The Impact of Price Variability on Cash/Futures Market Relationships: Implications for Market Efficiency and Price Discovery

Carlos Arnade
Linwood Hoffman


Copyright 2015 by authors. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.
The Impact of Price Variability on Cash/Futures Market Relationships: Implications for Market Efficiency and Price Discovery

Carlos Arnade

Linwood Hoffman¹

¹ The authors are economists for the ERS research Service of USDA. The views expressed are those of the author(s) and should not be attributed to the Economic Research Service or USDA.
The Impact of Price Variability on Cash/Futures Market Relationships: 
Implications for Market Efficiency and Price Discovery

This study investigates the relationship between cash and future prices of soybeans and soybean meal over periods of high and low price variability. Error Correction models are estimated for each commodity’s cash and futures price. An exogenous measure of price variability is included in the model to determine if variability influences the equilibrium adjustment process. This, in turn, is used to measure the impact of price variability on short run market efficiency and the price discovery process. The analysis is applied to daily cash and futures prices from 1992 to 2013. The findings support the idea that increased price variability increases market adjustment rates and the price discovery process.

Key Words: soybean prices, cash markets, futures markets, price discovery, price variability
Introduction

Over the past decade agricultural commodity prices have been more variable than any period since the 1970’s (Peters, Langley, P. Westcott, 2009). Recent price variability has primarily been attributed to exogenous factors to the price discovery process, such as weather shocks the growth of bio-fuels and associated links between agriculture and energy markets, (McPhail, Du, and Muhammad 2012; Hertel and Beckman, 2012), and on volatile economic conditions in emerging markets that buy and sell agricultural commodities (FAO, et al. Policy Report, 2011).1,2 Variability has also been blamed on growing speculative activity in futures and cash markets, (Yang, Balyeat, and Leatham, 2005).

Whatever the source, price variability is often viewed as harmful, increasing the risk for producers who make planting decisions months prior to harvest and providing mixed signals to buyers of agricultural commodities. High variability also presents resource allocation challenges for firms and policymakers. Variability is not in and of itself detrimental to the market if prices are reacting to fundamentals such as increased uncertainty about production, stocks, and use, but variability is detrimental if prices fluctuate without regard to fundamental factors. That is, when price variability reflects excessive speculative noise, it could impede the flow of fundamental information across markets. Thus price variability may or may not be harmful to the overall agricultural economy.

This paper addresses the issue of whether price variability improves the flow of information between the futures and cash market for soybeans and soybean meal. Specifically, this paper analyses the relationships between cash and futures prices for U.S. soybeans and soybean meal to determine whether an exogenous measure of price variability influences the speed which prices adjust to equilibrium. Using daily cash and futures prices, Error Correction Models (ECM) are estimated. An exogenous variable representing price variability (from the recent past) is included in the model and used to
measure the impact that price variability has on the speed which futures and cash markets converge to their long run equilibrium relationship. Relative adjustment rates derived from the estimated ECM are then used to estimate price discovery weights for cash and futures markets for the two soybean products.

The results reveal that price variability influences adjustment rates and price discovery weights; weights reveal that both cash and futures markets contribute to the discovery of soybean and soymeal prices. In contrast, during periods of low price variability the futures prices of both commodities often moved away from equilibrium leaving the burden of price adjustment completely to the cash market. That is, prices were exclusively discovered in the futures market.

Cash and Futures Price Relationships
Economists have argued that an effective futures market should absorb information on the evolution of prices and then transmit that information to other markets (Tomek, 1980, Mattos and Garcia 2004). That is, prices are “discovered” in the futures market. However, if participants in futures markets (such as portfolio managers) also trade in non-agricultural markets while participants in cash markets (farmers, elevator operators) are closely tied to a particular agricultural commodity, then information contained in the cash markets may be a more accurate reflection of market fundamentals and may relate more closely to price discovery. This, in particular, may be true during periods when speculative activity is high; periods which are often thought to be related to periods of high price variability.

Etienne, Irwin, and Garcia (2013) challenge the view that long periods of price variability relate to speculative activity. They show that price bubbles in the futures market for agricultural commodities often last less than three weeks and are less important than market fundamentals in explaining agricultural price variability. This is critical because if participants in one market believe that a second
market’s price movements are speculative, they may not respond as forcefully to price signals from that market. In this case price variability could slow or impede the flow of information between markets and reduce the second market’s role in the price discovery process. However, if price variability reflects changing market fundamentals, the flow of fundamental information between markets could be amplified by constantly changing prices.

The force of both arguments highlights the need for continued empirical investigation of the relationship between futures and cash markets over periods where the long run level of price variability is changing. Particularly useful would be evidence which can provide insights on whether: a) price variability improves or impedes the transmission of information between markets. b) whether the role cash and futures prices play in the price discovery process is influenced by the level of price variability.

Some Related Studies

Economists often use causality related tests and/or cointegration methods to measure price discovery. Using a framework developed by Garbade and Silber (1983), Schroeder and Goodwin (1991) found that, in the short turn, livestock prices tend to be discovered in futures markets and transferred to cash markets. Applying Granger causality tests to differenced prices Oellermann et al., (1989) found that futures prices of feeder cattle explained cash prices but not the reverse. Koontz et. al. (1990) tested the relationship between spatially separated cash and futures markets for livestock and found that prices in both cash and futures markets interact in both directions and that the nature of the interaction has changed over time. Applying causality tests to ECM models Yang et. al. (2005) found that the futures market dominates the price discovery process for most agricultural markets and this finding held regardless of the commodity’s storability.
Mattos and Garcia (2004) estimated error correction models (ECM) for Brazilian commodities, (which included soybeans) and also applied causality tests to the lagged price difference variables which were included in their ECM model. Their causality tests provided mixed results. However, these authors also choose to test the significance of adjustment rate coefficients in the futures price equation and the cash price equation; a test which can be said to have anticipated methods later used by other authors investigating price discovery. These authors found that for most commodities (including soybeans) cash prices adjusted to the future price.

