Journal of Agricultural and Resource Economics 37(1):77–97

Do USDA Announcements Affect Comovements Across Commodity Futures Returns?

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The value of USDA reports has long been a question of interest for researchers and practitioners. However, the impact of announcements on comovements across related commodity prices has not been explored beyond financial asset markets. This is important because the structure of the relationship between commodities could change depending on the type of information revealed in the announcement, thus affecting price perceptions, hedging ratios, and portfolio return variance. This study simultaneously measures the impact of selected USDA reports on the conditional variances and covariances of returns on corn, lean hogs, soybeans, soybean meal, and soybean oil futures contracts using a multivariate GARCH model. It is shown that the largest movements in covariances are observed on the release days of Feed Outlook, Grain Stocks, and Hogs and Pigs reports.

Key words: announcement effects, futures markets, market efficiency, multivariate GARCH, USDA reports

Introduction

Many researchers have investigated the impact of various USDA reports on commodity futures prices and volatility in response to the ongoing debate on the economic value of public information. For example, Sumner and Mueller (1989) report that releases of USDA harvest forecasts–especially in August, September, and October–impact daily price changes in corn and soybean futures markets. Colling and Irwin (1990) use market survey data to show that live hog futures prices react significantly to the unanticipated components of the Hogs and Pigs reports. Fortenbery and Summer (1993), on the other hand, examine the effects of Crop Production reports and World Agricultural Supply and Demand Estimates (WASDE) on corn and soybean futures and options markets. They find that the impact of USDA reports diminished from 1985 through 1989 relative to earlier periods. Mann and Dowen (1996) show that release of Hogs and Pigs reports increased price variability and trade volume in live hog and pork belly futures markets. Schaefer, Myers, and Koontz (2004) investigate the role of proprietary information on price discovery within the U.S. live cattle futures market and conclude that proprietary information has explanatory power for forecasting final revised numbers in Cattle on Feed reports and for predicting short-term price movements of futures contracts. They also report that initial estimates in the Cattle on Feed reports still have new information that moves prices even after accounting for proprietary data. Isengildina, Irwin, and Good (2006) analyze the impact of six selected USDA reports on volatility of live/lean hog and live cattle futures returns using a univariate TARCH-in-mean model and show that most USDA report releases increase volatility in these markets. More recently, McKenzie (2008) concludes that USDA

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Review coordinated by Gary Brester.

crop reports still convey new information to the corn futures market by showing that the reports would improve market participants' price expectations if released a day earlier.

However, as outlined in Isengildina, Irwin, and Good (2006), one of the main limitations of the existing literature on the value of public information is that previous studies analyze a single USDA report at a time. This approach does not allow for comparison of market reaction across related reports. The authors, therefore, include in their study six USDA announcements related to livestock markets and simultaneously estimate their impact in a given market. A limitation of the existing literature and not addressed by Isengildina, Irwin, and Good (2006) is the lack of investigation of covariances around announcement days. It has been shown that announcements have significant effects on distributions of futures prices (both on returns, the first moment, and their variances, the second moment). However, the impact of announcements on the structure of covariances (a mixed moment) is not well studied.

The study of comovement across commodity futures returns is important for several reasons. First, comovement patterns over time and changes in their structure in response to major announcements provide information that might help disaggregate announcement types. The traditional theory of comovement, called fundamental-based comovement, argues that comovement in prices reflects comovement in fundamentals (Barberis, Shleifer, and Wurgler, 2005). New information about commodity fundamentals leads to a search for a new equilibrium through the interactions of buyers and sellers. However, the arrival of important news could cause an interruption in the price discovery process if information is incorporated more quickly into the prices of some commodities than others (Christiansen and Ranaldo, 2007). Thus, analyzing the behavior of comovements on announcement days might help to discover whether changes in comovements can be linked to changes in fundamentals provided in the USDA reports. Second, covariance is a central issue in risk management and optimal hedging. Most studies on optimal hedging involve maximizing expected returns and minimizing return variances. Anderson and Danthine (1980, 1981) show that, for multiproduct hedging, the optimal hedge ratio depends on variances and covariances among futures prices and between futures and spot prices.[1] Thus, any change in covariances among futures returns on announcement days would affect optimal hedge ratios, making movement in and out of the markets around announcement days profitable (or unprofitable). Third, correlation among the assets is important for asset allocation decisions. According to modern portfolio theory, unsystematic risk can be minimized by holding negatively correlated assets. However, benefits from diversification can still be attained with positively correlated assets, as long as correlation is low. Thus, if correlation between asset returns changes around announcement days, so does portfolio return variance. This study focuses on the link between changes in comovements and changes in commodity fundamentals to better understand the structure of inter-related commodity markets and the effects of announcements on them. More specifically, it tries to answer how covariances vary with information contained in the USDA reports.

The importance of announcement effects on correlations between asset prices has been shown recently in the financial assets literature. Christiansen and Ranaldo (2007) analyze the news impact of macroeconomic announcements on realized variance and correlation of bond and stock returns and show that macroeconomic announcements have a significant impact on realized stock-bond correlation. Further, they find that realized correlation depends on general economic conditions, and that different announcements have different effects. Similarly, Thomakos et al. (2008) analyze the effects of macroeconomic announcements on return volatilities, covariances, and correlations between Eurodollar futures and U.S. Treasury bond futures and show that all three react to the information content of announcements.

However, to the best of our knowledge, no such published work exists for agricultural commodity futures markets, despite strong connections between these markets due to biological factors, fixed-

[1] For more information on this literature see, for example, Peterson and Leuthold (1987), Myers and Thompson (1989), Tzang and Leuthold (1990), Myers (1991), Fackler and McNew (1993), Myers and Hanson (1993), Myers and Hanson (1996), Garcia, Roh, and Leuthold (1995), Sanders and Manfredo (2004), Dahlgran (2002), Dahlgran (2005), Dahlgran (2009).

proportion production processes, and substitutability in production or consumption. Consider, for instance, a livestock producer (cattle, hog, or poultry) using a corn-based feeding program to grow animals to slaughter weight. Given the production process and the interaction between output and input prices, not only do potential direct effects on livestock prices exist as a result of new information contained in USDA livestock reports, but also a potential impact from grain reports as well. Further, depending on the information released in the reports, the direction of comovement between commodities might change. Previous studies can tell us how returns or volatility in livestock markets respond to USDA reports related to corn, but they cannot tell us whether covariance between these commodities changes. And, as discussed above, a change in comovement between commodity returns has implications for producers, hedgers, commodity traders, and speculators, since it affects price perceptions, hedging ratios, and portfolio variance.

Given the importance of the relationship between agricultural commodities linked through the supply chain, this study asks how the relationships among inter-related commodity futures contracts change on announcement days. To this end, two different production processes are considered: (1) a hog finisher who uses lean hogs futures contracts to hedge output price risk and corn and soybean meal futures contracts to hedge input price risk, and (2) a soybean processor who uses soybeans futures for input price risk and soybean meal and oil futures for output price risk. Both Christiansen and Ranaldo (2007) and Thomakos et al. (2008) use a two-step procedure in their analyses of correlations among financial assets, in which variances and covariances are estimated separately, and therefore might result in inefficient estimates. In contrast, this study adds to the literature on announcement effects by using a multivariate GARCH model both to capture the time-varying volatility of selected commodity futures returns and to simultaneously estimate the effects of USDA announcements on both conditional variances and covariances of these returns.

Results show that several USDA reports considered have a significant effect on both futures return variances and covariances for the hog finisher example. The conditional variance of corn futures returns increases by 75% on days when Grain Stocks reports are released and 56% on days when WASDE reports that coincide with crop production reports are released. The conditional variance of soybean meal increases by 54% on days when Crop Progress reports are released. Hogs and Pigs reports increase conditional variance of lean hogs returns by 61% and decrease covariances between corn and lean hogs returns and between soybean meal and lean hogs returns by approximately 416%, changing the sign of covariance from positive to negative. While Grain Stocks reports cause a dramatic increase in variance of soybeans returns (143%), Hogs and Pigs and WASDE reports with crop production reports moderately affect covariances in the soybean complex (from -4% to 8%). These results provide empirical evidence regarding the importance of USDA reports in individual commodity markets as well as their interaction, suggesting that the behavior of comovements among commodities can be linked to information in USDA reports.

