility of one market is influenced by any past volatility of other markets we say that volatility is interdependent or spills over from one market to another and this notion is termed 'meteor shower' effects. To evaluate 'heat wave' and 'meteor shower' effects following methods are followed.

In fact, the models are estimated in two steps. For the first step, we model each food price return series through an ARMA-CGARCH-M (1,1) model with equations 2 and 3. In the second step of estimation, in order to check mean and volatility spillover we compute standard deviation and conditional variance series from step 1 and incorporate them into appropriate mean and variance equations. More specifically, in line with the ideas of Engle et al. (1990), Baillie et al. (1993), Liu and Pan (1997), Lin and Tamvakis (2001), and Hammoudeh et al. (2003) we include conditional standard deviations derived for each variable from the first step into the mean equations of appropriate series to check mean spill over effects and insert conditional variances into the variance equations to assess volatility spillover effects form one food market to another. In particular, the following equations for checking mean spillover effects are estimated:

Mean Equation:

$$R_{i,t} = \beta_1 + \beta_2 R_{i,t-1} + \beta_3 e_{i,t-1} + \beta_4 \hat{h}_{j,t} + \varepsilon_{i,t} \tag{4}$$

$$\varepsilon_t \sim iid(0, h_t)$$

Variance Equations:

$$\begin{aligned} q_{i,t} &= \gamma_0 + \gamma_1 (q_{i,t-1} - \gamma_0) + \gamma_2 (e^2_{i,t-1} - h^2_{i,t-1}) \\ h^2_{i,t} &= q_t + \gamma_3 (e^2_{i,t-1} - q_{i,t-1}) + \gamma_4 (h^2_{i,t-1} - q_{i,t-1}) \end{aligned} \tag{5}$$

where i represents series 1 to 8 for 8 individual countries. In order to examine long run volatility spillover effects we put estimated conditional variances in the permanent component of the variance equations and hence we estimate the following ARMA-CGARCH (1, 1) model:

Mean Equation:

$$R_{i,t} = \beta_1 + \beta_2 R_{i,t-1} + \beta_3 e_{i,t-1} + \varepsilon_{i,t} \tag{6}$$

$$\varepsilon_t \sim iid(0, h_t)$$

Variance Equations:

$$\begin{aligned} q_{i,t} &= \gamma_0 + \gamma_1 (q_{i,t-1} - \gamma_0) + \gamma_2 (e^2_{i,t-1} - h^2_{i,t-1}) + \gamma_j \hat{h}^2_{j,t-1} \\ h^2_{i,t} &= q_{i,t} + \gamma_3 (e^2_{i,t-1} - q_{i,t-1}) + \gamma_4 (h^2_{i,t} - q_{i,t-1}) \end{aligned} \tag{7}$$

Where i represents number of return series of 8 countries, j stands for the number of computed conditional variance series for 7 countries except the one under estimation. Appropriate lag orders for ARMA were set by Box-Jenkins (1976) methods in each case and models are selected based on the lowest AIC, highest adjusted R squared and maximum log likelihood values. The parameters of each model are estimated via maximum likelihood methods. To avoid possible violations of normally distributed error term assumption, all models are estimated assuming generalised error distributions (GED).

Following Engle et al. (1990) and Baillie (1993) we compute robust Wald tests from each ARMA-CGARCH model to examine mean and volatility spill over effects across different countries covered by the study.

6. Empirical Results and Discussion

Table 2 exhibits robust Wald tests for mean spillover effects for the combined sample period of 1995 to 2010. The tests fail to find evidence of mean spillover effects for Korea, Hong Kong, Taiwan and Thailand food price return series. Mean returns of these countries are not systematically influenced even by their own lags. In the case of Australia, New Zealand, Singapore and India some evidence of cross country mean spillover is identified. Australian mean returns of food prices are influenced by New Zealand and India. New Zealand food prices are found to be influenced more significantly by other countries food price returns and mean spillover effects are detected from Australia, Korea and Singapore. Singapore food price returns in mean are found to be influenced by New Zealand and Korea and in both cases coefficients are statistically significant at 5% level of significance while Indian food price mean returns are found to be influenced by Singapore food price returns though the coefficient is statistically significant only at 10% level of significance.

