Economics Bulletin

Volume 31, Issue 2

Cross country mean and volatility spillover effects of food prices: multivariate GARCH analysis

Fardous Alom
Lincoln University, New Zealand

Bert D Ward
Lincoln University, New Zealand

Baiding Hu
Lincoln University, New Zealand

Abstract

This study assesses the mean and volatility spillover effects of changes in food prices among a number of Asia and Pacific countries - Australia, New Zealand, Korea, Singapore, Hong Kong, Taiwan, India and Thailand - including the USA as a special case using daily observations for 1995 to 2010. Employing an empirical multivariate-TGARCH model this study reveals that while there is weak evidence of own and cross country mean return spillover effects among the selected food markets with strong evidence of mean spillover effects from the USA food price returns to all other markets, but with respect to volatility spillovers there are considerable own and cross country effects and these effects are highly persistent and are non linear. These volatility effects and their persistence should be considered in policy analysis along with the US market's influence in mean return transmission. Keywords: Mean; volatility; spillover; multivariate TGARCH; cross country

Citation: Fardous Alom and Bert D Ward and Baiding Hu, (2011) "Cross country mean and volatility spillover effects of food prices: multivariate GARCH analysis", *Economics Bulletin*, Vol. 31 no.2 pp. 1439-1450.
Submitted: Mar 25 2011.   **Published:** May 15, 2011.

1. Introduction

Traditionally, food price levels and changes have attracted great attention and concern due to food being the most necessary of goods. The recent surge in food prices has added even more emphasis on gaining a more complete picture of the nature and scope of these price changes and their inter-linkages. It has been documented that, among all international prices, commodity prices are the most volatile - particularly agricultural commodity prices (Newbery 1989; Kroner et al. 1999) . Volatility of prices imposes costs in many aspects and thus has been given much importance because it leads to production, search, and opportunity costs, all of which ultimately leading to greater uncertainty and risk (Apergis and Rezitis 2003b; Pindyck 2004; Zheng et al. 2008) .

A body of literature has studied food prices from many angles regarding possible causes and consequences of food price changes such as supply shocks, demand shocks, gyration of energy and metal prices, depreciation of US dollars, rise of biofuel demand etc. (Radetzki 2006; Headey and Fan 2008; Mitchell 2008; Rosegrant et al. 2008; Abott et al. 2009; Du et al. 2009; Robles et al. 2009). Some of these studies focused on the relationship of food prices with other goods' prices (Voyiatzis et al. 2002; Arshad and Hameed 2009; Gnan 2009; Nazlioglu and Soytas 2010). A few studies focused on the effects of macroeconomic variables on food prices (Hua 1998; Apergis and Rezitis 2003b), while others examined the effects of food prices on macroeconomic factors including levels of inflation (Bloom and Ratti 1985; Galesi and Lombardi 2009; Hakro and Omezzine 2010). We do not consider contributing to this existing debate; rather we chose to focus on a different aspect of food price analysis. Food price or agricultural commodity prices have recently gained extra importance in the commodity futures market, where food prices are being regarded as financial assets. In addition to pure financial asset of stock prices, some other rates and prices are being frequently modelled by the technique of Financial Econometrics such as interest rate, bond rates, exchange rates, energy price and metal price involving gold, silver, copper and others (Blair 2001; Narayan and Narayan 2007; Regnier 2007; Wei et al. 2010). However, the aspect of food prices as a financial asset warrants greater research attention. Since 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). Moreover, Gilbert (2010) has shown that movements in the agricultural futures market is one of the other factors influencing the price surge of 2007-08.

A number of recent studies are available on modelling aspects of volatility and examining mean and volatility spillover effects of agricultural commodity prices in general and food prices in particular. Apergis and Rezitis(2003b) examined volatility spillover effects from macroeconomic fundamentals to relative food price volatility in Greece. Kim and Doucouliagos (2008) tested spillover effects for three grains by employing realized volatility and a correlation approach and uncovered significant spillover effects among them. Apergis and Rezitis(2003a) have also examined the volatility spillover effects from agricultural input and retail prices to food output prices and found significant spillover effect from input and retail prices to agricultural output prices. In a recent study Alom *et al.*, (2010) examined the cross country mean and volatility spillover effects of food prices for a number of Asia and Pacific countries by applying univariate Component GARCH models and found weak evidence of mean spillover across countries while significant evidence of volatility spillover effects have been documented.

The purpose of the current study is to analyze the relationship of inter-country food prices with their mean and volatility of returns. As in Alom *et al.*(2010), we chose food prices of eight countries from the Asia and Pacific region namely Australia, New Zealand, Korea, Singapore, Hong Kong, Taiwan, India and Thailand, providing due emphasis to status of the net exporters and importers of food products for a better representation. Australia, New Zealand, India and Thailand are regarded as net food exporters while all other four countries are net food importers. In addition, these eight countries were chosen in order to provide geographic spread throughout the region - two countries from the south Pacific (Australia and New Zealand), two from ASEAN (Singapore and Thailand), two from greater China (Hong Kong and Taiwan), one from East Asia (South Korea) and one from South Asia (India). Moreover, emerging and recently grown economies have been considered with emphasis on the rising demand for foods so we chose South Korea rather than Japan. These countries have considerable trade and other economic relationships and they have free trade agreements (FTA) under operation among them (Park 2009; Alom et al. 2010). Taking this rational mixture of countries into consideration this study intends to provide insights to the mean and volatility spillover effects of food price returns across countries. The current study differs from Alom *et al*.,(2010) in terms of econometric methodology and also sample composition. In particular, the current study is based on multivariate threshold generalized autoregressive conditional heteroskedasticity (MTGARCH) model whereas the previous study used univariate GARCH models. In addition to the eight countries considered in the previous study we now incorporate the US food price index in the current study to better understand the mean and volatility interconnections among the food markets.

The paper is structured as follows. The next section provides details on the sources and statistical properties of the data. Section 3 presents the model framework used for analysis, while section 4 reports the empirical findings along with possible interpretation. Section 5 concludes the study.