While causality testing can be informative, these tests focus on the impact of lagged prices on current prices and can be viewed as backward looking. In contrast, price discovery is about market absorption of new information. Plato and Hoffman (2010) used the Gonzalo Granger method to calculate price discovery weights for each market. These authors estimated ECM models for Brazil soybean futures and US (Chicago) soybean futures and emphasized the role adjustment rates play in determining price discovery weights. Adjustment rates represent the response to lagged error terms of a long run price relationship equation. These long run errors (sometimes called surprises) better reflect new or emerging information than the lagged prices. In any case, using closing prices these authors found Chicago dominates price discovery for soybean futures. However, using the opening price for Chicago and closing prices for Brazil they found Brazil dominates the price discovery process.

None of the above studies evaluated how price variability may influence the way markets exchange information. However, Adrangi, Chatrath, and Raffiiee (2006) used an ECM to evaluate the relationship between the future prices of soybeans, soy oil, and soymeal and used GARCH methods to account for volatility spillovers between markets. They found that the soybean market adjusts to soymeal markets. However, they also found that the price spread between soybeans and soybean oil diverges. Separately these authors found that there were volatility spillovers between markets for soy related commodities
(volatility for either beans, meal and oil influences volatility in the other markets). However, these authors did not investigate how this volatility may influence the interaction of prices in each market.

Whatever the case, it is notable that few studies have used ECM models to calculate price discovery weights for agricultural commodity markets. And, to our knowledge, no study has explicitly investigated the influence price variability has on the speed which prices adjustment to equilibrium or explored how variability influences the price discovery process. However, papers by Adrangi, Chatrath, and Raffiiee (2006) and VerCammen and Doroudian (2014) have investigated closely related issues.

**An ECM Model of Cash and Future Prices**

In this paper, an ECM model is specified which allows an exogenous measure of price variability to influence the speed of price adjustment between futures and cash markets. Estimates of absolute adjustment rates are related to market efficiency. That is, short run efficiency is defined by the speed which a displaced futures price and/or a displaced cash price returns (or converges) to the long equilibrium relationship between cash and futures prices (McKenzie, A. and M. Holt, 2002). If information fully transmits across markets, prices should quickly converge.

Estimates of *relative* adjustment rates are then used to measure the relative contribution that futures and cash markets make to the price discovery process. Unlike past studies which rely on causality tests and relationships of prices with their lag values, this study examines how the response to unexpected information (errors from a long run model) influences price discovery. We directly evaluate the role that price variability plays in influencing this response and the subsequent effect it has on price discovery weights. A typical ECM embodies the long run relationship among variables as well as the disequilibrium relationship. The long run price relationship between cash and future prices can be written as:
1) \[ P_{csh,t}^{si} = \beta_{fut} P_{fut,t}^{si} + c + u_t \]

where \( P_{csh,t}^{si} \) and \( P_{fut,t}^{si} \) represent cash prices and futures prices for the ith soybean product in time period \( t \). The term \( c \) represents a constant which can represent a number of factors such as expected storage costs, a risk premium factor, the convenience yield (Fama and French, 1987). The term \( u_t \) represents the long run error which is zero in equilibrium. The superscript “si”, refers to \( s=soy, \ i=beans \) or meal. If \( c=0 \) and \( \beta_{fut} = 1 \) markets are long run efficient Tomek and Gray (1970).

The two-price ECM contains this long run relationship and can be written as:

2a) \[ \Delta P_{csh,t}^{si} = \gamma_{csh} (P_{csh,t-1}^{si} - \beta_{fut} P_{fut,t-1}^{si} - c) + \sum_{i=1}^{k} \eta_{11,i} \Delta P_{csh,t-i}^{si} + \sum_{i=1}^{k} \eta_{12,i} \Delta P_{fut,t-i}^{si} + \varepsilon_{csh,t} \]

2b) \[ \Delta P_{fut,t}^{si} = \gamma_{fut} (P_{csh,t-1}^{si} - \beta_{fut} P_{fut,t-1}^{si} - c) + \sum_{i=1}^{k} \eta_{21,i} \Delta P_{csh,t-i}^{si} + \sum_{i=1}^{k} \eta_{22,i} \Delta P_{fut,t-i}^{si} + \varepsilon_{fut,t} \]

where \( \Delta P_{csh,t}^{si} \) and \( \Delta P_{fut,t}^{si} \) represents the daily change in cash prices and futures prices, respectively, for the ith soybean product. The right hand side term in parentheses contains a one period lag of the error term from the long run relationship between cash and futures prices. The next two terms represent lag price differences (whose length is often determined by empirical tests; 3 lags in this paper) while the fourth term represents an equation error. The parameters \( \gamma_{csh} \) and \( \gamma_{fut} \) are adjustment rate parameters. They represent the speed which a displaced futures (or cash) price returns to its long equilibrium relationship with the cash (futures) price.