Data Construction

To determine inter-related commodity markets, specific production processes in agriculture are considered. Producers face price risk in both input and output markets as a result of uncertainty in expected future prices. Increases in input prices raises production costs, while reductions in output prices lowers firm revenue. Producers can use futures markets to hedge the risk that prices may be unfavorable by the time production begins or output is sold. Thus, as argued in Tzang and Leuthold (1990), price risk can be hedged during the production planning period by a long futures position for input and a short futures position for output. When input is purchased the long input futures position is closed, and when output is sold the short output futures position is closed. This hedging strategy provides a link between futures markets of input and output commodities in a production process. Two scenarios, differing by number of inputs and outputs, are considered to determine which related futures contracts to use in the empirical analysis.

Table 1. Futures Contracts Used in Empirical Analyses

	Corn-Soybean Meal-Lean Hogs			Soybeans-Soybean Meal-Soybean Oil		
Calendar Month	**(C)**	**(SM)**	**(LH)**	**(S)**	**(SM)**	**(BO)**
January	March	March	June	March	May	May
February	March	March	June	March	May	May
March	May	May	July	May	July	July
April	May	May	July	May	July	July
May	July	July	August	July	September	September
June	July	July	August	July	September	September
July	September	September	December	September	December	December
August	September	September	December	September	December	December
September	December	December	April	November	January	January
October	December	December	April	November	January	January
November	December	December	April	January	March	March
December	March	March	June	January	March	March

Notes: All contracts refer to Chicago Board of Trade and Chicago Mercantile Exchange (now known as CME Group) futures contracts. C, SM, LH, S, and BO refer to corn, soybean meal, lean hogs, soybeans, and soybean oil futures, respectively.

Two Inputs-Single Output Case: Hog Finisher

A hog finisher buys young pigs and feeds them with mainly corn and soybean meal until they reach slaughter weight. By buying (long) corn and soybean meal futures contracts and selling (short) lean hogs futures contracts before any spot market transaction occurs, the finisher can hedge price risk in both input and output markets. For the empirical analysis, a continuous production process is assumed. Following the examples in Cook (2009), the data set is constructed by using nearby corn and soybean meal contracts that expire one to four months earlier than the lean hogs contracts in a given calendar month. Table 1 shows the futures contracts used in constructing the data set. This data set is called Corn-Soybean Meal-Lean Hogs (C-SM-LH). For example, in January and February, March corn, March soybean meal, and June lean hogs futures contracts are used while in March and April, May corn, May soybean meal, and July lean hogs contracts are used.

Single Input-Two Outputs Case: Soybean Processor

A soybean processor buys soybeans to produce and sell soybean meal and soybean oil. A soybean-crushing hedging strategy involves buying (long) soybeans futures and selling (short) soybean meal and oil futures contracts before any spot market transaction occurs.[2] The nearby soybeans futures contract is used (except for August) to construct the data for the empirical analysis. To allow some time for the soybean crushing process, soybean meal and oil contracts are chosen so that they expire two to three months later than the soybeans contract. This data set is called Soybeans-Soybean Meal-Soybean Oil (S-SM-BO). Table 1 shows that March soybeans and May soybean meal and oil contracts are used in January and February and May soybeans and July soybean meal and oil are used in March and April.

USDA Reports

Eleven USDA reports, most of which have been widely studied, are chosen for this analysis: Prospective Plantings, Acreage, Cattle, Cattle on Feed, Crop Progress, Feed Outlook, Grain Stocks,

[2] Tzang and Leuthold (1990) study risk-minimizing hedge ratios under this hedging strategy. Similar studies include Fackler and McNew (1993) and Dahlgran (2002), Dahlgran (2005).

Hogs and Pigs, Livestock, Dairy, and Poultry Outlook, Oil Crops Outlook, and WASDE. Market participants follow these reports closely for their information on market conditions.

Reports directly related to supply and demand conditions in corn, soybeans, and soybean products markets are as follows. Prospective Plantings reports are published once a year at the end of March by the National Agricultural Statistics Service (NASS) and contain the expected plantings as of March 1st for several crops, including corn and soybeans. At the end of every June, NASS releases Acreage reports to present planted and/or harvested acreages by state for those commodities. NASS issues weekly Crop Progress reports during the growing season; these contain planting, fruiting, and harvesting progress and overall condition of selected crops, including corn and soybeans in major producing states. Feed Outlook reports are published monthly by the Economic Research Service (ERS) and examine supply, use, prices, and trade for feed grains, including supply and demand prospects in major importing and exporting countries. These reports focus on corn but also contain information on sorghum, barley, oats, and hay. Grain Stocks reports are issued quarterly by NASS and contain stocks of multiple crops, including corn and soybeans, as well as the number and capacity of on- and off-farm storage facilities. Monthly Oil Crops Outlook reports are released by ERS and contain supply, use, prices, and trade for oil crops, primarily soybeans and products, including supply and demand prospects in major importing and exporting countries. WASDE reports are released monthly by the World Agricultural Outlook Board and provide comprehensive forecasts of supply and demand for major U.S. and global crops and U.S. livestock.

On the livestock side, additional reports are of concern to market participants. Cattle reports are released by NASS twice annually and contain the inventory numbers and values of all cattle and calves, number of operations and size group estimates by class and state. Monthly Cattle on Feed reports are also published by NASS, and they contain total number of cattle and calves on feed, placements, marketings, and other disappearances, number of feedlots and fed cattle marketings. Because corn is used to feed cattle, these two reports are important demand-side indicators for corn. Hogs and Pigs reports are issued by NASS four times yearly and present data on the U.S. pig crop for 17 major states and the entire U.S., including inventory number by class, weight group, and value of hogs and pigs, farrowings, farrowing intentions.[3] The report also includes the number of operations keeping hogs, the number of hog operations, and percent of inventory by size groups. Livestock, Dairy, and Poultry Outlook (LDPO) reports are issued monthly in newsletter format by ERS and focus on current and forecast production, prices, and trade for each of these sectors.

Release times vary across these reports. Acreage, Feed Outlook, Grain Stocks, and LDPO reports are all released before futures markets open, whereas the remaining reports (except for Prospective Plantings and WASDE) are released after futures markets close. In order to capture the impact, if any, of the reports on futures prices, the dummy variables representing the report release days should be constructed accordingly. For example, if a report is released today before trading hours, then the impact of this report should be observed in today's settlement price. Accordingly, for reports released before markets open, the announcement day dummy variables take the value of one on the exact release date. On the other hand, if a report is published today after trading hours then the impact of this report should not be seen on today's settlement price, but rather on tomorrow's settlement price. Thus, for reports released after markets close, the announcement day dummy variables take the value of one on the day following the release.[4] Prospective Plantings and WASDE report release times have changed during the sample period. Before 1996, Prospective Plantings reports were released after market close; for these years its dummy variable is set to one on the days following the release. Beginning in 1996 the dummy variable is set to one on the exact release days. Similarly, WASDE reports were scheduled to be released after market close before May 1994, after which its release

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[3] However, the report release schedule has changed to monthly from January 2001 through September 2003, after which quarterly schedule was resumed. All report release days including those monthly reports are included in the data.

[4] It should be noted that these dummy variables might also be capturing the effect of overnight trading or any other information flow after the trading hours.

time was switched to before market opening. Therefore, the WASDE dummy variable is set to one on the days following the release before May 1994, and on the exact release days afterwards.

Because both Acreage and Prospective Plantings reports are published only once a year, the number of observations on each report is very small during the sample period. Both reports represent supply conditions for corn and soybeans, so they can be considered as one report. Accordingly, the two dummy variables representing the release days are combined and denoted as APP. Further, following Fortenbery and Summer (1993) and Irwin, Good, and Gomez (2001), the WASDE dummy variable is divided into two categories: one that coincides with the NASS crop production reports from August through November (denoted as WASDE Mix) and one that conveys only outlook information from December through July (denoted as WASDE Pure).

