### Mean and Variance Dynamics Between Agricultural Commodity Prices, Crude Oil Prices and Exchange Rates

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- Energy impacts commodity production
  - Increased use of chemical and petroleum derived inputs in agriculture
  - Increased use of agricultural commodities in energy production
  - Recent developments in energy policy have fundamentally changed the relationship between agricultural commodity prices and energy commodities



- Investigate whether casual relationships exist between means and variances of agricultural commodity prices, crude oil prices and exchange rates
- Investigate whether these casual relationships change over time



- Study on variance causation to understand how information is transmitted across prices and markets
- Changes in variance reflect the arrival of information and the extent to which market evaluates and assimilates new information
- It is of interest to both academics and practitioners



- Campiche et al. (2007)
  - Covariability between crude oil prices and corn, sorghum, sugar, soybeans, soybean oil, and palm oil prices
  - Corn and soybeans prices are cointegrated with crude oil price during the 2006-2007 period but not during the 2003-2005 period
  - Crude oil prices do not adjust to changes in the corn and soybean market



- Harri, Nalley and Hudson (2009)
  - Price relationship between primary agricultural commodities, exchange rates, and crude oil prices
  - Cointegrating relation between corn, soybeans cotton prices and crude oil prices starts April 2006
  - Exchange rates play a role in the linkage of prices
  - Crude oil prices Granger-cause corn prices
  - Corn prices do not Granger-cause crude oil prices



- Daily data April 2003-March 2009
- Futures prices for corn and crude oil obtained from Commodity Research Bureau
- Exchange rate data obtained from Federal Reserve Economic Data database
- Based on previous research divide the sample in two subperiods:
  - April 2003-March 2006
  - April 2006-March 2009



• Assume that agricultural and crude oil prices and the exchange rate can be generated by:

• (1) 
$$Y_t = \mu_{Y,t} + h_{Y,t}^{0.5} \varepsilon_{Y,t}$$

 where Y is a vector of n series of exchange rates and prices, μ<sub>Y,t</sub> and h<sub>Y,t</sub> are respectively the conditional mean and conditional variance vectors of Y<sub>t</sub> and ε<sub>Y,t</sub> is a vector of independent white noise processes with zero mean and unit variance



• Use the vector autoregressive formulation between the price and exchange rate series:

• (2) 
$$\mu_{Y,t} = A + \sum_{i=1}^{p} B_i Y_{t-i}$$

 Specify conditional variances, h<sub>Y,t</sub> as multivariate generalized autoregressive conditional heteroscedastic (MGARCH) (p, q) processes:

• (3) 
$$h_{Y,t} = \kappa_Y + \sum_{i=1}^p \theta_{Y,i} (Y_{t-i} - \mu_{Y,t-i})^2 + \sum_{j=1}^q \varphi_{Y,j} h_{Y,t-j}$$
  
where  $\kappa_i \theta_i \varphi_j$  are parameters to be estimated



- Cheung and Ng (1996) test of causality in variance based on the sample cross-correlation function (CCF) of the squared residuals
- Similar to the causality in mean test
- Hong (2001) introduce flexible weights for the cross-correlations at each lag
- Hafner and Herwartz (2006) Lagrange multiplier test in the framework of the MGARCH model

### VAR with GARCH Heteroscedasticity Parameters for Period Apr 03 – Mar 06

Variable	FX	Crude	Corn	h(FX)	h(Crude)	h(Corn)
Intercept	-0.001	0.006**	0.001	-0.085	-0.233	-0.813*
FX(t)	-	-	-0.107**	-	-	-
Crude(t)	-0.04*	-	-	-	-	-
Crude(t-1)	-	-0.07***	-	-	-	-
Arch				9.481**	3.869***	36.20*
Garch				0.989*	0.958*	0.884*
	N=739		Log likeliho			

\*, \*\*, \*\*\* represent significance at the 1, 5, and 10 percent level respectively.