Within the long run component of equations 2a and 2b (the term in parenthesis), the cash market price has a positive sign. Therefore, if \( \gamma_{csh} < 0 \), cash prices return to their equilibrium relationship with the futures price. The futures price is expected to have a negative sign in equation 2a and 2b (with \( \beta_{fut} > 0 \)). Therefore, the futures price returns to equilibrium when \( \gamma_{fut} > 0 \). If \( \gamma_{csh} = -1 \) and \( \gamma_{fut} = 1 \), markets...
are short run efficient (Mckenzie and Holt 2002). That is, cash and futures prices return to their equilibrium relationship within one period (with our analysis this is a day). What is critical is that the relative magnitude of the two adjustment rate coefficients reveals “which market bears the burden of convergence” (Adrangi, Chatrath, and Raffiiee (2006)).

It is often more intuitive to write equation 2 explicitly in terms of the long run model error (from equation 1) or as:

\[ 3a) \Delta P_{csh,t} = \gamma_{csh} u_{t-1} + \sum_{i=1}^{k} \eta_{11,i} \Delta P_{csh,t-i} + \sum_{i=1}^{k} \eta_{12,i} \Delta P_{fut,t-i} + \epsilon_{csh,t} \]

\[ 3b) \Delta P_{fut,t} = \gamma_{fut} u_{t-1} + \sum_{i=1}^{k} \eta_{21,i} \Delta P_{csh,t-i} + \sum_{i=1}^{k} \eta_{22,i} \Delta P_{fut,t-i} + \epsilon_{fut,t} \]

Price differences are a function of their own lags, and lagged errors of the long run equation.

Therefore, to evaluate the role price variability plays in influencing market efficiency the following system was estimated:

\[ 4a) \Delta P_{csh,t} = \gamma_{csh} u_{t-1} + \theta_{csh} v_{csh,t-1} + \sum_{i=1}^{k} \eta_{11,i} \Delta P_{csh,t-i} + \sum_{i=1}^{k} \eta_{12,i} \Delta P_{fut,t-i} + \epsilon_{csh,t} \]

\[ 4b) \Delta P_{fut,t} = \gamma_{fut} u_{t-1} + \theta_{fut} v_{fut,t-1} + \sum_{i=1}^{k} \eta_{21,i} \Delta P_{csh,t-i} + \sum_{i=1}^{k} \eta_{22,i} \Delta P_{fut,t-i} + \epsilon_{fut,t} \]

where \( v_{i} \) is a lagged 12 day moving variance of the \( i \)th price. Lagging the variance of prices insures \( v_{i} \) is exogenous and could be viewed as a measure of the expected level price variability.

In equations 4a and 4b the adjustment rate term includes an interactive variable which allows the level of price variability in each market to influence the estimated adjustment rate. If the \( \theta_{csh} \) coefficient is significant and negative, price variability allows cash prices to return more quickly to their long run equilibrium relationship. That is, price variability improves short run market efficiency. If \( \theta_{csh} \) is
significant and positive, a higher $v_{pi}$ slows down the adjustment process and reduces market efficiency. The opposite is true for the sign on the $\theta_{fut}$ coefficient in the futures price equation.

Using daily data, covering the period 1992 to 2013, distinct cash/futures ECM systems were estimated for soybeans and soymeal. Engle and Granger’s (1987) two step method was used to estimate each ECM system. That is, for each commodity, a single OLS equation was estimated to capture the long run relationship between the cash price and futures price. Next, a set of two price difference equations was estimated to capture the disequilibrium relationship among prices. Right hand side exogenous variables included the lagged error terms from the long run model, lags of the price difference variables, and a variable representing the interaction of $v_{pi}$, a measure of past price variability, and the lagged error term.

**Price Discovery Cash or Futures**

The second goal of this paper is to determine whether prices are primarily formed in the cash market or in the futures market and to directly evaluate whether price variability has an influence on estimated of price discovery weights. A third goal is to determine whether the weights on the future and cash markets changed after agricultural prices became more volatile after 2005.

To uncover the role each market plays in establishing a price the Schwartz and Szakmary (1994) and Theissen (2002) method for calculating price discovery weights is applied. These authors developed a technique for calculating price discovery weights from the estimated adjustment rate coefficients of a two variable ECM model. The estimated weights reflect the contribution each market makes to the price discovery process. The implication is that prices are primarily discovered, or formed, in the market with the highest weight (see appendix). For example, if market A receives a weight of one and market B receives a weight of zero, prices are formed exclusively in market A.
There is an intuitive appeal to using adjustment rates to measure a market’s role in the price discovery process. Errors in the long run model often contain new or unpredicted information. Adjustments rates measure the degree that each price responds to the new information. In the Schwartz and Szakmary (1994) and Theissen (2002) approach, the market whose price adjusts the least receives the higher price discovery weight; a point also made by Mattos and Garcia (2004). That is, prices are more likely to be formed in a market that does little adjusting to new information contained in the error of the long run model. In contrast, price discovery weights are low for the market which adjusts relatively more. That is, prices are not likely to be formed in a market that is constantly forced to adjust new information contained in the error of the long run model. Underlying such analysis is the view that the market which does not adjust (or need not adjust) may be the source of the new information.

Data

The daily cash price of soybeans and soymeal was obtained from the U.S. Department of Agriculture’s, Agricultural Marketing Service (USDA, AMS, 1992 through October 2013). Future prices were obtained from Quandl (1992 through October 2013). Futures prices were represented by the settlement price. Seven soybean contracts are traded within one calendar year. In our data base we roll over from the nearby contract (S1) to the next nearby contract (S2) on the last day of month prior to the delivery period. Thus, the futures price series do not include the delivery months and this paper’s estimated adjustment rates and price discovery weights do not refer to the delivery period. The cash price series for soybeans was obtained from USDA, AMS, Decatur-Central Illinois (1992 through October 2013), average price of the truck-rail low and high bid. The soybean meal (high protein) cash prices series was obtained from USDA, AMS, Decatur-Central Illinois, average price of the truck-rail low and high bid. These prices reflect a basis range for soybean meal as of 2:30 pm daily. The cash price (bid price) that
is reported is computed by applying this basis range to the nearby futures price to reflect price offers over the previous hours of the day.\(^5\)

Finally, each commodity had several dates where one price was not available. For these observations a synthetic price was created by averaging the previous day’s price and next day’s price. To insure this process did not influence the results a dummy variable was created to represent those observations with a synthetic price and was tested for significance in subsequent models.