Futures Returns

During the period of study, corn, soybeans, soybean meal, and soybean oil futures contracts were traded at the Chicago Board of Trade (CBOT) and lean hogs futures contracts were traded at the Chicago Mercantile Exchange (CME). Both exchanges are now operating under the CME Group. Corn futures have contract months of March, May, July, September, and December. Contract size is 5,000 bushels; prices are quoted in cents per bushel. Delivery months for soybeans futures are January, March, May, July, August, September, and November. Prices are quoted as cents per bushel; contract size is 5,000 bushels. For soybean oil and soybean meal, delivery months are January, March, May, July, August, September, October, and December. Soybean oil futures are quoted as cents per pound; contract size is 60,000 pounds. Soybean meal prices are stated in dollars and cents per short ton; contract size is 100 short tons. Contract months for lean hogs futures are February, April, May, June, July, August, October, and December. Prices are quoted in cents per pound; contract size is 40,000 pounds.

Daily returns on these selected futures contracts are measured as:

$$R_{it} = 100 \times (\ln F_{it} - \ln F_{i,t-1}), \tag{1}$$

where $\ln F_{it}$ is the natural logarithm of the settlement price of commodity i's futures contract on day t.[5] Because some of the USDA reports were first available in 1995, the sample period is chosen as January 1995 though April 2009.[6]

All futures contracts are subject to daily price limits, which restricts futures price movements and may therefore suppress market reaction to new information or events. Corn price limits were 12 cents per bushel from 7/15/1993 to 8/27/2000, 20 cents from 8/27/2000 to 3/28/2008, and 30 cents afterwards (CME, 2011). Soybeans were subject to daily price limits of 30 cents per bushel from 10/18/1976 to 8/27/2000, 50 cents from 8/27/2000 to 3/28/2008, and 70 cents afterwards (Park and Irwin, 2005). The earliest price limit found for soybean meal is \$20 per short ton, which is the current limit. For soybean oil, the price limit was 2 cents per pound before 3/28/2008 and 2.5 cents afterwards. Live hogs futures were switched to lean hogs futures starting from February 1997 contract.[7] The price limit for live hogs was 1.5 cents per pound. For lean hogs, the limit was 2 cents, raised to 3 cents after 4/25/2006. Using these price limits, the days with limit moves during the study period were 50 times for corn, 30 times for soybeans, 10 times for soybean meal, 1 time for soybean oil, and 58 times for lean hogs. These correspond to 1.58%, 0.97%, 0.32%, 0.03%, and 1.83% of the sample size of each commodity. Based on the results in Park (2000), no adjustments for limit move days were made, as they represent a small portion of the data.

[5] Because USDA reports are released either before trading begins or after trading ends on day t and announcement dummy variables are constructed accordingly, $F_{i,t-1}$ and F_{it} span the report releases. Another measure of daily futures return uses close-to-open price changes to identify announcement effects, as seen in Isengildina, Irwin, and Good (2006). Here, close-to-close price changes are used to ensure that noninstantaneous reactions to announcements are captured. This makes the estimated announcement effects more conservative if the impact is disseminated into prices instantaneously in the opening.

[6] These reports are Crop Progress, Feed Outlook, LDPO, and Oil Crops Outlook.

[7] Because this study relies on futures returns for the analysis, the change in contract specifications should not affect results.

Table 2. Summary Statistics

	C-SM-LH (N=3,170)				S-SM-BO (N=3,086)			
	Mean	**Min.**	**Max.**	**Std. Dev.**	**Mean**	**Min.**	**Max.**	**Std. Dev.**
$R_t = 100 \times (\ln F_t - \ln F_{t-1})$								
Corn	−0.03	−7.58	7.40	1.60				
Lean Hogs	0.01	−5.52	4.94	1.24				
Soybean Meal	0.04	−8.54	7.53	1.66	0.03	−7.83	7.64	1.63
Soybeans					0.01	−7.41	6.73	1.52
Soybean Oil					−0.01	−7.14	8.08	1.49
$\lvert R_t \rvert = \lvert 100 \times (\ln F_t - \ln F_{t-1}) \rvert$								
Corn	1.17	0	7.58	1.09				
Lean Hogs	0.93	0	5.52	0.82				
Soybean Meal	1.22	0	8.54	1.12	1.19	0	7.83	1.11
Soybeans					1.11	0	7.41	1.03
Soybean Oil					1.10	0	8.08	1.01
Announcement Day Dummy Variables	*n*				*n*			
Acreage & Prospective Plantings	29				29			
Cattle	29				29			
Cattle on Feed	156				156			
Crop Progress	426				415			
Feed Outlook	163				163			
Grain Stocks	58				58			
Hogs and Pigs	63				64			
Livestock, Dairy, and Poultry Outlook	169				169			
Oil Crops Outlook	161				161			
WASDE Mix	57				55			
WASDE Pure	113				113			

Notes: Sample periods span from January 1995 to April 2009. Summary statistics are computed using both announcement and non-announcement days. The variable *n* for the announcement day dummy variables represent the total number of report releases in each sample. C, SM, LH, S, and BO refer to corn, soybean meal, lean hogs, soybeans, and soybean oil futures, respectively.

Table 2 presents summary statistics for daily returns and absolute daily returns for each data set using both announcement and non-announcement days. The total number of observations is 3,170 for the C-SM-LH data set and 3,086 for the S-SM-BO data set. The average size of the absolute daily returns (a commonly used volatility measure) of lean hogs futures is 0.9 percentage points. For corn and soybean meal futures it is 1.2 percentage points and for soybeans and soybean oil futures 1.1 percentage points. In total there were 1,424 and 1,412 report releases, respectively, in C-SM-LH and S-SM-BO data sets. Some of the report releases overlap, leaving a total of 1,121 and 1,109 announcement days.[8] As can be seen in the table, APP and Cattle reports were released 29 times, Cattle on Feed 156 times, Crop Progress between 415 to 426 times, Feed Outlook around 163 times,

[8] For days with more than one report release (24% of announcement days), this clustering might lead to a bias concern. However, as long as all relevant reports are included in the analysis their impact should be distributed in the estimated coefficients. Bias should occur when all relevant reports are not included and the one included picks up all the impact. However, results should be interpreted carefully, as clustering might result in less precise estimates.

Grain Stocks 58 times, Hogs and Pigs around 64 times, LDPO 169 times, Oil Crops Outlook around 161 times, WASDE Mix around 57 times, and WASDE Pure 113 times.

Multivariate GARCH Model

A multivariate GARCH model is used to capture time-varying volatility and simultaneously estimate the impact of external factors, including USDA reports, on variances of daily returns of related commodity futures. GARCH models are useful in explaining stock price distributions (Bollerslev, 1987; Bollerslev, Engle, and Wooldridge, 1988; French, Schwert, and Stambaugh, 1987; Baillie and DeGennaro, 1990). They are also useful for analyzing commodity futures price distributions. Commodity futures exhibit time-varying volatility and can be effectively studied using GARCH models (see, for example, Baillie and Myers, 1991; Myers, 1991; Myers and Hanson, 1993; Yang and Brorsen, 1993; Goodwin and Schnepf, 2000).

The main empirical issue with multivariate models is that covariance matrix must be positive definite at each time period in order for the likelihood function to be defined. Various parametric formulations have been developed to overcome this problem, including modelling the conditional covariance matrix directly; this class includes the VEC and BEKK models. In the VEC model, developed by (Bollerslev, Engle, and Wooldridge, 1988), each conditional variance and covariance is a function of all lagged conditional variances and covariances, as well as lagged squared returns and cross-products of returns. Estimating parameters is computationally demanding. Further, the conditions necessary for covariance matrix to be positive definite for all time periods are restrictive. A simplified version of the model assumes that the coefficient matrices on lagged squared returns and lagged conditional variances are diagonal matrices (called diagonal VEC model). However, this is too restrictive since no interaction is allowed across different variances and covariances. In the BEKK (Baba-Engle-Kraft-Kroner) model, the covariance matrix is positive definite by construction (Engle and Kroner, 1995). A simplified version is called diagonal BEKK, similar to the diagonal VEC model. Estimation of the full BEKK model is also computationally demanding, but since the structure itself ensures positive definiteness this does not need to be imposed separately, which is an advantage over the VECH model. Because the goal of this study is to analyze whether covariances between commodity returns are affected by USDA reports, the full BEKK model allowing interaction among different variances and covariances is chosen to specify the variance-covariance matrix.