2. Data - sources and statistical properties

This study utilizes 4,000 daily observations of food producer price indices for Australia (AFP), New Zealand (NFP), the USA (UFP), Korea (KFP), Singapore (SFP), Hong Kong (HFP), Taiwan (TNFP), India (IFP) and Thailand (TFP) for the period of 2 January 1995 to 30 April 2010 provided by DataStream. The sample period has been chosen based on the data availability for all countries. The daily return of food prices are computed as percentage form by using continuously compounded logarithmic technique and thus the return function becomes $R_{i,t} = 100 * \ln\left(\frac{P_{i,t}}{P_{i,t-1}}\right)$ where *i* refers to individual food market, $P_{i,t}$ stands for price index of present day for *i* market and $P_{i,t-1}$ represents price for previous day for the same market.

Table 1 displays the properties of returns series of food prices considered in the study. Except for New Zealand all mean returns are positive and the unconditional standard deviation of each return series exceeds its mean counterpart, implying considerable volatility in them. This is also visible from the plots of the series in Figure 1, which shows considerable volatility clustering of returns. It can be viewed that there are noticeable ups and downs in plots, exceeding plus and minus 10% in several times.

Table 1 also shows that food price returns in Korea, Taiwan, Hong Kong and Singapore show higher volatility than other countries indicating that importer countries' food markets are more volatile than those of exporter countries. The negative values of skewness for Australian and Korean food price returns imply long left tails while all other series exhibit evidence of positive long right tails. All the computed values for excess kurtosis are higher than 3 implying the distributions to be peaked rather than normal. Jarque-Bera statistics also reveal that the distributions lack normality because tests fail to reject the null hypotheses of non-normality, which is also confirmed with the theoretical quantile-quantile(q-q) plots shown in Figure 2. None of the edges of q-q plots fit the data normally.

The existence of volatility clustering and the non-normality properties of data, along with their stationarity according to ADF test statistics as shown in last row of Table 1 emphasizes that the returns data can be analyzed in the fashion of financial assets with GARCH-type models. Moreover, since food price returns of the concerned countries show positive correlation among them (Table 2) and have significant trade relationships, it is appropriate to conduct the analysis using *multivariate* GARCH models.

Table 1 Summary statistics for price returns over 1995-2010

	AFP	UFP	NFP	IFP	TFP	KFP	SFP	HFP	TNFP
Mean	0.014980	0.022489	-0.000678	0.045255	0.017493	0.026116	0.012016	0.045212	0.021774
Std. Dev.	1.230786	1.016181	1.603637	1.565841	1.861843	2.322283	1.932665	2.093400	2.257914
Skewness	-0.045589	0.135255	0.078259	0.393686	0.023463	-0.069149	0.254725	0.113108	0.111352
Kurtosis	11.07135	12.39791	23.41450	8.148596	11.87194	7.710103	9.486347	9.265749	5.002375
Jarque-Bera	10856.46	14728.62	69445.38	4520.202	13115.66	3699.775	7053.610	6550.159	676.3483
(P-value)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
ADF (p-value)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Observations	3999	3999	3999	3999	3999	3999	3999	3999	3999

Table 2 Cross correlation coefficients of food price returns over 1995-2010

	AFP	UFP	NFP	IFP	TFP	KFP	SFP	HFP	TNFP
AFP	1	0.0088	0.0899	0.0714	0.0634	0.1063	0.1402	0.1490	0.1031
UFP	0.0088	1	-0.0025	0.0087	0.0084	0.0462	0.0825	0.0470	0.0108
NFP	0.0899	-0.0025	1	0.0450	0.04131	0.0499	0.0748	0.0693	0.0361
IFP	0.0714	0.0087	0.0450	1	0.0555	0.0430	0.0840	0.11408	0.0608
TFP	0.0634	0.0084	0.0413	0.0555	1	0.0777	0.1323	0.0823	0.0561
KFP	0.1063	0.0462	0.0499	0.0430	0.0777	1	0.1488	0.1048	0.1185
SFP	0.1402	0.0825	0.0748	0.0840	0.13232	0.1488	1	0.2441	0.1589
HFP	0.1490	0.0470	0.0693	0.1140	0.0823	0.1048	0.2441	1	0.1600
TNFP	0.1031	0.0108	0.0361	0.0608	0.05618	0.1185	0.15897	0.1600	1