Table 1) reports the average prices over three periods: 1992-2000, 1999-2005, 2005-2013. All prices fall from the first to the second period and rise significantly in the final period. The table also reports two measures of the coefficient of variation (the standard deviation over the mean). The first measure (CV1) is derived from a twelve day moving average estimate of the standard deviation of prices. Its lagged value was used in the subsequent model since traders tend to respond to price movements over a short period of time. For soybean cash price (futures) there is a slight fall (rise) in this measure of short-run price variability during the 1992-1999 period and little change over the latter two periods. For soymeal the CV1 measure for both cash and futures price rise after the first period. In contrast CV2 is derived from the standard deviation of prices over the entire period of time. It reflects the overall level of variability over the entire sub-periods. Such a measure of variability would be endogenous if it were to be used in our model and serves mainly to provide an indicator of the environment which traders operated in each period. This measure indicates long run price variability has risen over time and is particularly large for the 2005-2013 time period.

Results

Dickey Fuller unit root tests were applied to all four prices (cash and futures for: soybeans and soymeal). It was not possible to reject the null hypothesis of nonstationarity for every price for each series over the
entire period (1992-2013). Next, a series of unit root equations was estimated for each price series, while constantly altering the time period (changing starting and terminal dates); in order to determine if the coefficient on the lagged price term was stable. This led to division of the data into three sub-periods, 1992-1999, 1999-2005, and 2005-2013. The former two periods were characterized by relatively low long run price variability while the later period experienced relative high price variability.  

Furthermore unit root (UR) tests revealed that it was not possible to reject the null hypothesis of nonstationarity of both cash and futures prices for both soybean and soymeal prices in all three time periods. Unit roots tests were then applied to the errors from each long run cash and futures price equation and the null hypothesis of nonstationary errors could be rejected. Therefore, every pair of cash and futures prices was revealed to be cointegrated in every test period.

### Price Adjustment and Variability

Following the UR test, one set of ECM equations was estimated for each commodity price pair over the entire 1992-2013 period. Next, this data was broken into 3 time periods (each characterized by different degrees of long run price variability) and analyzed to determine whether the adjustment rate coefficients had changed over time and to determine if the impact of price variability on the adjustment rate differed across time periods. Thus, all models were estimated 4 times over, once for each of the subperiods, and once over the entire 1992-2013 period.

Table 2 reports estimates of the long run equilibrium models for soybeans and soymeal which were estimated over the entire period. The high R²’s indicates that there is a close relationship between cash and futures price for both commodities. Table 3 reports estimates of second stage disequilibrium models representing the entire 1992-2013 period. For both commodities each ECM model included three lags.
of each price difference term (lag length was determined by a series of likelihood ratio tests) as well as the lagged error term from the long run model, and a variable that interacted the measure of lagged price variability \( (v_{pi}) \) with the long run lagged error term. This interaction term allowed us to determine how price variability influences the speed of price adjustment to equilibrium.

A likelihood ratio test was performed to determine if each \( v_{pi} \) variable contributed to the fit of each ECM system. A significant test statistic indicates that model performance improves when an exogenous price variability measure is included in the model.\(^9\) Table 4 reports Chi Square, \( (\chi^2) \) statistics of the likelihood ratio tests. The test statistics reveal that the lagged (exogenous) price variability measure was significant (0.01 confidence level) for soybean and soymeal models that were estimated over the entire period, and over the first (1992-1999) and last periods (2005-2013). This provides clear evidence that the level of price variability (measured by lagged 12 day estimate of the price variance), can influence both the adjustment rate and price discovery process for soybeans and soymeal. However, over the second period, (1999-2005) the variability measure was not significant in the soybean model and was only significant at the .1 level in the soymeal model.

Table 5 reports the estimated adjustment rates for soybeans and soymeal. In all long run models the cash price represented the dependent variable. Therefore, movement towards equilibrium requires a negative coefficient on the long run error in the cash price equation and requires a positive coefficient on the long run error in the futures price equation. The results reveal that soybean cash prices took 41 days to adjust half way to the long run equilibrium value in the first (1992-1999) period, 13 days in the second period, and 37 days in the final (2005-2013) period.\(^{10}\) In contrast, the future prices adjusted in 38 days to adjust half to equilibrium in the first period, adjusted the wrong way in the second period, and took 46 days to adjust halfway in the final-high price variability- period, 2005-2013. The lack of adjustment of future prices in the second period (1999-2005) reflects the dominance of the future market.
in the price discovery process. That is, a price which fails to correct deviations from the long run equilibrium relationship, but instead moves from away from that relationship, can be viewed as leading the market in its own direction.

For soymeal there is an even larger change in the adjustment rates over time. Cash prices for soymeal take 46 days to adjust the first period, 13 days in the second period, and 50 days in the final period. Futures prices take 231 days in to adjust halfway in the first period, 7 days in the last period. As with soybean futures, soymeal prices adjust the wrong way in the (1999-2005) period. The slow adjustment of futures prices in the first period reflects the dominance of the futures market; which appear to be forcing cash prices to do most of the adjusting to the error term of the long run model.