Lagged return values are included as regressors in the mean equations to account for autocorrelation in futures returns (Taylor, 1986; Yang and Brorsen, 1994). External factors affecting futures returns and their volatility are usually incorporated by adding dummy variables into the mean and/or variance equations. Common external factors include day-of-the-week effects (Junkus, 1986; Yang and Brorsen, 1994; Isengildina, Irwin, and Good, 2006) and seasonality (Anderson, 1985; Hennessy and Wahl, 1996; Isengildina, Irwin, and Good, 2006). Here, a Monday dummy variable[9] is included in both mean and variance equations, whereas monthly dummy variables, accounting for seasonality, and announcement day dummy variables are included only in the variance and covariance equations.[10] In a similar study, Isengildina, Irwin, and Good (2006) analyze the impact of selected USDA reports in lean hogs and live cattle futures return volatility, but they do not consider the interaction of these markets with other commodity futures. In this study, this is accomplished by simultaneously estimating inter-related commodity returns.

[9] The models including other days of the week are rejected based on likelihood ratio tests.

[10] Announcement effects can also be measured in the mean equation. However, in order to correctly measure the impact on mean return, one needs to distinguish between anticipated and unanticipated report components, which requires expectations data for the upcoming report releases. Because these data are not available for all reports considered in this study, announcement effects are included only in the variance equation. Further, models with announcement day dummy variables in the mean equations are rejected based on likelihood ratio tests.

Denoting the vector of commodity returns on day t by R_t, the trivariate case in matrix form is given by:

$$R_t = \mu + \sum_{p=1}^{5} \psi_p R_{t-p} + \theta MON_t + u_t, \tag{2}$$

where $u_t \sim MVN(0, H_t)$ and

$$H_t = C'C + A'u_{t-1}u'_{t-1}A + B'H_{t-1}B + G'GX_t. \tag{3}$$

In the above equation, X_t is a data matrix that includes the Monday dummy variable, monthly dummy variables, and announcement day dummy variables expected to affect conditional variances and covariances. H_t is a 3×3 symmetric matrix with variances on the diagonal and covariances off the diagonal, C and G are 3×3 lower triangular, and A and B are full 3×3 matrices defined as:

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\ h_{12,t} & h_{22,t} & h_{23,t} \\ h_{13,t} & h_{23,t} & h_{33,t} \end{bmatrix}, \quad C = \begin{bmatrix} c_{11} & 0 & 0 \\ c_{21} & c_{22} & 0 \\ c_{31} & c_{32} & c_{33} \end{bmatrix}, \quad G = \begin{bmatrix} g_{11} & 0 & 0 \\ g_{21} & g_{22} & 0 \\ g_{31} & g_{32} & g_{33} \end{bmatrix},$$

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}, \quad B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}. \tag{4}$$

In this BEKK representation variances $(h_{11,t}, h_{22,t}, h_{33,t})$ and covariances $(h_{12,t}, h_{13,t}, h_{23,t})$ involve several functions of the estimated parameters as follows:

$$\begin{aligned} h_{11,t} = {} & (c_{11}^2 + c_{21}^2 + c_{31}^2) + a_{11}^2 u_{1,t-1}^2 + a_{21}^2 u_{2,t-1}^2 + a_{31}^2 u_{3,t-1}^2 + 2a_{11}a_{21}u_{1,t-1}u_{2,t-1} + \\ & 2a_{11}a_{31}u_{1,t-1}u_{3,t-1} + 2a_{21}a_{31}u_{2,t-1}u_{3,t-1} + b_{11}^2 h_{11,t-1} + b_{21}^2 h_{22,t-1} + b_{31}^2 h_{33,t-1} + \\ & 2b_{11}b_{21}h_{12,t-1} + 2b_{11}b_{31}h_{13,t-1} + 2b_{21}b_{31}h_{23,t-1} + (g_{11}^2 + g_{21}^2 + g_{31}^2)X_t, \end{aligned} \tag{5}$$

$$\begin{aligned} h_{22,t} = {} & (c_{22}^2 + c_{32}^2) + a_{12}^2 u_{1,t-1}^2 + a_{22}^2 u_{2,t-1}^2 + a_{32}^2 u_{3,t-1}^2 + 2a_{12}a_{22}u_{1,t-1}u_{2,t-1} + \\ & 2a_{12}a_{32}u_{1,t-1}u_{3,t-1} + 2a_{22}a_{32}u_{2,t-1}u_{3,t-1} + b_{12}^2 h_{11,t-1} + b_{22}^2 h_{22,t-1} + b_{32}^2 h_{33,t-1} + \\ & 2b_{12}b_{22}h_{12,t-1} + 2b_{12}b_{32}h_{13,t-1} + 2b_{22}b_{32}h_{23,t-1} + (g_{22}^2 + g_{32}^2)X_t, \end{aligned} \tag{6}$$

$$\begin{aligned} h_{33,t} = {} & c_{33}^2 + a_{13}^2 u_{1,t-1}^2 + a_{23}^2 u_{2,t-1}^2 + a_{33}^2 u_{3,t-1}^2 + 2a_{13}a_{23}u_{1,t-1}u_{2,t-1} + \\ & 2a_{13}a_{33}u_{1,t-1}u_{3,t-1} + 2a_{23}a_{33}u_{2,t-1}u_{3,t-1} + b_{13}^2 h_{11,t-1} + b_{23}^2 h_{22,t-1} + b_{33}^2 h_{33,t-1} + \\ & 2b_{13}b_{23}h_{12,t-1} + 2b_{13}b_{33}h_{13,t-1} + 2b_{23}b_{33}h_{23,t-1} + g_{33}^2 X_t, \end{aligned} \tag{7}$$

$$
\begin{aligned}
h_{12,t} = {} & (c_{21}c_{22} + c_{31}c_{32}) + a_{11}a_{12}u_{1,t-1}^2 + a_{21}a_{22}u_{2,t-1}^2 + a_{31}a_{32}u_{3,t-1}^2 + \\
& (a_{11}a_{22} + a_{12}a_{21})u_{1,t-1}u_{2,t-1} + (a_{11}a_{32} + a_{12}a_{31})u_{1,t-1}u_{3,t-1} + \\
& (a_{21}a_{32} + a_{22}a_{31})u_{2,t-1}u_{3,t-1} + b_{11}b_{12}h_{11,t-1} + b_{21}b_{22}h_{22,t-1} + b_{31}b_{32}h_{33,t-1} + \\
& (b_{11}b_{22} + b_{12}b_{21})h_{12,t-1} + (b_{11}b_{32} + b_{12}b_{31})h_{13,t-1} + (b_{21}b_{32} + b_{22}b_{31})h_{23,t-1} + \\
& (g_{21}g_{22} + g_{31}g_{32})X_t,
\end{aligned} \tag{8}
$$

$$
\begin{aligned}
h_{13,t} = {} & c_{31}c_{33} + a_{11}a_{13}u_{1,t-1}^2 + a_{21}a_{23}u_{2,t-1}^2 + a_{31}a_{33}u_{3,t-1}^2 + \\
& (a_{11}a_{23} + a_{13}a_{21})u_{1,t-1}u_{2,t-1} + (a_{11}a_{33} + a_{13}a_{31})u_{1,t-1}u_{3,t-1} + \\
& (a_{21}a_{33} + a_{23}a_{31})u_{2,t-1}u_{3,t-1} + b_{11}b_{13}h_{11,t-1} + b_{21}b_{23}h_{22,t-1} + b_{31}b_{33}h_{33,t-1} + \\
& (b_{11}b_{23} + b_{13}b_{21})h_{12,t-1} + (b_{11}b_{33} + b_{13}b_{31})h_{13,t-1} + (b_{21}b_{33} + b_{23}b_{31})h_{23,t-1} + \\
& g_{31}g_{33}X_t,
\end{aligned} \tag{9}
$$

$$
\begin{aligned}
h_{23,t} = {} & c_{32}c_{33} + a_{12}a_{13}u_{1,t-1}^2 + a_{22}a_{23}u_{2,t-1}^2 + a_{32}a_{33}u_{3,t-1}^2 + \\
& (a_{12}a_{23} + a_{13}a_{22})u_{1,t-1}u_{2,t-1} + (a_{12}a_{33} + a_{13}a_{32})u_{1,t-1}u_{3,t-1} + \\
& (a_{22}a_{33} + a_{23}a_{32})u_{2,t-1}u_{3,t-1} + b_{12}b_{13}h_{11,t-1} + b_{22}b_{23}h_{22,t-1} + b_{32}b_{33}h_{33,t-1} + \\
& (b_{12}b_{23} + b_{13}b_{22})h_{12,t-1} + (b_{12}b_{33} + b_{13}b_{32})h_{13,t-1} + (b_{22}b_{33} + b_{23}b_{32})h_{23,t-1} + \\
& g_{32}g_{33}X_t,
\end{aligned} \tag{10}
$$