Figure 1 Food price returns over 1995-2010

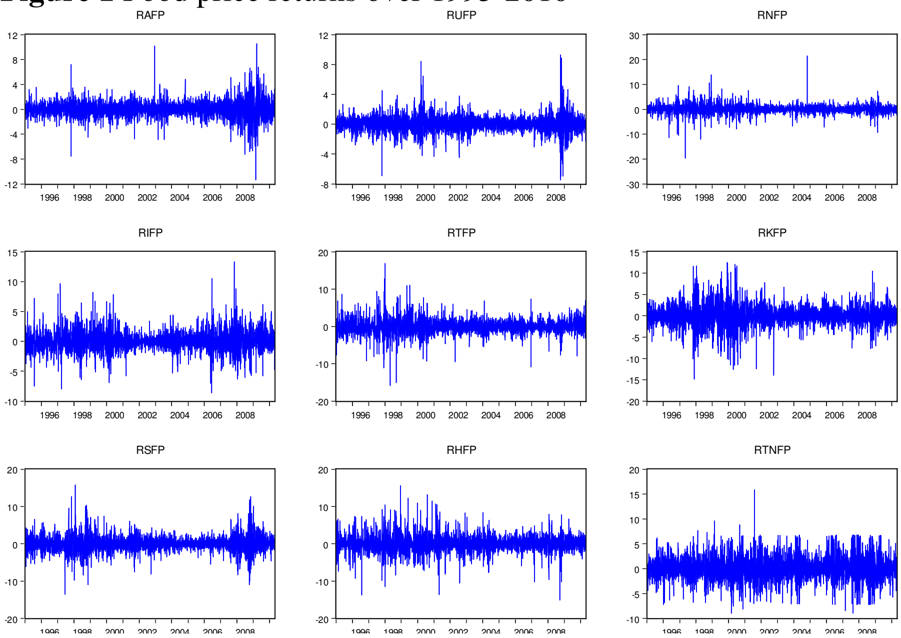
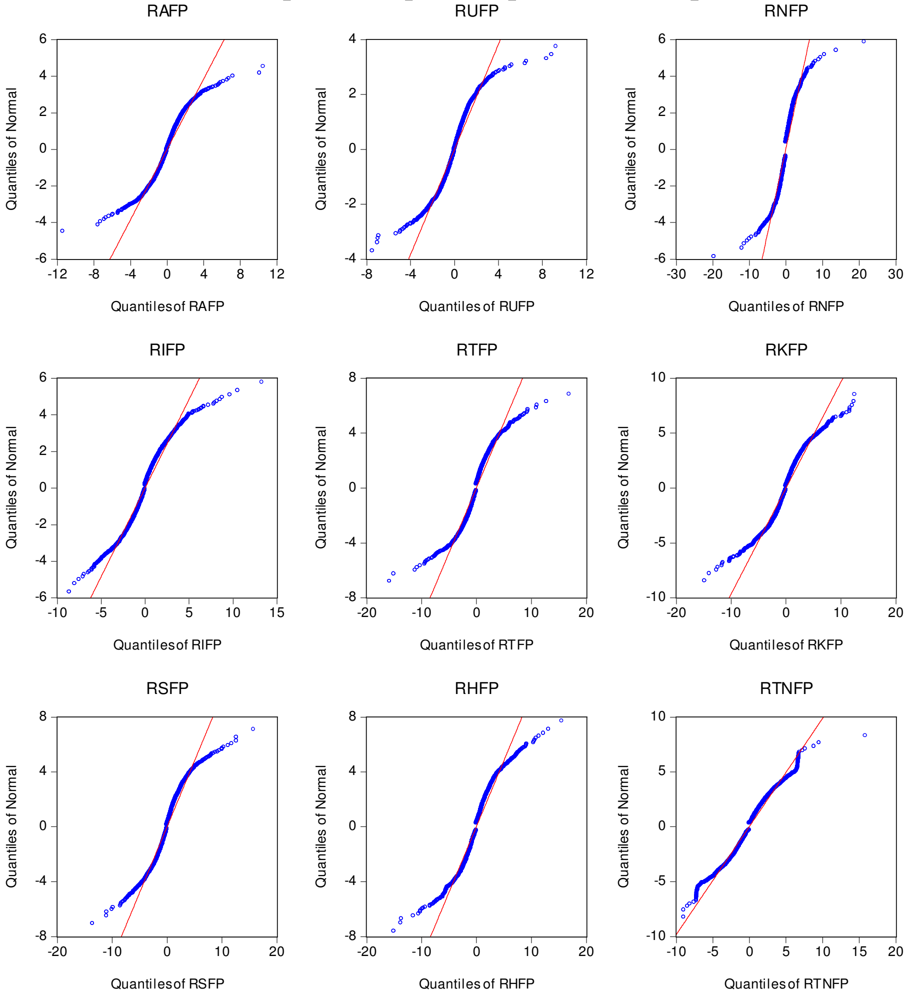


Figure 2 Theoretical quantile- quantile plots for food price returns 1995-2010



3. Modelling framework

In order to estimate the mean and volatility spillover effects of food price returns across countries we use the BEKK (Baba, Engle, Kraft, Kroner) representation of the multivariate GARCH (MGARCH) model proposed by Engle and Kroner(1995). Specifically we develop the model in line with the analysis procedure suggested by Higgs and Worthington (2004) and Lee (2009) with a modification of incorporating leverage term in the variance equation to capture possible asymmetric effects and hence our model becomes multivariate TGARCH. The model consists of mean and variance equations. The conditional mean returns equations for the food markets can be written as:

$$R_t = \gamma + AR_{t-1} + \varepsilon_t$$
$$\varepsilon_t \,|\, I_{t-1} \sim N(0, H_t) \tag{1}$$

where R_t is an *n x 1* vector of daily food price returns at time t for each market, γ is an n x 1 vector of constants, ε_t is a *n x 1* vector of innovations for each market at time *t* with its corresponding *n* x *n* conditional variance and covariance matrix, H_t . The elements of a_{ij} of the matrix *A* are the measures of the degree of mean return spillover effects across food markets, particularly, the estimates of the elements of the matrix A offer measures for own lagged and cross mean spillovers.

The variance equation in the BEKK representation for MTGARCH model can be written as: $H_t = M'M + B'\varepsilon_{t-1}\varepsilon'_{t-1}B + D'\varepsilon_{t-1}d_{t-1}D + G'H_{t-1}G$ (2)

where $m_{i,j}$ are elements of *n* x *n* symmetric M matrix of constants; $b_{i,j}$, the elements of *n* x *n* symmetric *B* matrix, measure the degree of lagged and cross innovation from market *i* to market *j;* d_{t-1} is a dummy variable equal to 1 if $e_{t-1}<0$ and 0 otherwise, the elements $d_{i,j}$ of the symmetric *n x n D* matrix measure lagged and cross asymmetric effects from market *i* to market *j,* and the elements $g_{i,j}$ of the *n* x *n* symmetric *G* matrix signifie the persistence of conditional volatility between markets *i* and *j*.

The equation in (2) can be written in its simple form for the bi-variate BEKK model as:

$$H_t = M'M + \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}' \begin{pmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{pmatrix} x \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} + \begin{pmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{pmatrix}' \varepsilon_{t-1}^2 d_{t-1} \begin{pmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{pmatrix} + \begin{pmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{pmatrix}' H_{t-1} \begin{pmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{pmatrix} \quad (3)$$

In equation (3) b_{21} measures the volatility spillover from market 2 to market 1 and b_{12} represents the volatility from market 1 to market 2, d_{21} identifies leverage effects from market 2 to 1 while d_{12} measures leverage effects from 1 to 2, g_{21} indicates volatility persistence effects form market 2 to market 1, and g_{12} shows the volatility persistence effects from market 1 to market 2. In our study of 9 food markets, the elements in the variance equation would be m_{11} to m_{99} for constants, b_{11} to b_{99} for ARCH parameters, d_{11} to d_{99} for leverage parameters and g_{11} to g_{99} for GARCH parameters.

To account for possible deviation from normality we estimate models by using the Student's t distribution and for residual autocorrelation test we conduct the Portmanteau autocorrelation test.