The ratio reported in table 5 represents two adjustment estimates from the same model: adjustment rates when the price variance is nonzero over the adjustment estimate when the price variance is zero. For example, for the cash market this ratio is: \( \frac{\gamma_{csh}}{\gamma_{csh}} \). As constructed, a ratio greater than one means that price variability increases the estimated speed of adjustment and makes markets more efficient. For soybean cash price, the adjustment ratio is greater than one in every period indicating that price variability increased the rate which soybean cash prices returned to their long run equilibrium value. Price, variability only increased the rate of adjustment for soybean futures prices in the final time period. Yet in this period adjustment rates increased by forty two percent leading to a large rise in short run efficiency.

For soymeal price variability had a similar impact; increasing the speed of adjustment for cash prices in every period and slowing adjustment speeds of futures prices in two periods. Overall, it could be said that price variability increased the speed of adjustment of cash prices and slowed the speed of adjustment of futures prices; and thus enhanced the role the futures prices play price discovery.
Price Discovery Weights

Table 6 reports price discovery weights for each time period. For soybeans, an estimated weight of .52 on the cash price and .48 on the futures price indicate that both cash and futures markets contributed almost equally to price discovery in the first period. The wrong way adjustment of future prices in the second period is a sign of complete dominance of the futures market in price discovery. That is a futures price that does not correct for an error, but instead responds to it positively, may be leading the market in a new direction, leaving the cash market to do all the adjusting. However, in the final period with high price variability the futures markets only slightly dominates contributing 58% to the price discovery process. Finally, price discovery rates calculated for a model estimated over the entire period show that future market dominating, contributing 66% to the price discovery process. What is notable is that the whole period model obscures the changing role played by each market across time periods characterized by different levels of long price variability.

In contrast, the futures market dominates price discovery for soymeal in every period; contributing 83.5%, in the first period, completely dominating price discovery in the second period, and contributing 72% to price discovery in the final period. Price discovery rates calculated for soymeal estimated over the entire period shows that the futures market contributing 86% to the price discovery process over the entire period.

The cash market played a significant role in soybean price discovery in two periods. Cash price played much smaller role in soymeal price discovery. The more dominant influence of the soymeal futures may reflect differences in the makeup of market participants. Individual producers and grain elevator operators are likely to participate in the soybean market. In contrast, producers are likely to play a smaller role in soymeal markets, a commodity that requires considerable processing to produce. Buyers
and sellers of processed products are likely to represent larger established firms that have more links to financial markets. Thus, it is no surprise that soymeal prices were primarily discovered in the futures market in every period.

**Soybean markets in the 2005-2013 period.**

Another clear result is that in the final two periods, the futures market dominated price discovery for both soybeans and soymeal. The importance of the futures market in soybean price discovery in the later periods may reflect the growing participation of producers and elevator operators in the futures markets. However for both soybeans and soymeal, the role of the cash market was larger in the 2005-2013 period than in the 2000-2005 period; where prices appeared to be exclusively discovered in the futures market. Table 4 shows a 42 percent price discovery weight for soybeans and a 28 percent price discovery weight for soymeal in the final 2005-2013 period.

The period from 2005 to 2013, not only experienced a high level of price variability, but also there was a perception that an increased number of firms and traders with strong links to financial markets participated in agricultural futures markets over this period. This may have led traders to believe that, over this period, the cash market more accurately reflected of market fundamentals than prices in the futures market. This view is supported by studies which found that market fundamentals, such as drought and corn-based ethanol, explained much of the price variability in 2005-2013 period (McPhail, Du, and Muhammad 2012; Hertel and Beckman, 2012).

**Conclusion**

In the past decade commodity markets have experienced a considerable amount of price variability which is often viewed as a problem. This view ignores the possibility that variability can enhance market efficiency by providing clear price signals to market participants concerning changing market
conditions. This study estimates the relationship between cash prices and futures prices for soybeans and soymeal. The first goal was to determine whether price variability influenced the speed which cash and futures prices absorb new information and adjust to long equilibrium. If price variability increases the adjustment rate, then variability makes markets more efficient in the short run. If it slows the adjustment rate, variability makes markets less efficient. Our second goal was to determine how price variability influenced the relative importance of cash and futures market in the price discovery process.

To achieve this goal an Error Correction Model that included an exogenous measure of (lagged) price variability was specified and estimated. Allowing adjustment rates to be a function of an outside exogenous variable (rather than stand-alone coefficient) represents than main innovation of our ECM model. The impact lagged price variability had on the rate of adjustment to equilibrium was measured and tested. Statistical tests indicated that price variability has a significant impact on the adjustment rates. This implies price variability influences convergence speeds, short run market efficiency, and thus, the relative importance that markets play in the price discovery process.

The analysis covered three time periods, each experiencing a different degree of long run price variability. Modeling results indicated that for both soybeans and soymeal variability increased the speed of adjustment of cash prices in every period. In contrast price variability tended to slow the speed of adjustment of futures prices. The combined effect of these differences served to enhance the role of the futures market in the price discovery process.

The one exception was a large increase in the speed of adjustment of soybean futures during the 2005-2013 period; a period of high long run price variability. In this period both cash and future prices returned to equilibrium more quickly. This result, combined with the higher adjustment speeds in the cash markets in every period, supports the view that in general, price variability improves short run
market efficiency. At a minimum, the analysis in this paper can serve to as a challenge to those who to claim price variability reduces market efficiency.