#### Standardized and Squared Standardized Residuals for Period Apr 03 – Mar 06

Lag	FX and Crude	FX and Corn	Crude and Corn	FX and Crude	FX and Corn	Crude and Corn
	CCF of Standardized Residuals (Mean Causality)			CCF of Squared Sta	s (Variance Causality)	
-6	-0.04522	0.08388	-0.03369	-0.0536	0.00899	-0.03053
-5	0.02821	-0.04026	-0.02882	-0.00322	-0.02618	-0.00812
-4	0.04056	0.03228	-0.01017	-0.03016	0.02743	-0.00891
-3	0.02283	0.00709	-0.06725	-0.00441	-0.01194	0.014
-2	0.04125	-0.01394	-0.00451	0.04204	-0.04111	-0.04239
-1	0.03009	-0.0485	-0.06574	-0.02197	-0.01668	-0.01681
0	-0.03816	-0.00349	0.04101	0.0427	0.00439	0.00982
1	-0.06801	-0.03023	0.00878	0.01267	0.01208	-0.01431
2	-0.0098	-0.01188	0.01207	-0.05025	0.01777	-0.00305
3	-0.02604	-0.02399	0.01677	-0.0237	-0.03148	-0.00568
4	0.02348	0.01799	0.04335	-0.01334	-0.03447	-0.00265
5	0.07232	-0.03371	-0.05219	0.06853	-0.00456	-0.012
6	-0.01455	0.02239	0.02303	0.03642	-0.01804	-0.01523

\*, \*\*, \*\*\* represent significance at the 1, 5, and 10 percent level respectively.



CCF of Standardized and Squared Standardized Residuals for Period Apr 03 – Mar 06

- VAR model results indicate the presence of causality in mean:
  - Crude oil prices Granger cause the exchange rates but not corn prices
  - The exchange rates Granger cause the corn prices
- CCF of standardized residuals show no further evidence of causality in mean
- CCF of squared standardized residuals show no evidence of causality in variance

# Results

#### **VAR with GARCH Heteroscedasticity Parameters for Period Apr 06 – Mar 09** before Accounting for Causality in Variance

Variable	FX	Crude	Corn	h(FX)	h(Crude)	h(Corn)
Intercept	-0.001	0.007	0.004	-0.578*	-0.334*	-0.240*
FX(t)	-	-	-0.373*	-	-	-
Crude(t)	-0.051*	-	0.157*	-	-	-
Arch				34.093*	1.511**	4.081*
Garch				0.925*	0.922*	0.958*
	N=730		Log likeliho	ood 2553		

\*, \*\*, \*\*\* represent significance at the 1, 5, and 10 percent level respectively.

#### **CCF of Standardized and Squared Standardized Residuals for Period Apr 06 – Mar 09** before Accounting for Causality in Variance

Lag	FX and Crude	FX and Corn	<b>Crude and Corn</b>	FX and Crude	FX and Corn	Crude and Corn
-	CCF of Stand	lardized Residuals (	Mean Causality)	CCF of Squared Sta	ndardized Residual	s (Variance Causality)
-6	-0.00446	0.08035	-0.04938	-0.00079	0.00588	0.17376*
-5	-0.02607	0.02974	-0.10184	0.02831	-0.03092	0.05839
-4	-0.02537	0.03804	-0.03099	0.00617	-0.00765	0.07941
-3	0.00618	0.03941	0.08037	-0.01323	0.02281	0.03344
-2	-0.01833	-0.07301	-0.10316	-0.03767	-0.02321	0.08096
-1	0.00374	0.03108	-0.10493	0.00267	-0.02517	0.13104*
0	0.01861	0.03259	-0.04298	-0.0134	-0.02299	0.10496*
1	-0.09649	-0.00818	0.02997	-0.00639	0.00707	0.07388
2	-0.02294	-0.0051	-0.01487	-0.01012	0.01157	0.09403
3	-0.02433	0.09211	-0.02545	-0.01854	-0.02187	-0.01342
4	-0.06638	0.02589	0.01715	-0.00389	0.02234	0.03787
5	-0.00734	0.00295	0.02057	-0.03807	-0.02082	0.05235
6	-0.07452	0.06944	0.03425	0.01215	-0.02784	0.05656

\*, \*\*, \*\*\* represent significance at the 1, 5, and 10 percent level respectively.