4. Empirical results

Table 3 exhibits estimated coefficients for conditional mean returns of concerned countries. For the most part, the evidence is weak regarding own and cross mean spillover effects. However, for Australia a negative mean return spillover effect from Taiwan (-0.017142) and a positive mean return spillover effects from the USA are found to be statistically significant at least at 5% level of significance. In the case of US negative mean return spillover effects can be viewed significant from Thailand (-0.0111308) and Singapore (-0.015062). In the New Zealand case, positive mean spillovers from the USA (0.088833), India (0.023990) and Thailand (0.019208) are statistically significant. The Indian and Korean food price returns have been found positively influenced only by the US food price returns with magnitudes of 0.073548 and 0.193430 respectively. Positive mean return spillover effects can also be seen in the Thai food market - from the USA (0.062593), India (0.032030) and Singapore (0.030032). Singapore food price mean returns are negatively influenced by the Hong Kong and Taiwan markets (-0.001577 and -0.017143) while it is positively influenced by the US market (0.215924). The Hong Kong food price returns appear to be positively influenced by the USA (0.263272), India (0.029115), Korea (0.029429) and Singapore (0.057674). In the case of Taiwan market, positive mean return spillover effects from the US (0.219574), Indian (0.036273), Korean (0.026785) and Singapore (0.078311) markets are found to be statistically significant while negative spillovers can be found from New Zealand. Except for Australia, India, Korea and Hong Kong none of the food markets get the strongest mean spillover effects from their own lagged mean returns. The US food market was found to be most influential for all other markets in terms of mean return spillover effects and the effects for the net food importers was even higher, exceeding 20% in most cases. On the other hand, the Indian, Korean and Singapore food markets are found to be influential for regional countries in terms of mean returns spillover because positive mean spillover effects can be viewed from these markets to other markets to some extent. It can also be inferred that food price mean returns do not significantly spillover from exporter countries to importer countries because none of the exporter countries significantly influence mean returns of importer countries excepting the USA and India. New Zealand and Australian markets are found to be non-influential in the food market in terms of mean spillovers. On the whole, these findings regarding mean spillover effects suggest that food markets are somehow interdependent in terms of mean returns though mean spillovers are not found in each and every case.

Table 3 Estimated return coefficients for MTGARCH conditional mean equations

	AFP*(i=1)*	UFP*(i=2)*	NFP*(i=3)*	IFP*(i=4)*	TFP*(i=5)*	KFP*(i=6)*	SFP*(i=7)*	HFP*(i=8)*	TNFP*(i=9)*
γ	0.025492[c] (0.014477)	0.027740[b] (0.011734)	-0.028306 (0.020368)	0.034168[c] (0.019401)	0.002245 (0.022713)	0.014889 (0.026430)	0.044410[b] (0.021379)	0.044937[c] (0.025920)	0.000395 (0.030172)
a_{i1}	-0.045001[a] (0.013313)	0.009520 (0.010425)	0.014614 (0.017420)	0.013648 (0.017897)	0.007750 (0.019274)	0.007043 (0.023155)	0.001380 (0.020386)	0.002653 (0.021958)	-0.005313 (0.026528)
a_{i2}	0.196820[a] (0.016262)	-0.012915 (0.05445)	0.088833[a] (0.020484)	0.073548[a] (0.021535)	0.062593[b] (0.024957)	0.193430[a] (0.030543)	0.215924[a] (0.025436)	0.263272[a] (0.026777)	0.219574[a] (0.031903)
a_{i3}	-0.006137 (0.009082)	0.009485 (0.008256)	-0.011043 (0.014039)	-0.003617 (0.012497)	0.004688 (0.016378)	0.004586 (0.018171)	0.014001 (0.014007)	-0.012718 (0.017086)	-0.05138[b] (0.019885)
a_{i4}	0.009097 (0.010235)	0.010225 (0.007644)	0.023990[c] (0.013636)	0.039542[a] (0.012931)	0.032030[b] (0.015261)	0.014486 (0.018314)	0.011325 (0.014588)	0.029115[c] (0.017370)	0.036273[c] (0.020287)
a_{i5}	0.016066[c] (0.008446)	-0.011308[c] (0.006415)	0.019208[c] (0.011565)	0.004903 (0.011713)	-0.005225 (0.014187)	-0.000889 (0.016015)	0.001206 (0.013917)	0.010577 (0.014345)	-0.008722 (0.017439)
a_{i6}	-0.008361 (0.007109)	0.000440 (0.005840)	0.008974 (0.009232)	0.004476 (0.009140)	0.015841 (0.010715)	0.042476[a] (0.014759)	0.010547 (0.010469)	0.029429[b] (0.011643)	0.026785[b] (0.014016)
a_{i7}	-0.013090 (0.008482)	-0.015062[b] (0.007343)	0.0013864 (0.011576)	-0.006047 (0.011814)	0.030032[b] (0.013067)	0.010103 (0.015893)	0.001128 (0.014242)	0.057674[a] (0.015239)	0.078311[a] (0.016859)
a_{i8}	-0.008985 (0.006938)	-0.011209[c] (0.006430)	0.014896 (0.010814)	0.008169 (0.009714)	-0.016414 (0.012051)	-0.016766 (0.014541)	-0.001577[c] (0.011405)	-0.000310 (0.014032)	0.011539 (0.016400)
a_{i9}	-0.017142[b] (0.007001)	-0.002935 (0.005515)	0.005589 (0.009201)	-0.012069 (0.009201)	-0.010548 (0.10264)	-0.017258 (0.012611)	-0.017143[c] (0.010090)	0.001239 (0.011890)	-0.017858 (0.014189)

Note: Values in parentheses are standard errors. [a],[b] and [c] indicates level of significance at 1%, 5% and 10% respectively.

Turning now to an analysis of possible interdependencies in the form of volatility spillover effects, Table 4 presents estimated coefficients of the variance-covariance matrix equations. The coefficients denoted as '*m*' are the constant terms in each equation; those denoted as '*b*' are ARCH parameters measuring the effects of the lagged own and cross innovation; the coefficients marked as '*d*' are leverage or threshold parameters measuring own and cross asymmetry and the '*g*' coefficients quantify the lagged own and cross volatility persistence on the current own and cross volatility of the eight Asia and Pacific food markets.