Table 3 shows robust Wald test statistics for volatility spillover effects across countries for the period 1995 to 2010. Except for Taiwan, all variance series for food price returns are found to be interdependent because parameters measuring volatility spillover effects are found to be statistically significant in most cases. There are considerable volatility spillover effects from India and Thailand to Australian food price returns. In the case of New Zealand, strong volatility spillover effects are identified from all other countries except Taiwan. Korean food price returns take a relatively independent way of volatility though there is a little evidence of volatility spillover from Singapore food price returns. Volatility in Singapore food price returns are found to be influenced by Australia, Hong Kong and Thailand. Hong Kong food price returns are volatile due to its own shocks as well as shocks from its regional countries i.e. Korea, Singapore and Taiwan. There are statistically significant volatility spillover effects from Australia, Singapore, Hong Kong, Taiwan and Thailand food price returns to Indian food price returns. In the case of Thailand, volatility spillover effect is found to be statistically significant only from Korea. No other countries' food price returns affect volatility of Thai food returns to a measurable extent.

Table 4 displays robust Wald tests for mean spill over effects for the early subsample period of 1995 to 2001. None of the series shows any statistically significant evidence of mean spill over effects from one country's food price returns to another country with only one exception, the New Zealand food price return series. New Zealand mean returns series are influenced by all other countries' food price return's conditional standard deviation.

Table 2: Robust Wald tests for mean spillover effects for the full sample period 1995-2010

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
$h_{(t-1)}$AUS	2.048	10.235[a]	0.560	1.535	0.071	0.065	1.401	0.030
$h_{(t-1)}$NZ	3.525[c]	23.379[a]	0.015	5.332[b]	0.011	0.007	0.196	0.416
$h_{(t-1)}$KOR	0.816	25.10[a]	2.411	4.157[b]	0.003	0.440	0.095	0.015
$h_{(t-1)}$SIN	0.594	5.575[b]	1.031	0.313	0.002	0.032	2.843[c]	0.011
$h_{(t-1)}$HK	0.576	1.125	0.101	6.10E05	0.002	0.436	0.236	0.008
$h_{(t-1)}$TWN	0.153	0.062	0.131	0.460	9.15E-05	0.943	0.398	0.006
$h_{(t-1)}$IN	7.327[a]	0.313	0.273	1.217	2.93E-05	0.538	0.250	0.119
$h_{(t-1)}$TH	0.168	0.164	1.998	2.562	0.000	0.229	0.060	0.016
$\sum_j h_{j(t-1)}$	15.068[c]	46.351[a]	6.656	22.127[a]	0.134	2.606	4.213	0.592

Note: [a], [b] and [c] indicate significance at 1%, 5% and 10% level respectively.

Table 3: Robust Wald tests for volatility spillover effects for the full sample period 1995-2010

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
$h^2_{(t-1)}$AUS	-	111.399[a]	0.416	4.795[a]	0.859	0.167	4.814[b]	2.123
$h^2_{(t-1)}$NZ	0.004	-	0.187	1.306	0.298	0.160	0.011	0.744
$h^2_{(t-1)}$KOR	0.249	19.231[a]	-	0.449	6.572[b]	0.448	0.353	8.164[a]
$h^2_{(t-1)}$SIN	2.195	2.845[c]	3.545[c]	-	2.812[c]	0.329	5.281[b]	1.789
$h^2_{(t-1)}$HK	2.347	17.869[a]	1.95E-05	3.205[c]	-	0.691	3.870[b]	2.249
$h^2_{(t-1)}$TWN	2.282	1.330	0.503	0.087	5.429[b]	-	3.270[c]	0574
$h^2_{(t-1)}$IN	5.662[b]	9.035[a]	0.021	0.084	0.200	1.000	-	2.532
$h^2_{(t-1)}$TH	4.753[b]	12.391[a]	0.060	3.211[c]	1.053	1.316	4.218[b]	-
$\sum_j h^2_{j(t-1)}$	14.879[c]	166.401[a]	5.113	8.597	16.298[a]	3.485	23.922[a]	10.096

Note: [a], [b] and [c] indicate significance at 1%, 5% and 10% level respectively.

