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Modelling Volatility Spillovers for Bio-ethanol, Sugarcane and Corn

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Abstract: The recent and rapidly growing interest in biofuel as an energy source has raised concerns about its impact on the prices, returns and volatility of related agricultural commodities. Analyzing the spillover effects on agricultural commodities and biofuel helps commodity suppliers hedge their portfolios and manage the risk and co-risk of their biofuel and agricultural commodities. In the past, there have been many papers concerned with analyzing crude oil and agricultural commodities separately. The purpose of this paper is to examine the volatility spillovers for spot and futures returns on bio-ethanol and related agricultural commodities, specifically corn and sugarcane, using the multivariate diagonal BEKK conditional volatility model. The daily data used are from 31 October 2005 to 14 January 2015. The empirical results show that in 2 of 6 cases, there were significant negative co-volatility spillover effects, specifically corn on subsequent sugarcane co-volatility with corn, and sugarcane on subsequent corn co-volatility with sugarcane. In the other 4 cases, there were no significant co-volatility spillover effects. There are significant positive co-volatility spillover effects in all 6 cases, namely between corn and sugarcane, corn and ethanol, and sugarcane and ethanol, and vice-versa for each of the three pairs of commodities. It is clear that the futures prices of bio-ethanol and the two agricultural commodities, corn and sugarcane, have stronger co-volatility spillovers than their spot price counterparts. These empirical results suggest that the bio-ethanol and agricultural commodities should be considered as viable futures products in financial portfolios for risk management.

Keywords: *Biofuel, spot prices, futures prices, returns, volatility*

1. INTRODUCTION

The recent and rapidly growing interest in biofuel as an energy source has raised concerns about its impact on the prices, returns and volatility of related agricultural commodities. Analyzing the spillover effects on agricultural commodities and biofuel helps commodity suppliers hedge their portfolios and manage the risk and co-risk of their biofuel and agricultural commodities. In the past, there have been many papers concerned with analyzing crude oil and agricultural commodities separately. The purpose of this paper is to examine the volatility spillovers for spot and futures returns on bio-ethanol and related agricultural commodities, specifically corn and sugarcane, using the multivariate diagonal BEKK conditional volatility model.

Of the alternative multivariate conditional volatility models that are available (see McAleer (2005) for a critical analysis), the only model with asymptotic properties, namely consistency and asymptotic normality, for the Quasi-Maximum Likelihood Estimator (QMLE) of the parameters is the diagonal BEKK model, which can be derived from a vector random coefficient autoregressive stochastic process (it should be noted that the full matrix version of the BEKK model cannot be derived from a stochastic process, so that the QMLE of the associated parameters have no asymptotic properties.

The daily data used are from 31 October 2005 to 14 January 2015. The empirical results show that in 2 of 6 cases, there were significant negative co-volatility spillover effects, specifically corn on subsequent sugarcane co-volatility with corn, and sugarcane on subsequent corn co-volatility with sugarcane. In the other 4 cases, there were no significant co-volatility spillover effects. There are significant positive co-volatility spillover effects in all 6 cases, namely between corn and sugarcane, corn and ethanol, and sugarcane and ethanol, and vice-versa for each of the three pairs of commodities.

It is clear that the futures prices of bio-ethanol and the two agricultural commodities, corn and sugarcane, have stronger co-volatility spillovers than their spot price counterparts. These empirical results suggest that the bio-ethanol and agricultural commodities should be considered as viable futures products in financial portfolios for risk management.

2. MODEL SPECIFICATIONS

Using univariate conditional volatility models, Lence and Hayes (2002) examined crude oil, bio-fuel and energy policy, Jin and Frechette (2004) used long memory models, and Egelkraut et al (2007) examined spillovers between spot and derivatives returns (though this can be problematic using univariate models). There seems to have been little or no analysis of asymmetry or leverage in differentiating the effects of positive and negative shocks of equal magnitude eon subsequent volatility.

Volatility spillovers using multivariate models have been considered by Cesar and Marco (2012) and Sendhil et al. (2013), while the BEKK model was used in Trujillo-Barrera et al. (2012), the DCC model was estimated in Cabrera and Schulz (2013), while the CCC, VARMA-GARCH, DCC and BEKK models were analyzed for crude oil spot and futures returns by Chang et al. (2011).

The diagonal BEKK model will be used to examine volatility spillover effects. The full BEKK model, together with the conditional mean equation for financial returns, is given as:

$$Y_t = A_0 + A_1 Y_{t-1} + \varepsilon_t \quad (1)$$

$$H_t = CC' + A\varepsilon_{t-1}\varepsilon'_{t-1}A' + BH_{t-1}B' \quad (2)$$

Where Y_t denotes returns, ε_t is the returns shock, H_t is the conditional covariance matrix of the returns shocks, and H, C, A and B are $m \times m$ matrices. As the full BEKK model in equation (2) is not derived from a stochastic process, it has no regularity conditions, except by assumption, and hence has no asymptotic properties. Moreover, estimation of the full BEKK model involves $3m(m+1)/2$ parameters. As the number of parameters increases, convergence of the estimation algorithm becomes problematic because of the associated "curse of dimensionality". Convergence of the estimation algorithm is more likely when the number of commodities is less than 4.