All ARCH parameters as shown in Table 4 are statistically significant at 1% level of significance showing strong ARCH effects. There are statistically significant positive own and cross lagged innovation effects though the magnitudes are low. Own lagged volatility effects vary from 0.001943 for Australia to 0.054567 for Taiwan while the second largest own volatility can be seen for Thailand followed by Korea, Hong Kong, Singapore, India, New Zealand and USA. Except for Taiwan, none of the countries get the strongest volatility from their own markets. Although there is evidence of cross country volatility spillover the estimated magnitudes of these effects are low. Again like own volatility effects, the Taiwan food market receives stronger volatility effects from other markets, with major volatility coming from Hong Kong, Thailand, Singapore and Korea. For the Australian market, Thailand, Korea, Singapore and Indian markets are major influencers. Returns volatility for the US food market comes primarily from Taiwan, India, Korea, Hong Kong, Singapore and

New Zealand. New Zealand food price volatility is affected mostly by the Taiwan, Korea, Hong Kong and Singapore markets. Indian food price returns volatility appears to be influenced more by Taiwan food markets followed by Thailand, Korea, Hong Kong and Singapore. Similarly Thai food price volatility is found to be influenced by Taiwan, Thailand, Korea, Hong Kong, and Singapore. The Korean food market also receives major volatility from Taiwan followed by India, Thailand, Hong Kong and Singapore. In the case of the Singapore food market, evidence reveals that the major volatility comes from the Taiwan, India,Thailand, and Hong Kong market. Hong Kong food market volatility appears to be much affected by the Taiwan, Thailand, Korea and Singapore markets. In terms of cross innovation effects, the Australia, the US and New Zealand food markets seem to be less influential among the markets included in the study. On the whole, volatility spillover effects were found to be more influenced by regionalism rather than by export/import status.

In Table 4 the parameters measuring asymmetry are denoted by d_{11} to d_{99} . Almost all the parameters are are statistically significant at 1% level of significance implying significant asymmetric lagged and cross volatility spillover effects among food markets considered in the study. Evidence of both positive and negative asymmetric effects have been found where positive asymmetric effects dominate negative ones. The evidence suggests that any positive shock volatility spillover from one country's food price returns to another country's food prices will not compensated fully by a negative shock. Overall, the study suggests that the volatility transmission from one food market to another food markets are asymmetric.

Table 4 also shows that all GARCH parameters are statistically significant at 1% level of significance. Volatility in all food markets shows high own and cross persistence. For the Australian food market, own volatility persistence is larger than cross volatility persistence. The Australian market exhibits the highest own lagged persistence (0.982043) followed by India (0.980433), Singapore (0.972621), Korea (0.949835), the US (0.934016), Hong Kong (0.921942), Taiwan (0.907573), Thailand (0.893212) and New Zealand (0.875658). Past volatilities of the Indian, Singapore, Korean, Hong Kong and the US food prices have more influences on the future volatility persistence of Australian food price returns over time than other markets. The US food market volatility persistence is influenced primarily by the Australian market followed by India, Singapore and Korean markets. For the New Zealand market Singapore, India, Australia, Korea, and the US markets show more influence on volatility persistence than other markets over time. Major volatility persistence for the Indian market comes from Australia, Singapore, the US, Hong Kong and Taiwan market and, interestingly, the Thai market receives more volatility persistence from almost the same source of India. Regarding spillover of o volatility persistence on the Korean food market, major influencers are Australia, India, Singapore, the US, Hong Kong, and Thai food market. For the Singapore food market, major persistence spilllovers can be viewed from India, Australia, Korea, the US, and Hong Kong. For the Hong Kong and Taiwan market, the Australian food price is the strongest influencer for volatility persistence effects.

The sum of the ARCH and GARCH parameters quantifies the overall own and cross conditional volatility persistence. Among all considered food markets the New Zealand food price returns exhibit the lowest persistence in terms of both own and cross volatility than other markets while the Indian market demonstrates highest persistence followed by Singapore, Australia and Korean markets. The average half life of the effects of a random shock in the New Zealand food market is 6 days only while it is 228 days in the Singapore market. In terms of volatility persistence effects it can be documented that big market such as Australia, India, Singapore and Korea are relatively more persistent to the shocks of volatility than smaller markets such as New Zealand and Thailand. These findings suggest that if food price increases due to random shocks it sustains for longer period in the big food markets and they spillover to other markets while in small markets the effects of shocks die out very quickly.

To evaluate the statistical validity of the model we conducted Portmanteau tests for residual autocorrelation. Up to lag 9 the L-B(Q)-stat is 679.0279 and adjusted Q-stat is 770.0234, both being statistically insignificant meaning there is no remaining serial correlation up to 9 lags .

Table 4 Estimated coefficients for MTGARCH conditional variance covariance equations