GARCH models have been extended to include long-memory effects, asymmetric effects, and structural changes. Jin and Frechette (2004), for instance, found that volatility of grain futures prices exhibits long-term memory. However, the authors did not account for systematic time-to-delivery and seasonal effects, which themselves could induce persistence. In contrast, the current study incorporates monthly dummy variables into the model to account for seasonality. Studying time-to-delivery effects and, more importantly, distinguishing its effect from seasonality requires the use of multiple futures contracts traded simultaneously (Goodwin and Schnepf, 2000; Karali and Thurman, 2010). Because this study considers only one futures contract for each commodity, the model does not include time-to-delivery effects. Further, because empirical evidence of asymmetry effects varies with the commodity studied,[11] they are not included in the multivariate GARCH model to be consistent across the commodities included. Finally, structural changes, shown as time-varying spillover effects between markets, have minor effects on hedging performance.[12] The current study,

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[11] Park and Jei (2010) investigated time-varying hedge ratios for corn and soybeans using bivariate GARCH models with various distributional assumptions and included asymmetry effects in the conditional variances (correlations) to see whether past values of negative shocks generate higher volatility (correlations) than positive shocks. Their results showed that asymmetric effects in conditional variances were significant for corn futures returns but insignificant for soybeans. Asymmetric effects in the conditional correlation equations were not significant for either commodity. Further, for both corn and soybeans, models with normal distributions outperformed models with Student-*t* and skewed-*t* distributions in terms of variance reduction.

[12] Wu, Guan, and Myers (2011) found significant volatility spillovers from crude oil to corn cash and futures markets, and that markets have become more connected following the introduction of the Energy Policy Act of 2005. Based on this stronger volatility link between crude oil and corn prices, the authors studied the performance of a new cross-hedging strategy for managing corn price risk using crude oil futures. However, they found no significant benefit from cross-hedging compared with traditional hedging in corn futures alone, despite the dramatic structural change in the volatility link between these two commodities.

however, allows a constant spillover effect between the markets in the multivariate GARCH model through the use of full BEKK parametrization of the covariance matrix.

Empirical Results

Multivariate GARCH models for each data set are estimated using the RATS software package. Results include the elements in vectors μ, ψ, θ in mean equation (2) and the elements in matrices C, G, A, and B in variance equation (3). However, as shown in equations (5)-(10), the conditional variance and covariance equations are composed of combinations of these estimated parameters. Because the main interest here is the impact of public information on futures return volatility and covariances, only the coefficients on the announcement variables in equations (5)-(10) and their t-statistics (computed with the Delta method) are presented in tables 3 and 4. The complete set of results are available upon request.

Corn-Soybean Meal-Lean Hogs

Mean equation results (not shown here) indicate a constant return of 0.06 in lean hogs futures markets. Autocorrelation exists in the first and fifth lags of both corn and soybean meal returns. Only the third lagged return is significant for lean hogs. Evidence of a Monday effect is found in corn and lean hogs futures returns; both are lower by about 0.1 percentage points compared to other days of the week.

Table 3 presents the transformed announcement-day parameters in the variance and covariance equations and their t-statistics. The bottom part of the table shows model diagnostics. Based on the Ljung-Box Q statistics, the independence of the standardized residual series for corn and soybean meal cannot be rejected, while that of lean hogs can be rejected at the 1% level. However, the multivariate Q statistic (not reported here), a multivariate version of the Ljung Box Q statistic, shows evidence of joint independence of standardized residual series. To test whether the announcement day dummy variables add any value to the model, an alternative model with no announcement effects in the variance-covariance matrix is also estimated. Based on the likelihood ratio test, this restricted model can be rejected at the 1% level, showing that the USDA reports are an important source of new information in corn, soybean meal, and lean hogs markets.

Estimation results show constant variances of 0.48 for corn and 0.09 for lean hogs futures returns. Constant covariance is -0.13 between corn and soybean meal, -0.17 between corn and lean hogs, and 0.09 between soybean meal and lean hogs. The own ARCH and GARCH effects in a given variance equation ($u^2_{i,t-1}$ and $h_{ii,t-1}$ for commodity i) are statistically significant in all commodity markets. While volatility is highly persistent in corn and soybean meal markets (with GARCH parameters of 0.90 and 0.85), it is much less persistent in lean hogs markets (0.15). The coefficient on $h_{22,t-1}$ is statistically significant in both corn and lean hogs conditional variance, showing spillover effects from soybean meal market to the others. That is, lagged volatility of soybean meal return affects current volatilities of corn and lean hogs returns, but the magnitude is small. Except for the conditional variance of soybean meal, the dummy variable for Monday is significant. Variances of corn and lean hogs returns and their covariance are higher on Mondays, while covariances between corn and soybean meal and between soybean meal and lean hogs are lower. Seasonal volatility is prominent in all markets, especially in the corn market, with higher levels of volatility in all months compared to December.

The expected sign for a USDA report in a conditional variance equation is positive, as it implies that under market efficiency, the report provides new information to market participants. On the other hand, a negative sign would indicate that the report is decreasing the conditional variance and therefore reducing the information available to the market, creating an anomaly (Isengildina, Irwin, and Good, 2006). Results in table 3 show that all announcement day dummy variables have positive coefficients, as expected. All of the USDA announcements except for the APP and Cattle

Table 3. Transformed Variance Parameters: Corn - Soybean Meal - Lean Hogs

Variable/Statistics	Var (C)	Var (SM)	Var (LH)	Cov (C,SM)	Cov (C,LH)	Cov (SM,LH)
APP	0.83	0.11	0.34	−0.08	−0.39	−0.06
	(1.63)	(0.85)	(1.25)	(−0.36)	(−1.60)	(−0.33)
Cattle	0.69	0.27	0.25	0.09	0.08	0.26
	(1.70)	(0.78)	(0.98)	(0.49)	(0.56)	(1.23)
Cattle on Feed	0.09	0.10	0.00	0.03	−0.00	−0.00
	(1.09)	(0.57)	(0.02)	(0.52)	(−0.04)	(−0.04)
Crop Progress	0.28	1.45	0.03	0.63	0.08	0.20
	(2.21)	(6.31)	(0.32)	(4.61)	(0.63)	(0.64)
Feed Outlook	0.62	0.25	0.11	0.39	0.26	0.17
	(2.99)	(1.53)	(0.92)	(2.90)	(1.68)	(1.88)
Grain Stocks	1.84	0.77	0.47	0.98	−0.29	−0.41
	(3.74)	(3.54)	(1.34)	(4.62)	(−1.56)	(−2.30)
Hogs and Pigs	0.84	0.93	0.92	0.47	−0.56	−0.71
	(3.96)	(2.79)	(3.90)	(2.26)	(−4.05)	(−2.77)
LDPO	0.27	0.05	0.03	−0.01	−0.07	−0.21
	(2.32)	(1.15)	(0.75)	(−0.16)	(−1.54)	(−0.77)
Oil Crops Outlook	0.18	0.06	0.05	0.07	−0.04	−0.05
	(1.84)	(0.90)	(0.76)	(1.46)	(−0.99)	(−1.07)
WASDE Mix	1.39	0.36	0.11	0.29	0.11	−0.10
	(5.67)	(2.68)	(0.97)	(2.74)	(1.51)	(−1.62)
WASDE Pure	0.37	0.15	0.41	−0.01	−0.04	−0.25
	(2.48)	(1.12)	(1.96)	(−0.12)	(−0.47)	(−2.45)
No. of Obs.	3,170					
Log Likelihood	-15,739.61					
Ljung-Box Q statistics	45.82	32.28	63.57			
and p-values	(0.24)	(0.80)	(0.01)			
Likelihood Ratio test	316.60					
for the null of no announcement	(0.00)					
effects in variance equations						