The results in this paper also reveal that the role futures market in soybean price discovery was larger after the year 2000 than before it. And the futures market played a much large role in price discovery in the soymeal markets than soybean markets. Finally in the final 2005-2013 period, where variability was high, the cash market played a more significant role in price discovery than in the 1999-2005 period. This final result may reflect the perception that of that the futures market contained more speculative noise over years from 2005 to 2013 than the cash market.

Further work along these lines, in other markets, are needed to draw conclusions about the price variability’s effect on commodity markets in general. Future work also could explore how different aspects of price volatility influences market efficiency. For example, it would be interesting to compare how different measures of price volatility (other than the variances of prices) influences market efficiency. Or it may be interesting to compare the impact of price variability at different frequencies (daily, weekly, monthly) on market interaction and the price discovery process. Finally, other factors (such as producer demographics) might be included in the model to help understand the changing role of the cash and futures markets in the price discovery process.
Appendix Price Discovery Weights in A Two Variable Model

Gonzalo Granger (1995) (GzGr) developed a method for measuring changes in the common factor underlying the long run relationship among economic variables. A number of economists have applied this technique towards the issue of market price discovery (Plato and Hoffman, 2011; Figuerola-Ferretti and Gonzalo, 2010). The goal is to determine which market is primarily responsible for generation of new price information.

Within the GzGr model an ECM model is estimated which contains only one long run relationship. Differences in adjustments rates, to the same error term, determine the role different markets play in the price discovery process and in establishing a common long run stochastic trend among prices.

Theissen (2002) showed how the price discovery weights can be explicitly derived from estimated adjustment rate coefficients when a model consists of only two prices (also see Schwartz and Szakmary (1994). Price discovery weights for models with more than two prices are derived through a procedure similar to the Johansen eigenvalue test for cointegration (Gonzalo and Granger 1995; Plato and Hoffman 2011).

When prices are cointegrated they follow to a common stochastic trend; a trend which is often said to be caused by some underlying common factor that influences the prices. The innovation of GzGr was to show that the missing common factor could be approximated as a weighted average of a model’s endogenous variables. Call $\varepsilon$ the linear combination of prices that produces the common stochastic price trend. This can be written as:

1a)  

$$\nu_{\text{csh}} b_{\text{csh},t-1} - \nu_{\text{fut}} b_{\text{fut},t-1} = \varepsilon$$
where the vector $\mathbf{y}_\perp = \{y_{\perp_{csh}}, y_{\perp_{fut}}\}$ is called the complement of the adjustment rate vector of the error correction model (i.e. $\mathbf{y} = \{y_{csh}, y_{fut}\}$). To qualify as a complement vector the following orthogonality condition must be met: $\mathbf{y}_\perp' \mathbf{y} = 0$. That is, the multiplication of the complement vector and the estimated coefficients of the error correction vector must equal zero.

Harris, McInish, and Wood (2002) showed that a relative adjustment rate complement represents that market’s contribution to a common stochastic price trend and can be thought of as a price discovery weight. In a cash/futures price model the weights ($W_g$) are

$$2a) \quad \frac{y_{\perp_{csh}}}{(y_{\perp_{csh}} + y_{\perp_{fut}})} + \frac{y_{\perp_{fut}}}{(y_{\perp_{csh}} + y_{\perp_{fut}})} = 1 = W_{g_{csh}} + W_{g_{fut}}$$

Expanding on the work of Schwartz and Szakmary (1994), Theissen (2002) showed that in a two-variable model price discovery weights, $W_g$, can be directly derived from estimated error correction coefficients. Using this paper’s model the Schwartz and Szakmary/Theissen weights are:

$$3a) \quad W_{g_{csh}} = \frac{\hat{y}_{fut}}{\hat{y}_{fut} - \hat{y}_{csh}}$$

$$4a) \quad W_{g_{fut}} = -\frac{\hat{y}_{csh}}{\hat{y}_{fut} - \hat{y}_{csh}}$$

Where $\hat{y}_{csh}$ and $\hat{y}_{fut}$ represent the adjustment rate coefficients estimates from this paper’s ECM.
Endnotes

1. In contrast, oil price shocks, dramatic shifts in exports, low food stocks, and inflation contributed to commodity price variability in the 1970’s.

2. Some analysts view price variability as being distinct from price volatility. Such a distinction is not critical in this paper.

3. Studies which rely on causality tests implicitly give one market a weight of one and the other market a weight of zero.

4. A vast literature, too large to briefly summarize, uses ECM models to deal with the issue of cointegration of cash and future prices.

5. Millers and buyers sometimes quote cash prices as the deviation from futures price. Use of this language among millers may have led many economists to believe that it is the futures market which signals the cash market. Yet, anecdotal evidence suggests that local conditions and market fundamentals often determine the cash price for a particular transaction. It would be an interesting behavioral economics study to see if this language has influenced the views of analysts who study cash and future markets.

6. For robustness checks we also estimated the models with opening price, and the average of the each day’s high and low future’s price. The results were not remarkably different when using the average of the daily high and low price, but were a different when using the opening price.

7. Unit root equations were estimated from 1992 to 1995, and again from 1992 to 1996, up until 2013. Then the same procedure was applied while moving both starting and ending dates up one year. These rolling estimates showed that the estimated coefficient on the lagged price in each equation significantly changed for all price series after 1999. And there were significant differences between 2004 and 2006 (the exact date depending on the commodity or market).
Soybean prices changed dramatically over the 2004-2005 period, while the 1999 break was not obvious from observing the data. Test results can be provided upon request.

8. When applied to stationary variables, adjustment rates represent the speed which a displaced mean-reverting price returns to its equilibrium relationship with another such price.