	AFP(*i=1*)	UFP(*i=2*)	NFP(*i=3*)	IFP(*i=4*)	TFP(*i=5*)	KFP(*i=6*)	SFP(*i=7*)	HFP(*i=8*)	TNFP(*i=9*)
m_{i1}	0.007145[a]	0.004871[a]	-0.002394	-4.60E-05	-0.002842	0.004495[a]	0.000731	-0.000166	0.007327[a]
	(0.001121)	(0.000700)	(0.001872)	(0.000598)	(0.001930)	(0.001336)	(0.000699)	(0.001703)	(0.002395)
m_{i2}	0.004871[a]	0.017875[a]	0.005126[b]	0.000355	0.009158[a]	1.63E-05	0.002243[b]	0.011058[a]	-0.002126
	(0.000700)	(0.002479)	(0.002025)	(0.001014)	(0.002175)	(0.001720)	(0.001110)	(0.002086)	(0.002764)
m_{i3}	-0.002394	0.005126[b]	0.160937[a]	0.000855	-0.006299	0.010588[b]	0.002215	-0.003075	0.008748
	(0.001872)	(0.002025)	(0.018542)	(0.002568)	(0.004565)	(0.004347)	(0.003069)	(0.004830)	(0.006189)
m_{i4}	-4.60E-05	0.000355	0.000855	0.007098[a]	0.001266	0.001950	-0.000149	0.002744	0.003168
	(0.000598)	(0.001014)	(0.002568)	(0.001434)	(0.002569)	(0.001565)	(0.000801)	(0.002270)	(0.003000)
m_{i5}	-0.002842	0.009158[a]	-0.006299	0.001266	0.143102[a]	0.013075[a]	0.007890[a]	-0.006592	0.011900[c]
	(0.001930)	(0.002175)	(0.004565)	(0.002569)	(0.015908)	(0.004377)	(0.004087)	(0.004789)	(0.005225)
m_{i6}	0.004495[a]	1.63E-05	0.010588[b]	0.001950	0.013075[a]	0.058364[a]	0.005236[a]	0.017084[a]	0.013876[a]
	(0.001336)	(0.001720)	(0.004347)	(0.001565)	(0.004377)	(0.008844)	(0.001973)	(0.004070)	(0.005225)
m_{i7}	0.000731	0.002243[b]	0.002215	-0.000149	0.007890[a]	0.005236[a]	0.015085[a]	0.013804[a]	0.011020[a]
	(0.000699)	(0.001110)	(0.003069)	(0.000801)	(0.004087)	(0.001973)	(0.002525)	(0.003050)	(0.003590)
m_{i8}	-0.000166	0.011058[a]	-0.003075	0.002744	-0.006592	0.017084[a]	0.013804[a]	0.126349[a]	0.030884[a]
	(0.001703)	(0.002086)	(0.004830)	(0.002270)	(0.004789)	(0.004070)	(0.003050)	(0.015462)	(0.006396)
M_{i9}	0.007327[a]	-0.002126	0.008748	0.003168	0.011900[c]	0.013876[a]	0.011020[a]	0.030884[a]	0.209891[a]
	(0.002395)	(0.002764)	(0.006189)	(0.003000)	(0.005225)	(0.005225)	(0.003590)	(0.006396)	(0.031407)
b_{i1}	0.001943[b]	0.004430[a]	0.005606[a]	0.005667[a]	0.008588[a]	0.008550[a]	0.006615[a]	0.007838[a]	0.010297[a]
	(0.000891)	(0.001130)	(0.001394)	(0.001331)	(0.002083)	(0.001991)	(0.001553)	(0.001883)	(0.002426)
b_{i2}	0.004430[a]	0.010099[a]	0.012781[a]	0.012921[a]	0.019580[a]	0.019493[a]	0.015080[a]	0.017869[a]	0.023475[a]
	(0.001130)	(0.002839)	(0.002149)	(0.001902)	(0.002873)	(0.002926)	(0.002202)	(0.002670)	(0.003586)
b_{i3}	0.005606[a]	0.012781[a]	0.016174[a]	0.016351[a]	0.024779[a]	0.024669[a]	0.019084[a]	0.022613[a]	0.029708[a]
	(0.001394)	(0.002149)	(0.003051)	(0.001749)	(0.002849)	(0.002590)	(0.002018)	(0.002560)	(0.003291)
b_{i4}	0.005667[a]	0.012921[a]	0.016351[a]	0.016530[a]	0.025051[a]	0.024939[a]	0.019293[a]	0.022861[a]	0.030033[a]
	(0.001331)	(0.001902)	(0.001749)	(0.001570)	(0.002074)	(0.001726)	(0.002003)	(0.001765)	(0.002596)
b_{i5}	0.008588[a]	0.019580[a]	0.024779[a]	0.025051[a]	0.037962[a]	0.037794[a]	0.029238[a]	0.034644[a]	0.045514[a]
	(0.002083)	(0.002873)	(0.002849)	(0.002074)	(0.004912)	(0.003106)	(0.002362)	(0.003145)	(0.003934)
b_{i6}	0.008550[a]	0.019493[a]	0.024669[a]	0.024939[a]	0.037794[a]	0.037626[a]	0.029108[a]	0.034491[a]	0.045312[a]
	(0.001991)	(0.002926)	(0.002590)	(0.001726)	(0.003106)	(0.003601)	(0.001984)	(0.002656)	(0.003453)
b_{i7}	0.006615[a]	0.015080[a]	0.019084[a]	0.019293[a]	0.029238[a]	0.029108[a]	0.022518[a]	0.026683[a]	0.035054[a]
	(0.001553)	(0.002202)	(0.002018)	(0.002003)	(0.002362)	(0.001984)	(0.002080)	(0.002035)	(0.002596)
b_{i8}	0.007838[a]	0.017869[a]	0.022613[a]	0.022861[a]	0.034644[a]	0.034491[a]	0.026683[a]	0.031617[a]	0.041536[a]
	(0.001883)	(0.002670)	(0.002560)	(0.001765)	(0.003145)	(0.002656)	(0.002035)	(0.003716)	(0.003419)
b_{i9}	0.010297[a]	0.023475[a]	0.029708[a]	0.030033[a]	0.045514[a]	0.045312[a]	0.035054[a]	0.041536[a]	0.054567[a]
	(0.002426)	(0.003586)	(0.003291)	(0.002596)	(0.003934)	(0.003453)	(0.002596)	(0.003419)	(0.006182)
d_{i1}	0.021591[a]	-0.041767[a]	0.035591[a]	0.005173[b]	0.031276[a]	-0.007533[a]	0.003230[c]	0.023689[a]	-0.008674[a]
	(0.002724)	(0.003549)	(0.003330)	(0.002396)	(0.003343)	(0.002704)	(0.001919)	(0.002972)	(0.003718)
d_{i2}	-0.041767[a]	0.080799[a]	-0.068851[a]	-0.010007[a]	-0.060504[a]	0.014573[a]	-0.006248[c]	-0.045826[a]	0.016781[b]
	(0.003549)	(0.008908)	(0.006137)	(0.004538)	(0.006009)	(0.005392)	(0.003619)	(0.005261)	(0.007339)
d_{i3}	0.035591[a]	-0.068851[a]	0.058670[a]	0.008527[b]	0.051557[a]	-0.012418[a]	0.005324[a]	0.039050[a]	-0.014299[b]
	(0.003330)	(0.006137)	(0.007971)	(0.003909)	(0.005611)	(0.004524)	(0.003138)	(0.004923)	(0.006174)
d_{i4}	0.005173[b]	-0.010007[a]	0.008527[b]	0.001239	0.007493[b]	-0.001805[c]	0.000774	0.005676[b]	-0.002078[c]
	(0.002396)	(0.004538)	(0.003909)	(0.001123)	(0.003495)	(0.000979)	(0.000593)	(0.002662)	(0.001262)
d_{i5}	0.031276[a]	-0.060504[a]	0.051557[a]	0.007493[b]	0.045307[a]	-0.010912[c]	0.004679[c]	0.034316[a]	-0.012566[a]
	(0.003343)	(0.006009)	(0.005611)	(0.003495)	(0.007470)	(0.003934)	(0.002800)	(0.004727)	(0.005402)
d_{i6}	-0.007533[a]	0.014573[a]	-0.012418[a]	-0.001805[c]	-0.010912[c]	0.002628	-0.001127	-0.008265[a]	0.003027[c]
	(0.002704)	(0.005392)	(0.004524)	(0.000979)	(0.003934)	(0.001893)	(0.000698)	(0.002957)	(0.001797)
d_{i7}	0.003230[c]	-0.006248[c]	0.005324[a]	0.000774	0.004679[c]	-0.001127	0.000483	0.003544	-0.001298
	(0.001919)	(0.003619)	(0.003138)	(0.000593)	(0.002800)	(0.000698)	(0.000564)	(0.002179)	(0.000857)
d_{i8}	0.023689[a]	-0.045826[a]	0.039050[a]	0.005676[b]	0.034316[a]	-0.008265[a]	0.003544	0.025991[a]	-0.009517[b]
	(0.002972)	(0.005261)	(0.004923)	(0.002662)	(0.004727)	(0.002957)	(0.002179)	(0.005341)	(0.004052)
d_{i9}	-0.008674[a]	0.016781[b]	-0.014299[b]	-0.002078[c]	-0.012566[a]	0.003027[c]	-0.001298	-0.009517[b]	0.003485
	(0.003718)	(0.007339)	(0.006174)	(0.001262)	(0.005402)	(0.001797)	(0.000857)	(0.004052)	(0.002994)
g_{i1}	0.982043[a]	0.957729[a]	0.927326[a]	0.981238[a]	0.936575[a]	0.965805[a]	0.977321[a]	0.951519[a]	0.9444074[a]
	(0.001934)	(0.003219)	(0.006208)	(0.001279)	(0.004623)	(0.002427)	(0.001484)	(0.003569)	(0.005250)
g_{i2}	0.957729[a]	0.934016[a]	0.904366[a]	0.956943[a]	0.913386[a]	0.941892[a]	0.953123[a]	0.927960[a]	0.920699[a]
	(0.003219)	(0.005885)	(0.006748)	(0.003131)	(0.005265)	(0.003689)	(0.003168)	(0.004433)	(0.005819)
g_{i3}	0.927326[a]	0.904366[a]	0.875658[a]	0.926566[a]	0.884392[a]	0.911993[a]	0.922867[a]	0.898502[a]	0.891472[a]
	(0.006208)	(0.006748)	(0.011615)	(0.006213)	(0.007264)	(0.006376)	(0.006215)	(0.006731)	(0.007684)
g_{i4}	0.981238[a]	0.956943[a]	0.926566[a]	0.980433[a]	0.935807[a]	0.965013[a]	0.976519[a]	0.950738[a]	0.943300[a]
	(0.001279)	(0.003131)	(0.006213)	(0.001719)	(0.004606)	(0.002397)	(0.001435)	(0.003567)	(0.005227)