CCF of Standardized and Squared Standardized Residuals for Period Apr 03 – Mar 06 before Accounting for Causality in Variance

- VAR model results indicate the presence of causality in mean:
  - Crude oil prices Granger cause both the exchange rates and corn prices
  - The exchange rates Granger cause the corn prices
- CCF of standardized residuals show no further evidence of causality in mean
- CCF of squared standardized residuals show evidence of causality in variance between crude and corn

# Results

## VAR with GARCH Heteroscedasticity Parameters for Period Apr 06 – Mar 09 after Accounting for Causality in Variance

Variable	FX	Crude	Corn	h(FX)	h(Crude)	h(Corn)
Intercept	-0.001	0.004	0.002	-0.571*	-0.313*	-1.678*
FX(t)	-	-	-0.362*	-	-	-
Crude(t)	-0.052*	-	0.168*	-	-	-
Arch				33.869*	1.423**	16.792*
Garch				0.926*	0.927*	0.569*
Crude(t)**2						-0.054**
Crude(t-1)**2						0.126*
Crude(t-6)**2						0.058*
	N=730		Log likeliho	od 2599		

\*, \*\*, \*\*\* represent significance at the 1, 5, and 10 percent level respectively.

#### **CCP of Standardized and Squared Standardized Residuals for Period Apr 06 – Mar 09** after Accounting for Causality in Variance

Lag	FX and Crude	FX and Corn	Crude and Corn	FX and Crude	FX and Corn	Crude and Corn		
	CCF of Standardized Residuals (Mean Causality)			CCF of Squared Sta	CCF of Squared Standardized Residuals (Variance Co			
-6	0.06839	-0.03241	-0.00078	-0.00201	0.00397	0.06839		
-5	0.02077	-0.05908	0.02826	-0.0428	-0.0271	0.02077		
-4	0.00911	-0.03405	0.00604	-0.0174	0.02962	0.00911		
-3	0.03544	0.05224	-0.01323	-0.01998	-0.03767	0.03544		
-2	-0.08996	-0.0909	-0.03765	0.00294	-0.01453	-0.08996		
-1	0.02011	-0.10238	0.00257	-0.04315	-0.00108	0.02011		
0	0.02116	-0.02709	-0.01346	0.01496	-0.03518	0.02116		
1	-0.02867	0.00209	-0.00621	0.04306	-0 00045	-0 02867		
2	0.0187	0.0317	0.00073	0.02700	0.00/98	0.0187		
3	-0.0107	-0.0317	-0.00973	0.02/99	0.00400	-0.0107		
5	0.09563	-0.00429	-0.01827	0.03428	-0.02331	0.09563		
4	0.02551	0.02883	-0.00357	0.0163	0.00389	0.02551		
5	-0.01309	0.05258	-0.038	-0.05322	0.00727	-0.01309		
6	0.07662	0.04026	0.01187	-0.04973	0.03663	0.07662		

\*, \*\*, \*\*\* represent significance at the 1, 5, and 10 percent level respectively.



CCF of Standardized and Squared Standardized Residuals for Period Apr 03 – Mar 06 after Accounting for Causality in Variance

- The squared terms of current and lagged (lag one and six) crude oil prices in the variance equation for corn are highly significant
  - Crude oil price variance Granger causes the variance of corn prices
- CCF of standardized residuals show no further evidence of causality in mean
- CCF of squared standardized residuals show no further evidence of causality in variance



- Empirical evidence shows that variance of crude oil prices Granger causes the variance of corn prices
- Empirical evidence supports the findings that information flows from the energy markets into the corn markets
- These findings raise implications for the role of the corn futures contracts as a hedging tool for corn producers