9. The long run price variability measure (CV2) represents a one-point estimate for the entire period. The exogenous measure of short run price variability (CV1) which was used in the model varies across observations, but does not change remarkably over longer periods of time. By estimating models across three periods it possible to determine if the impact of short run price variability on adjustment rates is distinct during periods with different levels long run variability.

10. Adjustment rates can be used to measure the time to adjust. However, since rates are derived from a based estimate the error correction term, which dwindles over times it is common to report the adjustment half-life, the time it takes to adjust halfway (Macdonald, 1995).

11. The GzGr eigenvector method for price discovery is similar to the Johansen (1995) eigenvalue test for cointegration using residual matrices from two VAR models. A different product matrix is calculated from these matrices and the minimum eigenvector (rather maximum eigenvalue) is calculated to determine price discovery weights (Gonzalo and Granger 1995, Plato and Hoffman 2011).
References


Mattos, F. and P. Garcia. Price Discovery in Thinly Traded markets: Cash and Futures Relationships in


Table 1: Mean and Coefficient of Variation of Prices

<table>
<thead>
<tr>
<th>Prices</th>
<th>Mean Beans</th>
<th>Mean Meal</th>
<th>C-Var1 Beans</th>
<th>C-Var1 Meal</th>
<th>C-Var2 Beans</th>
<th>C-Var2 Meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999-2005</td>
<td>220</td>
<td>182</td>
<td>2.75</td>
<td>3.38</td>
<td>24.76</td>
<td>22.93</td>
</tr>
<tr>
<td>2005-2013</td>
<td>416</td>
<td>310</td>
<td>2.76</td>
<td>3.47</td>
<td>32.40</td>
<td>33.08</td>
</tr>
<tr>
<td>Futures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992-1999</td>
<td>238</td>
<td>197</td>
<td>1.95</td>
<td>2.241</td>
<td>13.01</td>
<td>17.84</td>
</tr>
<tr>
<td>1999-2005</td>
<td>203</td>
<td>1176</td>
<td>2.83</td>
<td>3.13</td>
<td>23.64</td>
<td>22.82</td>
</tr>
<tr>
<td>2005-2013</td>
<td>387</td>
<td>302</td>
<td>2.74</td>
<td>3.08</td>
<td>30.75</td>
<td>30.20</td>
</tr>
</tbody>
</table>

1/ Average prices are in metric tons

2/ C-Var is the coefficient of variation represented by the standard deviation of price over its mean multiplied by 100.

3/ C-Var1 is the coefficient of variation derived from a 12 day moving average measure of the variance. This represents variability of a short period of time, and it lagged value is used to in our model.

4/ C-Var2 is the coefficient of variation derived from the variance of the price over the entire period listed. This represents long run variability; reflecting overall changes in price movements over the period. Such a measure of variability would be endogenous if it were used in our model.
Table 2: Long Run Cash/Futures Models of Soy Prices: 1992-2013

<table>
<thead>
<tr>
<th></th>
<th>Beans</th>
<th></th>
<th>Meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>R²</td>
<td>.99</td>
<td>R²</td>
<td>.97</td>
</tr>
<tr>
<td>Coef</td>
<td></td>
<td>Coef</td>
<td></td>
</tr>
<tr>
<td>T-stat</td>
<td></td>
<td>T-stat</td>
<td></td>
</tr>
<tr>
<td>Con</td>
<td>-0.12</td>
<td>Con</td>
<td>-9.58</td>
</tr>
<tr>
<td></td>
<td>-13.37</td>
<td></td>
<td>-14.94</td>
</tr>
<tr>
<td>F-price</td>
<td>1.02</td>
<td>F-price</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>1019</td>
<td></td>
<td>459.8</td>
</tr>
<tr>
<td>DVM</td>
<td>0.062</td>
<td>DVM</td>
<td>4.11</td>
</tr>
<tr>
<td></td>
<td>9.73</td>
<td></td>
<td>9.67</td>
</tr>
</tbody>
</table>

1/ The dependent variable is the cash price, con is the constant, and F-price represents the futures price. The high R²'s indicates that cash and future prices are closely related over the long run.

2) Dvm is a dummy variable representing the delivery (rollover) month.
Table 3: ECM For Soybeans 1992-2013

<table>
<thead>
<tr>
<th>Soybean Variable</th>
<th>Cash Coeff</th>
<th>T-stat</th>
<th>Futures Coeff</th>
<th>T-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>g1-pch</td>
<td>0.191</td>
<td>4.18</td>
<td>0.222</td>
<td>4.93</td>
</tr>
<tr>
<td>g2-pch</td>
<td>0.028</td>
<td>0.60</td>
<td>-0.019</td>
<td>-0.42</td>
</tr>
<tr>
<td>g3-pch</td>
<td>-0.063</td>
<td>-1.37</td>
<td>-0.077</td>
<td>-1.71</td>
</tr>
<tr>
<td>g1-pf</td>
<td>-0.149</td>
<td>-3.19</td>
<td>-0.191</td>
<td>-4.17</td>
</tr>
<tr>
<td>g2-pf</td>
<td>-0.029</td>
<td>-0.63</td>
<td>0.006</td>
<td>0.13</td>
</tr>
<tr>
<td>g3-pf</td>
<td>0.079</td>
<td>1.70</td>
<td>0.095</td>
<td>2.06</td>
</tr>
<tr>
<td>GE</td>
<td>-0.021</td>
<td>-2.52</td>
<td>0.010</td>
<td>1.16</td>
</tr>
<tr>
<td>GE*VP</td>
<td>-0.027</td>
<td>-1.40</td>
<td>0.035</td>
<td>2.08</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soymeal Variable</th>
<th>Cash Coeff</th>
<th>T-stat</th>
<th>Futures Coeff</th>
<th>T-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>g1-pch</td>
<td>-0.129</td>
<td>-4.86</td>
<td>0.065</td>
<td>2.67</td>
</tr>
<tr>
<td>g2-pch</td>
<td>0.102</td>
<td>3.83</td>
<td>-0.089</td>
<td>3.64</td>
</tr>
<tr>
<td>g3-pch</td>
<td>0.031</td>
<td>1.21</td>
<td>0.0075</td>
<td>0.31</td>
</tr>
<tr>
<td>g1-pf</td>
<td>0.271</td>
<td>9.34</td>
<td>-0.0071</td>
<td>-0.27</td>
</tr>
<tr>
<td>g2-pf</td>
<td>-0.055</td>
<td>-1.85</td>
<td>-0.081</td>
<td>-2.92</td>
</tr>
<tr>
<td>g3-pf</td>
<td>-0.01</td>
<td>-0.33</td>
<td>-0.004</td>
<td>-1.46</td>
</tr>
<tr>
<td>GE</td>
<td>-0.028</td>
<td>-4.75</td>
<td>0.0047</td>
<td>1.08</td>
</tr>
<tr>
<td>GE*VP</td>
<td>-0.0003</td>
<td>-5.21</td>
<td>-0.000009</td>
<td>-1.84</td>
</tr>
</tbody>
</table>