Table 4: Robust Wald tests for mean spill over effects for the sample period 1995-2001

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
$h_{(t-1)}$AUS	0.187	51044.27[a]	0.040	0.580	0.482	0.744	0.013	0.034
$h_{(t-1)}$NZ	0.006	7734.5[a]	0.204	0.472	0.442	1.106	0.151	0.294
$h_{(t-1)}$KOR	0.240	21276.26[a]	2.588	0.070	0.023	0.037	0.011	0.040
$h_{(t-1)}$SIN	0.001	483.752[a]	0.686	0.048	0.002	0.033	0.612	0.002
$h_{(t-1)}$HK	0.155	1216.483[a]	0.016	0.125	0.015	1.086	0.031	0.006
$h_{(t-1)}$TWN	0.226	236.021[a]	0.189	0.037	0.003	0.112	0.389	0.092
$h_{(t-1)}$IN	0.732	381.118[a]	0.046	0.495	0.005	0.041	0.169	0.009
$h_{(t-1)}$TH	0.922	87.913[a]	2.601	2.437	0.000	0.439	0.002	0.001
$\sum_j h_{j(t-1)}$	2.470	479489[a]	4.878	4.876	2.335	4.647	1.237	0.341

Note: [a], [b] and [c] indicate significance at 1%, 5% and 10% level respectively.

Table 5 shows Wald test statistics for volatility spillover for the period 1995 to 2001. Excepting Singapore all other countries food price returns show some evidence of volatility spillovers. Food price return volatility spillover is found to be statistically significant from New Zealand, Singapore, Hong Kong and Taiwan to Australia, from Australia, Korea, Singapore, Taiwan, India and Thailand to New Zealand. Food price return volatility from Australia to Korea, form Korea to Hong Kong and from Thailand to Taiwan is also found to be statistically significant though the level of significance is at only 10%. Indian food price return volatility is rather influenced by regional countries food prices e.g. Korea, Taiwan and Thailand. There is statistically significant food price return volatility spillover effects from New Zealand, Singapore, Taiwan and India to Thailand.

Table 5: Robust Wald tests for volatility spillover effects for the sample period 1995-2001

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
$h^2_{(t-1)}$AUS	-	69.755[a]	3.001[c]	2.458	0.182	0.088	0.259	0.178
$h^2_{(t-1)}$NZ	14.632[a]	-	0.002	0.182	1.503	0.129	0.252	3.345[c]
$h^2_{(t-1)}$KOR	1.629	13.596[a]	-	0.753	2.887[c]	0.096	5.242[b]	0.096
$h^2_{(t-1)}$SIN	3.286[c]	73.905[a]	0.039	-	0.338	1.740	0.018	6.764[a]
$h^2_{(t-1)}$HK	5.710[b]	1.316	0.136	0.946	-	0.669	0.472	0.120
$h^2_{(t-1)}$TWN	7.879[a]	41.308[a]	0.000	0.453	2.039	-	4.607[b]	2.702[c]
$h^2_{(t-1)}$IN	0.110	6.396[b]	0.120	0.406	0.028	0.755	-	4.143[b]
$h^2_{(t-1)}$TH	2.011	60.247[a]	0.062	0.550	0.000	2.850[c]	2.869[c]	-
$\sum_j h^2_{j(t-1)}$	59.758[a]	597.219[a]	4.046	4.952	6.921	3.962	8.645	14.883[c]

Note: [a], [b] and [c] indicate significance at 1%, 5% and 10% level respectively.

Table 6 presents results of robust Wald tests for mean spillover for the recent period of 2002 to 2010. Very much different results are found for this latest subsample or for the period of sharp increase of food commodity prices. Except for New Zealand all countries show some evidence of mean spillover effects. Food price return mean spillover effect is found to be statistically significant from India to Australia, from Singapore to Korea, from Taiwan to Singapore, from Australia and Singapore to Hong Kong, from Korea to Taiwan, from Singapore to India and from India to Thailand.