A special case of full BEKK is the diagonal BEKK model, which can be derived from an underlying stochastic process when the matrices A and B are diagonal or scalar matrices, with $a_{ii} > 0$ for all $I = 1,\ldots,m$

and $|b_{jj}| < 1$ for all $j = 1,\ldots,m$. The QMLE of the parameters of the diagonal BEKK model can be shown to be consistent and asymptotically normal, so that standard statistical inference is valid. The diagonal BEKK model is given as equation (2), but where the matrices A and B are given as:

$$A = \begin{bmatrix} a_{11} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & a_{mm} \end{bmatrix}, \quad B = \begin{bmatrix} b_{11} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & b_{mm} \end{bmatrix}$$

The diagonal BEKK model permits a test of Co-volatility Spillover effect, which is the effect of a shock in commodity *j* at *t*-1 on the subsequent co-volatility between *j* and another commodity at *t*. Given the nature of the diagonal BEKK model, the subsequent covolatility must be between *j* and *i* at *t*. This leads to the definition of a Co-volatility Spillover Effect as:

Definition:

$$\frac{\partial H_{ij,t}}{\partial \varepsilon_{j,t-1}} = a_{ii} \times a_{jj} \times \varepsilon_{i,t-1}, \quad i \neq j.$$

As $a_{ii} > 0$ for all i, a test of the co-volatility spillover effect is:

$H_0: a_{ii}a_{jj}=0$,

which is a test of the significance of $a_{ii}a_{jj}$ in the following co-volatility spillover effect, as $\varepsilon_{i,t-1} \neq 0$:

$$\frac{\partial H_{ij,t}}{\partial \varepsilon_{j,t-1}} = a_{ii}a_{jj}\varepsilon_{i,t-1}, \; i\neq j.$$

If H_0 is rejected, there is a spillover from the returns shock of commodity *j* at *t*-1 to the (co-)volatility between commodities *i* and *j* at *t* that depends only on the returns shock of commodity *i* at *t*-1. It should be emphasized that the returns shock of commodity *j* at *t*-1 does not affect the co-volatility spillover of commodity *j* on the (co-) volatility between commodities *i* and *j* at *t*. Moreover, spillovers can and do vary for each observation *t*-1.

3. EMPIRICAL RESULTS

It was found in 2 of 6 cases that there were significant negative co-volatility spillover effects, specifically corn on subsequent sugarcane co-volatility with corn, and sugarcane on subsequent corn co-volatility with sugarcane. In the other 4 cases, there were no significant co-volatility spillover effects. Unlike the case of spot prices, there are significant positive co-volatility spillover effects in all 6 cases, namely between corn and sugarcane, corn and ethanol, and sugarcane and ethanol, and their reverse counterparts. It is clear that the futures prices of bio-ethanol and the two agricultural commodities, corn and sugarcane, have stronger co-volatility spillovers than their spot price counterparts. These results suggest that the bio-ethanol and agricultural commodities should be considered as viable futures products in financial portfolios for risk management.

4. CONCLUDING REMARKS

For spot prices, it was found that in 2 of 6 cases, there were significant negative co-volatility spillover effects, specifically corn on subsequent sugarcane co-volatility with corn, and sugarcane on subsequent corn co-volatility with sugarcane. In the other 4 cases, there were no significant co-volatility spillover effects. For futures prices, unlike the case of spot prices, there were significant positive co-volatility spillover effects in all 6 cases, namely between corn and sugarcane, corn and ethanol, and sugarcane and ethanol, and their reverse counterparts. It is clear that the futures prices of bio-ethanol and the two agricultural commodities, corn and sugarcane, have stronger co-volatility spillovers than their spot price counterparts. These results suggest that the bio-ethanol and agricultural commodities should be considered as viable futures products in financial portfolios for risk management.

Table 1. Daily data from 31 October 2005 to 14 January 2015.

Variable name	Definitions	Transaction market	Description
$Corn_{sr}$	Corn spot returns	United States Department of Agriculture (USDA)	Corn Number 2 Yellow (Cents / Bushel)
$Corn_{fr}$	Corn future returns	Chicago Board of Trade (CBOT)	Chicago Board of Trade (CBOT) - Corn
$Sugar_{sr}$	Sugar spot returns	United States Department of Agriculture (USDA)	Raw Cane Sugar (Cents / Pound)
$Sugar_{fr}$	Sugar future returns	Coffee, Sugar & Cocoa Exchange Inc (CSCE)	CSCE-Sugar #11
$Ethanol_{sr}$	Ethanol spot returns	Thomson Reuters	Ethanol, Spot Chicago United States (Dollars / Gallon)
$Ethanol_{fr}$	Ethanol future returns	Chicago Board of Trade (CBOT)	ECBOT-Ethanol

Table 2. Descriptive Statistics.