g_{i5}	0.936575[a]	0.913386[a]	0.884392[a]	0.935807[a]	0.893212[a]	0.921089[a]	0.932071[a]	0.907464[a]	0.900364[a]
	(0.004623)	(0.005265)	(0.007264)	(0.004606)	(0.008611)	(0.004960)	(0.004608)	(0.005471)	(0.006527)
g_{i6}	0.965805[a]	0.941892[a]	0.911993[a]	0.965013[a]	0.921089[a]	0.949835[a]	0.961160[a]	0.935785[a]	0.928463[a]
	(0.002427)	(0.003689)	(0.006376)	(0.002397)	(0.004960)	(0.004374)	(0.002496)	(0.004071)	(0.005561)
g_{i7}	0.977321[a]	0.953123[a]	0.922867[a]	0.976519[a]	0.932071[a]	0.961160[a]	0.972621[a]	0.946943[a]	0.939534[a]
	(0.001484)	(0.003168)	(0.006215)	(0.001435)	(0.004608)	(0.002496)	(0.002272)	(0.003614)	(0.005270)
g_{i8}	0.951519[a]	0.927960[a]	0.898502[a]	0.950738[a]	0.907464[a]	0.935785[a]	0.946943[a]	0.921942[a]	0.914729[a]
	(0.003569)	(0.004433)	(0.006731)	(0.003567)	(0.005471)	(0.004071)	(0.003614)	(0.006690)	(0.006030)
g_{i9}	0.944074[a]	0.920699[a]	0.891472[a]	0.943300[a]	0.900364[a]	0.928463[a]	0.939534[a]	0.914729[a]	0.907573[a]
	(0.005250)	(0.005819)	(0.007684)	(0.005227)	(0.006527)	(0.005561)	(0.005270)	(0.006030)	(0.009926)

Note: Values in parentheses are standard errors. [a],[b] and [c] indicate level of significance at 1%, 5% and 10% respectively.

5. Conclusion

This study examines the mean and volatility spillover effects of food price returns for a number of Asia and Pacific markets namely Australia, New Zealand, Korea, Singapore, Hong Kong, Taiwan, India and Thailand including the USA as special case within the framework of a multivariate threshold GARCH models. The major findings include that there is no strong mean returns spillover effects among countries except some evidence of regional cross country mean returns spillover effects mainly with geographical proximity while a strong mean spillover effects is revealed from the USA market to all other markets. Food prices in the USA are important for all other prices because all of them are affected by the American price returns. Net food importers are highly influenced where the magnitudes are low for net exporter countries. After the USA, India is the biggest influencer among all exporter countries. Secondly, there is strong evidence of own lagged and cross innovation spillover and own and cross volatility persistence spillover effects of food price returns, which are consistent with *Alom et al.* (2010) with few exceptions. In terms of own and cross innovation effects no major influences can be viewed from exporters rather these effects are dominated by importer countries such as Taiwan, Korea, Hong Kong and Singapore. Australia has the least influence in terms of volatility spillover effects. This study also sheds light on the behaviour of the effects of external shocks. It has been revealed that the lagged and cross volatility spillover effects are asymmetric, with some cases positive and other cases negative. On balance, positive effects dominate. However, in regards to the own and cross volatility persistence effects, over time India, Singapore, Australia and Korea are the major players while New Zealand has the least influence. Despite having unique influence of the US market in terms of mean spillover effects it is found to be less influential in case of volatility transmission where regional or geographical proximity matters. Although food price mean returns reveal weak evidence regarding most markets, the influence of the US market should be taken account of in policy and forecasting purposes. The main message this study brings forward is that although there is weak mean own and cross spillover effects among food markets there is strong persistent risk spillover effects (in terms of volatility) among them which should be considered for business and public policy analysis. A further examination of this issue can be done with broader sets of data from other parts of the world, and also the analysis can be performed with panel econometric methods.