Table 6: Robust Wald tests for mean spillover effects for the sample period 2002-2010

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
$h_{(t-1)}$AUS	0.002	0.593	2.295	0.000	5.332[b]	0.196	0.279	0.005
$h_{(t-1)}$NZ	0.236	0.389	0.062	2.110	0.659	0.001	0.002	0.506
$h_{(t-1)}$KOR	0.254	0.630	2.940[c]	2.177	0.040	3.906[b]	0.221	1.565
$h_{(t-1)}$SIN	1.012	0.136	7.580[a]	0.099	10.618[a]	2.542	3.860[b]	1.058
$h_{(t-1)}$HK	1.837	1.038	0.654	1.528	3.384[c]	0.629	0.536	0.213
$h_{(t-1)}$TWN	0.190	1.956	1.880	2.922[c]	3.120[c]	1.164	0.710	0.045
$h_{(t-1)}$IN	5.653[b]	0.278	0.010	0.097	0.700	0.974	0.297	3.273[c]
$h_{(t-1)}$TH	0.950	1.408	0.062	0.307	3.708	0.220	0.080	0.034
$\sum_j h_{j(t-1)}$	12.186	5.755	15.355[c]	9.181	20.477[a]	8.250	6.989	7.065

Note: [a], [b] and [c] indicate significance at 1%, 5% and 10% level respectively.

Table 7 exhibits results of robust Wald test statistics for the volatility spillover effects of food price returns for the period 2002 to 2010. In this sharp volatile period, Singapore and Thailand food prices take independent ways to move. There is no evidence of return volatility spillover effects from other countries to these two countries. Australian food price return volatility is affected by Singapore, Taiwan and Indian food prices while New Zealand series does not show any statistically significant spillover effects from any other countries except from Hong Kong. Korean return series is found to be volatile by its own along with some volatility form its region, Singapore and Hong Kong. Strong volatility spill over effects for this period is identified for Hong Kong food price returns. There are statistically significant volatility spillover effects from New Zealand, Singapore, Taiwan and India to Hong Kong food price returns. Taiwan return series are found to be influenced by volatility of Korean food price returns. The tests find some evidences of volatility spillover effects from New Zealand and Hong Kong food market to Indian food market.

Table 7: Robust Wald tests for volatility spillover effects for the sample period 2002-2010

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
$h^2_{(t-1)}$AUS	-	2.035	0.005	2.027	1.908	0.870	0.018	0.305
$h^2_{(t-1)}$NZ	0.390	-	0.154	0.043	15.898^{a}	0.337	3.040^{c}	0.645
$h^2_{(t-1)}$KOR	0.803	2.287	-	0.032	0.016	4.922^{b}	0.035	0.2160
$h^2_{(t-1)}$SIN	5.040^{b}	0.333	3.622^{c}	-	8.249^{a}	1.715	0.357	0.407
$h^2_{(t-1)}$HK	2.146	2.821^{c}	2.818^{c}	0.058	-	0.067	3.155^{c}	1.209
$h^2_{(t-1)}$TWN	5.185^{b}	0.020	0.842	0.564	77.507^{a}	-	2.009	0.862
$h^2_{(t-1)}$IN	4.026^{b}	1.140	0.018	0.005	57.727^{a}	2.044	-	1.478
$h^2_{(t-1)}$TH	0.781	0.135	0.717	0.113	1.386	0.030	1.916	-
$\sum_j h^2_{j(t-1)}$	15.043^{b}	8.894	7.742	2.811	754.193^{a}	6.173	13.792^{c}	5.246

Note: ^{a}, ^{b} and ^{c} indicate significance at 1%, 5% and 10% level respectively.

Main findings of the mean and volatility spillover effects can be summarized as follows: There is no strong evidence of cross country mean spillover effects of food price returns across all samples. For the full sample period, mean spillover effects are found from India and New Zealand to Australia, from Australia, Korea and Singapore to New Zealand, from New Zealand and Korea to Singapore and from Singapore to India only. Mean spillover effects of food price returns from all countries to New Zealand are statistically significant while no evidence of spillover is found in the cases of the other countries. For the recent subsample 2002-2010, mean spillover effects from India to Australia; from Singapore to Korea, from Taiwan to Singapore; from Australia, Singapore and Taiwan to Hong Kong; from Korea to Taiwan; from Singapore to India and from India to Thailand are found to be statistically significant.