1/Gipch (gipf) is the ith lag of the differenced cash (futures) price, GE lag error from the long run model, GE*VP is the lagged long run error with a measure of lagged price variances. Dummy variable to represent the few observations with filled in prices which were not significant and were dropped from the model.
Table 4: Testing Whether Price Variability Influences Adjustment Rates

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\chi^2(2)$</td>
<td>$\chi^2(2)$</td>
<td>$\chi^2(2)$</td>
<td>$\chi^2(2)$</td>
</tr>
<tr>
<td>Beans</td>
<td>24.6***</td>
<td>17.9***</td>
<td>2.1</td>
<td>14***</td>
</tr>
<tr>
<td>Meal</td>
<td>27.8***</td>
<td>19.6***</td>
<td>12.6*</td>
<td>28.2***</td>
</tr>
</tbody>
</table>

1/ Likelihood ratio tests were applied to test the coefficient on the lagged $vp_t$, lagged error interaction was zero in each ECM model. The numbers in the table refer to the subsequent test statistic. A significant test static reveals that inclusion of the variable significantly improve model performance.

2/* indicates significance at the .1, confidence level, ** at .05 level, *** at .01 confidence level.
Table 5: Estimated Adjustment Rates

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjustment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Estimate</td>
<td>Days to Adjust</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Half way</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash Bean</td>
<td>-0.017</td>
<td>41</td>
<td>1.6</td>
<td>-0.055</td>
<td>13</td>
<td>1.02</td>
</tr>
<tr>
<td>Futures Bean</td>
<td>0.018</td>
<td>38</td>
<td>0.18</td>
<td>-0.02</td>
<td>Nc</td>
<td>Nc</td>
</tr>
<tr>
<td>Cash Meal</td>
<td>-0.015</td>
<td>46</td>
<td>1.4</td>
<td>-0.053</td>
<td>13</td>
<td>1.13</td>
</tr>
<tr>
<td>Futures Meal</td>
<td>0.003</td>
<td>231</td>
<td>0.57</td>
<td>-0.002</td>
<td>Nc</td>
<td>Nc</td>
</tr>
<tr>
<td>cash bean</td>
<td>-0.004</td>
<td>173</td>
<td>0.98</td>
<td>-0.014</td>
<td>50</td>
<td>1.21</td>
</tr>
<tr>
<td>cash meal</td>
<td>0.010</td>
<td>63</td>
<td>1.16</td>
<td>0.009</td>
<td>77</td>
<td>0.89</td>
</tr>
</tbody>
</table>

1/ Adjustment rates are estimated from an ECM model. With the cash market the left side in the long run equation adjustment rate coefficients should be negative for cash markets and positive for the futures price. NC stands for not converge where the futures market prices moves away from equilibrium and the cash prices market does all the adjustment. 2/ Adjustment rates ratios represents the estimated adjustment rate compared to what it would be if the measure of price variability were zero. A ratio < 1, indicates the price variability slows the rate of adjustment to market equilibrium and thus impedes market efficiency.
Table 6: Price Discovery Weights: Cash and Futures

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Closing Futures Price</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash Bean</td>
<td>0.34</td>
<td>0.52</td>
<td>Nc</td>
<td>0.42</td>
</tr>
<tr>
<td>Futures Bean</td>
<td>0.66</td>
<td>0.48</td>
<td>Nc</td>
<td>0.58</td>
</tr>
<tr>
<td>Closing Futures Price</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash Meal</td>
<td>0.14</td>
<td>0.165</td>
<td>Nc</td>
<td>0.28</td>
</tr>
<tr>
<td>Futures Meal</td>
<td>0.86</td>
<td>0.835</td>
<td>Nc</td>
<td>0.72</td>
</tr>
</tbody>
</table>

1/ The reported price discovery weights and adjustment rates have been slightly rounded so the two vectors may not appear to be exactly orthogonal (see appendix). However, without rounding, the vector containing two adjustment rates are exactly orthogonal to the two price discovery rates (see appendix).

2/Nc represents periods when cash and futures prices did not converge in the nondelivery months. In each of these cases the futures price moved away from equilibrium leaving cash prices to do all the adjusting. In such situation prices are exclusively discovered in the futures market.