Notes: C, SM, and LH refer to corn, soybean meal, and lean hogs futures, respectively. Mean equation is $R_t = \mu + \sum_{p=1}^{5} \psi_p R_{t-p} + \theta MON_t + u_t$, where $u_t = [u_{1t} \quad u_{2t} \quad u_{3t}]'$ follows multivariate normal distribution with mean zero and variance H_t. The variance-covariance matrix is defined with BEKK formulation as $H_t = C'C + A'u_{t-1}u'_{t-1}A + B'H_{t-1}B + G'GX_t$, where C and G are 3×3 lower triangular and A and B are full 3×3 matrices. The matrix X_t includes the Monday dummy variable, monthly dummy variables, and announcement day dummy variables. Variance and covariance equations are given in equations (5)-(10). The coefficients on each term in the variance and covariance equations and (t-statistics) are presented here. Ljung-Box Q statistics for the test of independence of each standardized residual series and (p-values) are shown. Likelihood ratio test statistic and (p-value) for the null hypothesis of no announcement effects in the variance-covariance matrix are presented.

on Feed reports significantly affect corn futures return variance. The conditional variance of corn futures returns increases on days USDA reports are released, showing that new information is provided to the market in these reports. Variance of soybean meal returns increases on the days with Crop Progress, Grain Stocks, Hogs and Pigs, and WASDE Mix report releases. Variance of lean hogs returns, on the other hand, increases only on days with Hogs and Pigs and WASDE Pure report releases. The conditional covariance between corn and soybean meal returns increases with Crop Progress, Feed Outlook, Grain Stocks, Hogs and Pigs, and WASDE Mix report releases. Covariance between corn and lean hogs increases with Feed Outlook and decreases with Hogs and Pigs reports. Finally, covariance between soybean meal and lean hogs increases with Feed Outlook report releases and decreases with Grain Stocks, Hogs and Pigs, and WASDE Pure reports. The

Table 4. Transformed Variance Parameters: Soybeans - Soybean Meal - Soybean Oil

Variable/Statistics	Var (S)	Var (SM)	Var (BO)	Cov (S,SM)	Cov (S,BO)	Cov (SM,BO)
APP	0.11	0.07	0.11	−0.08	0.03	−0.03
	(1.38)	(0.57)	(0.78)	(−1.09)	(0.64)	(−0.33)
Cattle	0.01	0.02	0.02	0.00	−0.01	−0.02
	(0.31)	(0.43)	(0.48)	(0.09)	(−0.26)	(−0.60)
Cattle on Feed	0.05	0.01	0.02	−0.00	−0.02	0.01
	(0.54)	(0.39)	(0.71)	(−0.05)	(−0.92)	(0.46)
Crop Progress	0.00	0.00	0.00	−0.00	−0.00	0.00
	(0.42)	(0.57)	(0.07)	(−0.31)	(−0.14)	(0.13)
Feed Outlook	0.21	0.00	0.00	−0.00	0.00	−0.00
	(1.61)	(0.22)	(0.09)	(−0.12)	(0.19)	(−0.16)
Grain Stocks	3.22	0.01	0.00	−0.08	−0.01	0.00
	(7.26)	(0.24)	(0.08)	(−0.67)	(−0.15)	(0.15)
Hogs and Pigs	0.07	0.09	0.18	−0.08	−0.09	0.09
	(0.99)	(1.23)	(2.39)	(−1.89)	(−1.36)	(1.83)
LDPO	0.01	0.01	0.00	0.01	−0.00	−0.00
	(0.19)	(1.12)	(0.20)	(0.30)	(−0.07)	(−0.35)
Oil Crops Outlook	0.16	0.00	0.01	−0.00	0.01	−0.00
	(1.48)	(0.13)	(0.42)	(−0.07)	(0.61)	(−0.23)
WASDE Mix	1.14	0.16	0.04	0.01	0.10	−0.07
	(2.82)	(1.62)	(0.94)	(0.21)	(1.79)	(−1.73)
WASDE Pure	0.05	0.00	0.01	−0.01	0.01	−0.00
	(0.73)	(0.18)	(0.40)	(−0.36)	(0.62)	(−0.34)
No. of Obs.	3,086					
Log Likelihood	-11,641.97					
Ljung-Box Q statistics	40.42	47.87	38.42			
and p-values	(0.45)	(0.18)	(0.54)			
Likelihood Ratio test	110.97					
for the null of no announcement	(0.00)					
effects in variance equations						

Notes: C, SM, and LH refer to corn, soybean meal, and lean hogs futures, respectively. Mean equation is $R_t = \mu + \sum_{p=1}^{5} \psi_p R_{t-p} + \theta MON_t + u_t$, where $u_t = [u_{1t} \quad u_{2t} \quad u_{3t}]'$ follows multivariate normal distribution with mean zero and variance H_t. The variance-covariance matrix is defined with BEKK formulation as $H_t = C'C + A'u_{t-1}u'_{t-1}A + B'H_{t-1}B + G'GX_t$, where C and G are 3×3 lower triangular and A and B are full 3×3 matrices. The matrix X_t includes the Monday dummy variable, monthly dummy variables, and announcement day dummy variables. Variance and covariance equations are given in equations (5)-(10). The coefficients on each term in the variance and covariance equations and (t-statistics) are presented here. Ljung-Box Q statistics for the test of independence of each standardized residual series and (p-values) are shown. Likelihood ratio test statistic and (p-value) for the null hypothesis of no announcement effects in the variance-covariance matrix are presented.

finding of significant WASDE Mix and WASDE Pure reports contrasts with findings from Irwin, Good, and Gomez (2001) and Isengildina-Massa et al. (2008), who found that WASDE reports containing both outlook and situation information (WASDE Mix) have significant impact on corn and soybeans futures return variance, while those containing only outlook information (WASDE Pure) do not.

To evaluate the economic impact of these results, the proportions of estimated marginal announcement effects relative to the mean values of estimated conditional variances and covariances are calculated, as in Isengildina, Irwin, and Good (2006). More specifically, each statistically significant announcement effect in the variance and covariance equations presented in table 3 is divided by the average of the associated conditional variance and covariance and then multiplied by 100. Resulting numbers show changes in variance (covariance) as a result of report releases as a proportion of the mean conditional variance (covariance). Table 5(a) presents these proportions, along with average values used in calculations. Grain Stocks reports have the greatest impact on corn futures, with variance 75.05% higher than its average value. The conditional variance of soybean meal is 54.22% higher on days when Crop Progress reports are released. The conditional variance of lean hogs futures return increases the most (60.56%) on days when Hogs and Pigs reports are released. This is not surprising, as Hogs and Pigs is directly related to hog market supply conditions.[13] The conditional covariance between corn and soybean meal is 63.95% higher on days with Grain Stocks reports. On the other hand, WASDE Mix reports have the smallest impact (18.84%) on this covariance. Covariances between corn and lean hogs and between soybean meal and lean hogs are both dramatically lower (by approximately 416%) on days with Hogs and Pigs report releases.

Following Isengildina, Irwin, and Good (2006), these results are interpreted in absolute terms based on the average daily futures prices of the commodities during the sample period. The average prices for corn, soybean meal, and lean hogs were \$2.80/bushel, \$203.63/short ton, and \$64.48/cwt, respectively. In dollar terms, the average conditional variances of corn, soybean meal, and lean hogs were \$0.07/bushel, \$5.44/short ton, and \$0.99/cwt. Thus, an increase of 75.05% in the variance of corn returns due to the Grain Stocks report is about \$0.05/bushel. Similarly, an increase of 54.22% in variance of soybean meal on Crop Progress report days is about \$2.95/short ton, and an increase of 60.56% in lean hogs variance due to Hogs and Pigs reports is about \$0.60/cwt. However, the interpretation of covariances in dollar terms is not straightforward.

Instead, a simple supply and demand analysis can be used to help to understand why covariances change on announcement days. Consider the Hogs and Pigs reports, which have significant effects in all three covariances. These reports provide information on inventories of all hogs by class and weight groups as well as the number of sows farrowing in future months. The market reaction to these reports would depend on the kind of information these reports provide. If, for instance, according to these reports there will be more hogs in the future due to the increasing number of sows farrowing, this could be perceived as an outward supply shift in the hog market, resulting in a decline in hog price. Demand for corn and soybean meal would increase to feed a larger number of hogs, driving up feed prices. Thus, while the prices of two inputs would move in the same direction, the price of the output would move in the opposite direction. As a result, covariance between corn and soybean meal would be positive, as is seen in the empirical results. Table 5(a) shows that covariance between these two inputs is 30.90% higher than its average value of 1.53. On the other hand, covariances between corn and lean hogs and between soybean meal and lean hogs would be negative. Covariance between corn and lean hogs decreases by 415.36% from its average value of 0.13 to -0.41 on days with Hogs and Pigs report releases. Similarly, covariance between soybean meal and lean hogs decreases by 416.35% from its average value of 0.17 to -0.54.