There are important differences between the first and second subsamples. During sharp rise of food price periods mean returns of food prices are not independent they are rather interdependent. In the first sample, all countries' data support the notion that food markets have strong-form efficiency (Baillie et al., 1993). That means the effects of news die out rapidly and do not make any opportunity for excess cross country mean returns, while in the second subsample there are some deviations from this inference. In the second subsample, there is some evidence of news not dying out rapidly in some cases with the exception of New Zealand only. For the first subsample period New Zealand food price returns show some evidence of failure of strong-form market efficiency, however, during the period of sharp rises in food prices New Zealand data do not support the failure of strong form efficiency.

Evidence of volatility spillover effects is stronger than mean spillover effects. For the full sample period, except Taiwan all other countries' food price returns show some sort of cross country volatility spillover effects. Volatility spillover effects of food price returns from India and Thailand to Australia; from Australia, Korea, Singapore, Hong Kong, India and Thailand to New Zealand; from Singapore to Korea; from New Zealand, Singapore and Taiwan to Hong Kong; from Australia, Singapore, Hong Kong, Taiwan and Thailand to India and Korea to Thailand are statistically significant. For the subsample period of 1995 to 2001, it is found that volatility spills over from New Zealand, Singapore, Hong Kong and Taiwan to Australia; from Australia, Korea, Singapore, Taiwan, India and Thailand to New Zealand; from Australia to Korea; from Korea to Hong Kong; from Thailand to Taiwan; from Korea, Taiwan and Thailand to India and from New Zealand, Singapore, Taiwan and India to Thailand. No volatility spillover effect is found in the case of Taiwan.

In the period 2002 to 2010, long run volatility spillover effects are found to be statistically significant from Singapore, Taiwan and India to Australia; from Hong Kong to New Zealand, from Singapore and Hong Kong to Korea; from New Zealand, Singapore, Taiwan and India to Hong Kong; from Singapore to Taiwan; from New Zealand and Hong Kong to India. Although Volatility spillover effects are found in the case of New Zealand, Korea and India the evidence is weak because coefficients measuring volatility are significant only at 10 % level of significance.

Noticeable similarities and differences were observed between the two time periods. There are strong volatility spillover effects in Australia, New Zealand, India and Thai food market during 1995 to 2001 whereas strong evidences are found for Australia and Hong Kong market for the period 2002 to 2010. The New Zealand food market seems to be more stable during the 2002 to 2010 period. Its volatility originates from itself during this period.

Although there are significant trade relationships from net food exporter countries to net food importer countries covered by this study, no exact directions of mean or volatility spillover effects from exporter to importer or importer to exporter could be drawn. Instead, rather mixed evidence is found and geographical proximity also matters. Australia being a big net exporter of food products has no unique influence over food price return volatility of its importing countries. For the long horizon of time period it has been found that volatility spills over from Australia to New Zealand, Singapore and in India. Over the period of 1995-2001, there are statistically significant volatility spillover effects from Australia to New Zealand while during the period of

2002-2010 there is no evidence of volatility spillovers. That means even though Australia and New Zealand are neighbours with high trade relationship the food price volatility during recent food price hike in New Zealand is due to other reasons not Australian food price volatility. Indian food prices really seem to influence food prices in Australia. Thailand and some other importer countries also affect food price volatility of Australia. Out of the other three major exporters, India plays an important role to influence volatility of other countries' food prices. For the full sample and 1995-2001 periods it affects only exporters' prices while in the period of 2002-2010 it affects food prices of Thailand as well. New Zealand does not show any evidence of influencing food prices of other countries during 1995-2010 while for the period 1995-2001 it affects two other exporters namely Australia and Thailand. However, during the 2002-2010 period volatility spillover has been found from New Zealand to Hong Kong and India. Volatility spillover effects from Thailand is more important for full and first subsample while for the period 2002-2010 no mean or volatility spillover effects could not be recognised by the study.