References

Abott, P.C., C. Hurt, and W.E. Tyner (2009) "What's driving food prices?" *Farm foundation issue report*.

Alom, M.F., B. D. Ward and B. Hu (2010) "Cross country mean and volatility spillover effects of food prices: evidence for Asia and Pacific" *International Review of Business Research Papers* **6**, 334-355.

Apergis, N. and A. Rezitis (2003a) "Agricultural Price Volatility Spillover Effects: The Case of Greece" *European Review of Agricultural Economics* **30**, 389-406.

Apergis, N. and A. Rezitis (2003b) "Food price volatility and macroeconomic factor volatility: 'heat waves' or 'meteor showers'?" *Applied Economics Letters* **10**, 155-160.

Arshad, F.M. and A. A. A. Hameed (2009) "The longrun relationship between petroleum and cereal prices" *Global Economy and Finance Journal* **2**, 91-100.

Blair, B.J., Ser-Huang, Poon and S. J. Taylor (2001) "Modelling S&P 100 volatility:the information content of stock returns" *Journal of banking and finance* **25**, 1665-1679.

Bloom, S. and R. A. Ratti (1985) "The contribution of food and energy price shocks to relative price variability" *Economics Letters* **18**, 49-52.

Du, X., C. L. Yu and D. J. Hayes (2009) "Speculation and volatility spillover in the crude oil and agricultural commodity markets: A Bayesian analysis", Iowa State University, Department of Economics, Staff General Research Papers.

Engle, R.F. and K. F. Kroner (1995) "Multivariate Simultaneous Generalized ARCH" *Econometric Theory* **11**, 122-150.

Galesi, A. and M. J. Lombardi (2009) "External shocks and interantional inflation linkages: a global VAR analysis" *European central bank* **WP. 1062**.

Gilbert, C.L. (2010) "How to understand high food prices" *Journal of Agricultural Economics* **61**, 398-425.

Gnan, E. (2009) "Energy, Commodity and Food Price Volatility: What Policy Responses?" *CESifo Forum* **10**, 21-28.

Hakro, A.N. and A. M. Omezzine (2010) "Macroeconomic Effects of Oil and Food Price Shocks to the Oman Economy" *Middle Eastern Finance and Economics*, 72-90.

Headey, D. and S. Fan (2008) "Anatomy of a Crisis: The Causes and Consequences of Surging Food Prices" *Agricultural Economics* **39**, 375-391.

Higgs, H. and A. C. Worthington (2004) "Transmission of Returns and Volatility in Art Markets: A Multivariate GARCH Analysis" *Applied Economics Letters* **11**, 217-222.

Hua, P. (1998) "On Primary Commodity Prices: The Impact of Macroeconomic/Monetary Shocks" *Journal of Policy Modeling* **20**, 767-790.

Kim, J.H. and H. Doucouliagos (2008) "Realized Volatility and Correlation in Grain Futures Markets: Testing for Spillover Effects" *Review of Futures Markets* **17**, 275-300.

Kroner, K.F., K. P. Kneafsey, S. Claessens and T. C. Mills (1999) Forecasting Volatility in Commodity Markets. In *Economic forecasting Volume 2*. pp.486-504: Elgar Reference Collection. International Library of Critical Writings in Economics, vol. 108.

Cheltenham, U.K. and Northampton, Mass.:

Elgar; distributed by American International Distribution Corporation, Williston, Vt.

Lee, S.J. (2009) "Volatility Spillover Effects among Six Asian Countries" *Applied Economics Letters* **16**, 501-508.

Mitchell, D. (2008) "A note on rising food prices" The World Bank, Policy Research Working Paper Series: 4682.

Narayan, P.K. and S. Narayan (2007) "Modelling oil price volatility" *Energy Policy* **35**, 6549-6553.

Nazlioglu, S. and U. Soytas (2010) "World oil prices and agricultural commodity prices: Evidence from an emerging market" *Energy Economics* **In Press, Corrected Proof**.

Newbery, D.M. (1989) "The Theory of Food Price Stabilisation" *Economic Journal* **99**, 1065-1082.

Park, I. (2009) "Regional trade agreements in East Asia: will they be sustainable?" *Asian Economic Journal* **23**, 169-194.

Pindyck, R.S. (2004) "Volatility in natural gas and oil markets" *Journal of Energy and Development* **30**, 1-19.

Radetzki, M. (2006) "The Anatomy of Three Commodity Booms" *Resources Policy* **31**, 56-64.

Regnier, E. (2007) "Oil and energy price volatility" *Energy Economics* **29**, 405-427.
Robles, M., M. Torero and von Braun (2009) "When speculation matters" *International Food Policy Institute Issue Brief* **57**.
Rosegrant, M.W., T. Zhu, S. Msangi and T. Sulser (2008) "Global Scenarios for Biofuels: Impacts and Implications" *Review of Agricultural Economics* **30**, 495-505.
Voyiatzis, A., D. Pallis and E. Katsouli (2002) "Causality between Food Prices and Other Goods Prices: Evidence from the EU Member-States" *Agricultural Economics Review* **3**, 61-70.
Wei, Y., Y. Wang and Huang, D. (2010) "Forecasting crude oil market volatility: further evidence using GARCH-class models" *Energy Economics* **In Press, Corrected Proof**.
Zheng, Y., H. W. Kinnucan and H. Thompson (2008) "News and volatility of food prices" *Applied Economics* **40**, 1629-1635.