The impact of USDA announcements can also be analyzed visually by looking at weighted futures returns on these three commodities, computed using the fixed production proportions among them. A common ratio for the hog feeding mix is that three pounds of corn and 0.71 pounds of soybean meal will be converted into one pound of pork (Liu, 2005; Cook, 2009). Using these ratios, corn and soybean meal futures returns are converted to a pound equivalent return and the resulting weighted futures return–defined as the difference between the return on lean hogs and the sum of the adjusted returns on corn and soybean meal–is plotted in figure 1(a). The figure shows the weighted return on both days with Hogs and Pigs reports and non-announcement days. Horizontal lines in the figure show one standard deviation range around the mean of the weighted return. The weighted return falls outside this range 36 times out of 63 days with Hogs and Pigs report releases. Thus,

[13] The 60.56% increase in the conditional variance of lean hogs returns due to Hogs and Pigs reports translates into a 31.66% increase in the standard deviation of returns. This is smaller than the 96% reported impact in Isengildina, Irwin, and Good (2006), in which a univariate GARCH model is estimated with only six USDA announcements.

57.14% of the Hogs and Pigs reports during the sample period causes the weighted futures return to widen relative to its average value of 0.01%.

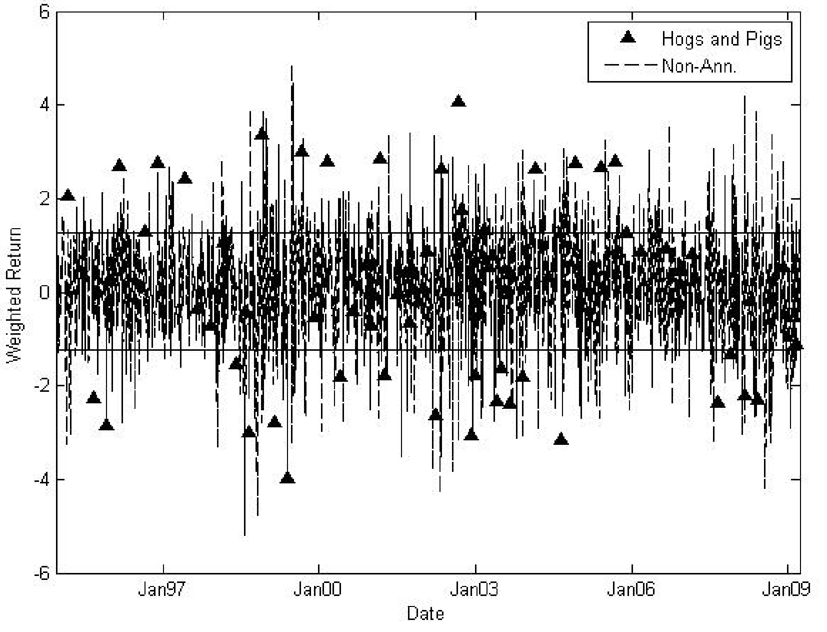
Soybeans-Soybean Meal-Soybean Oil

The estimated conditional mean equation for soybean meal has a constant of 0.02. For soybeans, the first and fifth lags of the daily return are significant, while for soybean meal the fourth and fifth lags are significant. None of the lagged returns of soybean oil are statistically different from zero. The Monday effect on daily returns is significant at the 10% level only for soybean futures, with returns being lower by 0.04 percentage points compared to other days of the week.

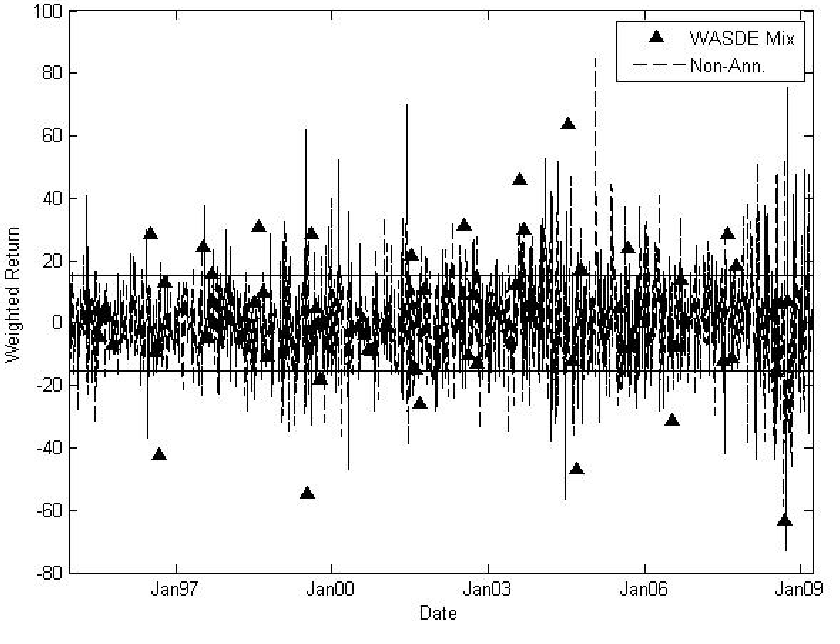
Table 4 presents the transformed announcement-day parameters on the variance and covariance equations and their t-statistics. The p-values of the Ljung-Box Q statistics show that the independence of the standardized residual series obtained from this multivariate GARCH model cannot be rejected; no autocorrelation is left in the residuals and the model fits the data well. Again, the model with no announcement effects in the variance-covariance matrix is rejected using a likelihood ratio test.

Results indicate constant conditional variances of 0.25 and 0.01 for soybeans and soybean meal and a constant covariance of 0.04 between the two of them. In all three variance equations, own ARCH parameters ($u^2_{i,t-1}$ for commodity i) are significant. Further, the squared past disturbances in soybean returns ($u^2_{1,t-1}$) is also significant in soybean meal and oil variance equations. Similarly, $u^2_{2,t-1}$ is significant in variance equations of soybeans and soybean oil. These show spillover effects from soybeans to its by-product markets, as well as from soybean meal to soybeans and soybean oil markets. The own GARCH parameters for each commodity ($h_{ii,t-1}$ for commodity i) show high persistence with coefficients of about 0.9. Further, the lagged variance of soybeans ($h_{11,t-1}$) is significant in the variance equation of soybean oil, showing very small volatility spillover from soybeans to soybean oil markets. The lagged variance of soybean meal returns ($h_{22,t-1}$) is significant in both soybeans and soybean oil return variances. Similarly, the lagged variance of soybean oil returns ($h_{33,t-1}$) is significant in soybeans and soybean meal variances. However, the magnitude of these volatility spillover effects among these markets is very small. There is no evidence that the conditional variances or covariances are different on Mondays compared to other days of the week. January is the only month in which the conditional variance of soybeans returns is higher than December. This differs from the seasonality pattern seen above for corn volatility, most likely because soybeans are less sensitive to weather shocks and Brazil offers an alternative supply source. Soybean meal variance is higher in February, September, and November compared to the reference month of December. The conditional covariances do not exhibit strong seasonality. Covariance between soybeans and soybean meal is higher in January, September, and November, while covariance between soybean meal and oil is higher only in February.

As can be seen in table 4, only Grain Stocks and WASDE Mix report releases increase the conditional variance of soybean returns, showing that these two reports increase the amount of information available to the soybeans market. Interestingly, none of the USDA reports affect soybean meal return variance in contrast to the Corn-Soybean Meal-Lean Hogs case. However, it should be noted that the soybean meal contracts used in these two data sets differ. The C-SM-LH data set includes the first nearby soybean meal contracts while the S-SM-BO data set includes the second nearby soybean meal contracts. Thus, one might argue that the impact of the selected USDA reports are short term for soybean meal, affecting only nearby contracts. The conditional variance of soybean oil return increases only with the release of Hogs and Pigs reports. The same report release causes the conditional covariance to decrease between soybeans and soybean meal and increase between soybean meal and oil. While the release of WASDE Mix reports increases covariance between soybeans and soybean oil, it decreases covariance between soybean meal and oil.