Based on above discussion, mixed evidence of heat wave and meteor shower effects can be reported in this study for food markets. For the long time series meteor shower dominates heat wave effects while the reverse is true in short time series data. For the period 1995-2001, partial meteor shower effects are found to be statistically significant for Australia, New Zealand, India and Thailand; however, recent data supports some meteor shower effects for the Australian, Hong Kong and Taiwan food markets but other countries either show complete heat wave effects or weak meteor shower effects.

6.1 Diagnostic Validity of Models

All models estimated in CGARCH form for assessing mean and volatility spillover effects show no indication of serious misspecification. As presumed, all models show evidence of non-normality because GED parameters (Appendix A and B) of all series for every subsamples are less than 2 and statistically significant at 1% level of significance and therefore, justification of estimating models by using generalised error distribution has been reinforced. As a measure of diagnostic check we compute Ljung-Box Q statistics at both level and squared form and also derived ARCH (LM) test statistics. The results are shown in Appendix A and B. Results for mean spillover effects are portrayed in Table A1, Table A2 and Table A3 for full sample, 1995-2001 and 2002-2010 periods respectively in Appendix A. Tables A1, A2 and A3 show that there are no or little evidence of further autocorrelation in the series estimated because none or few of the statistic are statistically significant at 5% level of significance. Similarly, in Appendix B, the models for volatility spillover effects do not show any statistically significant further evidence of autocorrelation in them. Moreover, models capture volatility persistency and mean reversions which are properties of good volatility models (Engle and Patton, 2001.)

7. Conclusion

The objective of this study was to examine cross country mean and volatility spillover effects of food prices using Component GARCH models with daily food producer price indices ranging from 1995 to 2010. In regards to the mean and volatility spillover effects, this study reports mixed evidence of cross country spillover effects. Scant evidence of mean spillover effects is found for different countries across different subsamples. Over the full sample period, some cross country mean spillover effects are found for Australia, New Zealand and Singapore. For the first subsample period mean spillover effects from other countries are found for New Zealand only, but for the recent subsample, some sort of mean spillover is found for all countries except New Zealand. This implies that food markets are currently more interdependent in recent times than before and shocks create some room for excess returns. The ‘meteor shower’ hypothesis that the conditional variance of the change in one market depends on the past information of other markets dominates the ‘heat wave’ hypothesis that the conditional variance depends on the past information of that market, while for shorter time periods ‘heat wave’ effects dominate ‘meteor shower’ effects. Partial meteor shower effects are found to be statistically significant for Australia, New Zealand, India and Thailand over the early subsample; however, recent data supports some meteor shower effects for the Australian, Hong Kong and Taiwan food markets. No exact directions for mean and volatility spillover effects from exporter to importer or importers to exporters can be identified based on the empirical findings of the study. However, it can be concluded that regime shifts and geographical proximity matter for cross country mean and volatility spillover effects. The empirical results of this study will be useful for food policymakers of concerned countries in terms of considering financial characteristics of food prices along with its primary product features, and also should inform policy responses of countries to prepare appropriate measures to respond to cross country spillover effects. The time periods involved (short v long run) are relevant, as are geographical proximities, in preparing policy options. The findings in this study also provide some empirical insights for food futures and options traders. This study remains limited with the estimation procedure in a univariate GARCH framework. Although the results of this study are econometrically robust, it leaves room for future research to extend the work within the framework of *multivariate* GARCH models.

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APPENDIX A

Table A1: Diagnostic Test Results for Mean Spillover Models 1995-2010

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
GED	1.242 (0.025657)[a]	0.240646 (0.002240)[a]	1.187357 (0.033013)[a]	1.27952 (0.026434)[a]	0.902352 (0.022168)[a]	1.096323 (0.033366)[a]	1.032405 (0.025549)[a]	0.853242 (0.021189)[a]
L-BQ(10)	16.999[b]	10.826	12.495[c]	16.418[c]	12.695	13.168	10.494	24.352[a]
L-BQ^2(10)	4.4515	22.488[a]	4.2894	2.5196	2.3665	8.1679	8.8692	3.5431
ARCH-LM(10)	0.4113	0.5470	0.4917	0.8464	0.4804	0.2557	0.0371[b]	0.9585