Returns	Mean	SD	Max	Min	Skewness	Kurtosis	Jarque-Bera
$Corn_{sr}$	0.005	1.661	10.888	-12.307	-0.287	4.704	8796.03
$Corn_{fr}$	0.005	1.581	9.801	-24.528	-0.643	14.858	87105.45
$Sugar_{sr}$	-0.003	2.321	20.904	-20.097	-0.118	5.644	10666.35
$Sugar_{fr}$	0.006	2.892	81.621	-35.390	2.656	81.990	2644229.19
$Ethanol_{sr}$	-0.014	3.637	94.039	-79.729	2.341	290.993	8480493.70
$Ethanol_{fr}$	-0.027	2.178	9.403	-21.566	-2.115	15.951	26030.49

Table 3. Diagonal BEKK-Spot ($Corn_{sr}$) ($Ethanol_{sr}$).

	C		**A**		B	
$Corn_{sr}$	0.099*** (0.016)	0.002 (0.005)	**0.222*** (0.012)**		0.964*** (0.004)	
$Ethanol_{sr}$		0.086*** (0.004)		**0.172*** (0.002)**		0.983*** (0.000)

*** significance level 1%.

Table 4. Diagonal BEKK-Spot ($Sugar_{sr}$) ($Ethanol_{sr}$).

	C		A		B	
$Sugar_{sr}$	0.908***	0.106	**0.297*****		0.862***	
	(0.018)	(0.102)	**(0.013)**		(0.004)	
$Ethanol_{sr}$		2.120***		**-0.001**		0.203***
		(0.009)		**(0.591)**		(0.020)

*** significance level 1%.

Table 5. Diagonal BEKK-Spot ($Corn_{sr}$) ($Sugar_{sr}$) ($Ethanol_{sr}$).

	C			A			B		
$Corn_{sr}$	0.422***	0.171***	0.164	**0.224*****			0.958***		
	(0.076)	(0.045)	(0.162)	**(0.0256)**			(0.011)		
$Sugar_{sr}$		0.753***	0.074		**0.248******			0.902***	
		(0.029)	(0.110)		**(0.024)**			(0.008)	
$Ethanol_{sr}$			1.999***			**-0.001**			0.377***
			(0.013)			**(0.024)**			(0.014)

** significance level 5%, *** significance level 1%.

Table 6. Risk Spillovers.

Market	$\frac{\partial H_{ij,t}}{\partial \varepsilon_{j,t-1}}$	**Average Co-volatility Spillovers**
Spot	j=corn, i=sugarcane	-0.0036 (0.224 0.248 (-0.064))
	j=sugarcane, i=corn	-0.0009 (0.224 0.248 (-0.016))
	j=corn, i=ethanol	0
	j=ethanol, i=corn	0
	j=sugarcane, i=ethanol	0
	j=ethanol, i=sugarcane	0

Table 7. Diagonal BEKK-Futures ($Corn_{fr}$) ($Ethanol_{fr}$).

	C		A		B	
$Corn_{fr}$	0.082***	0.044***	**0.205*****		0.972***	
	(0.010)	(0.005)	**(0.009)**		(0.002)	
$Ethanol_{fr}$		0.038***		**0.327*****		0.951***
		(0.007)		**(0.007)**		(0.002)

** significance level 5%, *** significance level 1%.

Table 8. Diagonal BEKK-Futures ($Sugar_{fr}$) ($Ethanol_{fr}$).

	C		A		B	
$Sugar_{fr}$	0.025***	0.004	**0.199*** **		0.978***	
	(0.006)	(0.005)	**(0.009)**		(0.002)	
$Ethanol_{fr}$		0.095***		**0.299*** **		0.949***
		(0.012)		**(0.010)**		(0.003)

** significance level 5%, *** significance level 1%.

Table 9. Diagonal BEKK-Futures ($Corn_{fr}$) ($Sugar_{fr}$) ($Ethanol_{fr}$).

	C			A			B		
$Corn_{fr}$	0.080***	0.004	0.047***	**0.187*** **			0.975***		
	(0.010)	(0.003)	(0.005)	**(0.010)**			(0.002)		
$Sugar_{fr}$		0.022***	0.002		**0.176*** **			0.982***	
		(0.005)	(0.004)		**(0.008)**			(0.002)	
$Ethanol_{fr}$			0.045***			**0.323*** **			0.951***
			(0.007)			**(0.007)**			(0.002)

** significance level 5%, *** significance level 1%.

Table 10. Risk Spillovers.

Market	$\frac{\partial H_{ij,t}}{\partial \varepsilon_{j,t-1}}$	**Average Co-volatility Spillovers**
Futures	j=corn, i=sugarcane	0.0009 (0.187 0.176 0.028)
	j=sugarcane, i=corn	0.0004 (0.187 0.176 0.011)
	j=corn, i=ethanol	0.0005 (0.187 0.323 0.008)
	j=ethanol, i=corn	0.0007 (0.187 0.323 0.011)
	j=sugarcane, i=ethanol	0.0005 (0.176 0.323 0.008)
	j=ethanol, i=sugarcane	0.0016 (0.176 0.323 0.028)

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