(a) Hog Feeding



(b) Soybean Crushing

Figure 1. Weighed Futures Returns

Table 5. Proportions of Estimated Announcements Effects Relative to Mean Conditional Variances and Covariances

(a) Corn-Soybean Meal-Lean Hogs

Announcement	**Var(C)**	**Var(SM)**	**Var(LH)**	**Cov(C,SM)**	**Cov(C,LH)**	**Cov(SM,LH)**
Cattle	27.92%					
Crop Progress	11.23%	54.22%		40.81%		
Feed Outlook	25.40%			25.26%	192.74%	97.90%
Grain Stocks	75.05%	28.72%		63.95%		−242.38%
Hogs and Pigs	34.11%	34.85%	60.56%	30.90%	−415.36%	−416.35%
LDPO	11.15%					
Oil Crops Outlook	7.49%					
WASDE Mix	56.49%	13.50%	27.17%	18.84%		
WASDE Pure	15.14%					−146.25%
Average	2.46%	2.67%	1.53%	1.53%	0.13%	0.17%

(b) Soybeans-Soybean Meal-Soybean Oil

Announcement	**Var(S)**	**Var(BO)**	**Cov(S,SM)**	**Cov(S,BO)**	**Cov(SM,BO)**
Grain Stocks	143.52%				
Hogs and Pigs		8.35%	−3.70%		7.58%
WASDE Mix	50.87%			5.77%	−5.42%
Average	2.24%	2.17%	2.16%	1.70%	1.25%

Notes: C, SM, LH, S, and BO refer to corn, soybean meal, lean hogs, soybeans, and soybean oil, respectively. The proportions of the predicted announcement effects relative to the mean values of conditional variances and covariances are presented. The announcement effects shown in tables 3-4 are divided by the average values of the estimated conditional variances and covariances from the multivariate GARCH models, and then multiplied by 100.

The proportions of the estimated announcement effects to the mean values of conditional variances and covariances are given in table 5(b). Again, only announcements that had a statistically significant effect as seen in table 4 are presented here. Between the two announcements that affect soybeans return variance, Grain Stocks reports have the greatest impact, with a 143.52% increase in variance. The conditional variance of soybean oil increases by 8.55% from its average value on days with Hogs and Pigs report releases. On the same report release days, covariance is 3.70% lower between soybeans and soybean meal and 7.58% higher between soybean meal and oil. While covariance between soybeans and soybean oil is 5.77% higher on the release days of WASDE Mix reports, covariance between soybean meal and oil is lower by 5.42%. Compared to the results with the C-SM-LH data set, the impacts of USDA reports are significantly smaller, except for soybeans variance.

Variance equation results are interpreted in absolute terms based on average daily futures prices as above. Average prices for soybeans and soybean oil were \$6.73/bushel and \$0.26/lb., respectively. Thus, in absolute terms, the average conditional variance of soybeans and soybean oil was \$0.16/bushel and \$0.56/lb. An increase of 143.52% in the conditional variance of soybeans due to Grain Stocks report releases is about \$0.23/bushel. Similarly, an increase of 8.35% in soybean oil variance due to Hogs and Pigs report releases is about \$0.02/lb. Thus, announcement effects on soybean oil volatility is fairly small.

To understand the change in covariances on announcement days, consider the WASDE Mix reports. These reports provide information on both supply and demand conditions in soybeans and soybean products. If, for instance, demand for soybeans is forecasted to increase but demand and supply conditions of soybean products are forecasted to remain unchanged, the covariation among these commodities would be temporarily disrupted. As seen in table 5(b), covariance between soybeans and soybean oil increases by 5.77% from its average value of 1.70 to 1.80 on the days with WASDE Mix report releases. On the other hand, covariance between soybean meal and oil decreases by 5.42% from its average value of 1.25 on the release days of WASDE Mix reports.

In soybean crushing, one bushel of soybeans yields 48 pounds of soybean meal and 11 pounds of soybean oil (Johnson et al., 1991; Garcia, Roh, and Leuthold, 1995). Using these ratios, soybean meal and soybean oil futures returns are converted to a bushel equivalent return. Figure 1(b) shows the resulting weighted futures return, computed as the sum of the adjusted returns on soybean meal and oil less the return on soybeans. The figure shows the weighted return on both days with WASDE Mix reports and non-announcement days, along with horizontal lines representing one standard deviation range around the mean. The weighted soybean crushing return falls outside this range 21 times out of 55 days with WASDE Mix report releases. Thus, 38.18% of the WASDE Mix reports during the sample period results in a wider weighted futures return relative to its average value of -0.17%.

Conclusions

The impact of USDA reports on commodity prices is well studied. Extensive research has been conducted to determine whether information contained in these reports has any value; that is, whether reports convey new information to market participants about commodities. In general, empirical findings have supported the contribution of USDA reports.

While previous research has explored the price and volatility reaction of commodity futures following an announcement, the impact of announcements on comovement or correlation among related asset prices has not been investigated beyond financial asset markets, despite the strong link between some agricultural commodities throughout the production process. This study fills the gap by simultaneously estimating the impact of several USDA reports on conditional variances and covariances of returns on related agricultural commodity futures contracts. Understanding how comovements across commodity futures evolve around the USDA reports is important because (1) a change in covariance in response to news provides a link to the changes in commodity fundamentals revealed in reports; (2) optimal hedging decisions depend on both variances and covariances of futures and spot prices; (3) diversification benefits from a portfolio depend on correlations among assets.

In this study, two types of producers are considered to analyze related commodity futures contracts: a hog finisher using corn, soybean meal, and lean hogs futures contracts and a soybean processor using soybeans, soybean meal, and soybean oil futures contracts. For most of the commodities studied here, several USDA reports considered have a statistically significant effect on both return variances and covariances. In the hog finisher example, the release of the quarterly Grain Stocks reports and the WASDE reports that include NASS production reports (from August through November) have the largest impact on the conditional variance of corn futures returns. The conditional variance of soybean meal increases the most with Crop Progress reports, while that of lean hogs increases with Hogs and Pigs reports. Increase in variances in response to announcements is interpreted as more information flowing to markets on those days. The most dramatic change in covariances among corn, soybean meal, and hog returns is found for Hogs and Pigs report days, with a sign reversal from positive to negative. An example that would result in such an effect is an increase (decrease) in the supply of hogs revealed in these reports. This would result in an increase (decrease) in the demand for feed, therefore decreasing (increasing) hog prices while increasing (decreasing) feed prices.

In the soybean processor example, Grain Stocks reports significantly increase variance of soybean returns, while Hogs and Pigs reports increase variance of soybean oil returns. The release of WASDE reports that include both situation and outlook information increases covariance between soybeans and soybean oil and to decrease covariance between soybean meal and oil. Such a change in covariances occurs when a report affects one commodity but not the other, causing comovement across commodities to be temporarily disrupted. Further, while four USDA reports studied affect the conditional variance of the nearby soybean meal contracts used in the hog finisher example, none of them affect conditional variance of the second nearby soybean meal contracts used in the soybean processor example, suggesting implications for the time profile of information provided in the reports. Different types of information affect different time horizons and the results suggest that the selected USDA reports have stronger implications for soybean meal return variance in the near term than in the longer term.

Overall, this empirical study shows that comovement in commodity returns linked to each other through production processes are affected by several USDA reports studied. The sign of comovement might even change, implying that these reports contain information that changes the structure of the relationship among commodities. Because some of the reports contain both demand and supply information for more than one commodity, change in comovements would depend on the dominant information revealed in those reports and how market participants perceive them. These findings also have implications for hedging. Hog finishers and soybean processors would be locking in gross margins (revenue less costs) using futures contracts to hedge price risk in both input and output markets. Thus, a possible alternative study is to explicitly model futures margin (output futures price less input futures price) as a function of USDA reports to determine its behavior around announcement days. As shown in figure 1, the total adjusted return from the three futures contracts in both examples deviates from its mean level on announcement days. This can be further analyzed by regressing the absolute value of the futures margin on announcement day dummy variables along with other relevant explanatory variables to statistically show the widening or narrowing impact of announcements on the futures margin.

[Received June 2011; final revision received October 2011.]

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