Table A2: Diagnostic Test Results for Mean Spillover Models 1995-2001

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
GED	1.327479 (0.057172)[a]	0.239997 (0.005465)[a]	1.120643 (0.048069)[a]	0.960746 (0.033895)[a]	0.6545811 (0.023459)[a]	1.067734 (0.047652)[a]	0.929042 (0.035645)[a]	0.656796 (0.025159)[a]
L-BQ(10)	23.657[a]	8.1726	12.333	18.256[c]	6.5536	12.610[c]	17.133[c]	17.704[c]
L-BQ^2(10)	8.3050	6.4606	5.2592	1.5547	3.1602	8.4095	7.2449	2.7198
ARCH-LM(10)	0.3390	0.2626	0.6769	0.8165	0.7194	0.1526	0.0357[b]	0.9451

Table A3: Diagnostic Test Results for Mean Spillover Models 2002-2010

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
GED	1.175847 (0.032278)[a]	1.141178 (0.029658)[a]	1.253234 (0.048544)[a]	1.333386 (0.058072)[a]	1.206024 (0.040263)[a]	1.159763 (0.049552)[a]	1.105883 (0.039772)[a]	1.071857 (0.038404)[a]
L-BQ(10)	10.338	9.8309[c]	6.1328	16.707[c]	13.447[b]	14.085[c]	7.3587	8.8827
L-BQ^2(10)	2.1873	3.3912	5.5197	8.3852	2.5944	5.8172	3.5789	3.1681
ARCH-LM(10)	0.6946	0.9036	0.0875[c]	0.1318	0.3630	0.6097	0.6886	0.6254

APPENDIX B

Table B1: Diagnostic Test Results for Volatility Spillover Models 1995-2010

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
GED	1.250227 (0.029670)[a]	0.221638 (0.001584)[a]	1.177589 (0.032781)[a]	1.108661 (0.026815)[a]	0.903723 (0.022724)[a]	1.076904 (0.032611)[a]	1.034904 (0.026989)[a]	0.943824 (0.021543)[a]
L-BQ(10)	22.902[b]	10.045	12.638	19.017[b]	13.103	11.011	10.625[c]	22.550[a]
L-BQ^2(10)	3.5585	20.283[a]	4.1018	1.9872	4.2836	7.9565	6.9892	3.1908
ARCH-LM(10)	0.5220	0.5382	0.6611	0.7236	0.5976	0.2702	0.0606[c]	0.8516

Table B2: Diagnostic Test Results for Volatility Spillover Models 1995-2001

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
GED	1.352684 (0.060391)[a]	0.131766 (0.001466)[a]	1.138988 (0.053619)[a]	0.959347 (0.035571)[a]	0.773351 (0.028159)[a]	1.080798 (0.049186)[a]	0.972215 (0.039004)[a]	1.271989 (0.033293)[a]
L-BQ(10)	12.118[b]	8.1319	13.806	17.934[b]	8.8126	8.9371	13.968	20.683[b]
L-BQ^2(10)	8.3466[c]	5.9479	5.4568	1.3798	4.0693	7.4027	4.7589	7.1917
ARCH-LM(10)	0.5288	0.8079	0.7795	0.9626	0.7107	0.2290	0.2269	0.3910

Table B3: Diagnostic Test Results for Volatility Spillover Models 2002-2010

	AUS	NZ	KOR	SIN	HK	TWN	IN	TH
GED	1.241684 (0.043821)[a]	1.080069 (0.035542)[a]	1.262160 (0.050405)[a]	1.329859 (0.057587)[a]	1.279597 (0.047463)[a]	1.160903 (0.050089)[a]	1.113387 (0.040620)[a]	1.077635 (0.039082)[a]
L-BQ(10)	11.139	5.5443	2.7190	13.583[c]	9.7994	14.335[c]	9.2152	9.9545
L-BQ^2(10)	3.4204	18.414[c]	4.7724	7.7064	4.3315	5.3133	5.0666	3.4548
ARCH-LM(10)	0.7852	0.7946	0.1138	0.3884	0.2759	0.9376	0.4742	0.5686