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Hedge Ratio Estimation and Soybean Storage

Michael D. Patterson, Marvin L. Hayenga, and Sergio H. Lence*

Farmers often store soybeans to profit from expected increases in cash prices. In such situations, marketing experts and agricultural economists often advise that farmers use futures markets to hedge against the price risk involved with placing soybeans in storage. Since soybean hedging is a "direct hedge" producers often take a short position in the futures market which is equal to their long position in the physical commodity. This is known as a "one-to-one" hedge. In more advanced hedging approaches, regression techniques are used to calculate hedge ratios which tell producers what percentage of the physical stock of soybeans to hedge in the futures market.

The majority of the empirical hedging literature published in recent years has dealt with the estimation of the minimum-variance hedge ratio. For a given cash position, the minimum-variance hedge is the hedge that minimizes the variance of returns to the combined cash-futures position. While there has been considerable debate about the proper specification of the model, the question of profitability has received very little attention. This omission is commonly justified by the fact that empirical studies have usually found futures prices to be unbiased. If this is true, the expected profitability of the futures position is zero. But unbiased futures markets do not ensure profitability in the cash position. For example, it is quite possible for the basis to move in a relatively predictable fashion throughout the year, and to also have storage costs exceeding the expected increase in cash prices.

Cash and futures prices of storable commodities behave in a predictable fashion when supplies are abundant in the cash market. In this situation, competition prevents cash prices from being below futures prices by more than the cost of carrying inventories into future months. If this were not the case, speculative profits could be made by buying cash grain and selling futures contracts. In the case of a cash market shortage, however, there is no mechanism analogous to storage that can limit the difference between cash and futures prices. Theoretically, cash prices can shoot well above futures prices in these situations, and storing and hedging probably does not make much sense. In these situations, the market is essentially telling producers to sell their product without hesitation. If it is true that cash and deferred futures prices act differently in periods of cash market surplus versus periods of shortage, then hedge ratios calculated without differentiating between the two scenarios may not be appropriate for use in storage hedge models. Only hedge ratios corresponding to the surplus scenario are to be used if, as it seems reasonable to assume, storage and hedging occurs only when the commodity is abundant.

This study will examine standard methods of hedge ratio estimation, and will consider alternative approaches to the traditional model specification for the specific case of storing and hedging in the soybean market. In particular, it will focus on whether

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minimum-variance hedge ratios are different at times of shortages and surpluses in the cash market.

Literature Review and Hedge Ratio Estimation Models

The traditional minimum-variance hedge ratio is obtained by using a simple regression of cash price on futures prices or of cash price changes on futures price changes. The slope estimates in these simple regressions are the minimum-variance hedge ratios. Kahl (1983) examines several earlier studies and concludes that assumptions about the cash position determine the impact of individual risk aversion on the size of the hedge ratio. Benninga, Eldor, and Zilcha (1984) show that the minimum-variance hedge position is an optimal hedge ratio in cases where futures markets are assumed to be unbiased. They also point out that the model is empirically useful because the data requirements are minimal, and because no assumptions about utility functions are necessary.

Much of the current debate in the hedging literature centers around the proper specification of the minimum-variance hedge model. Witt, Schroeder, and Hayenga (1987) examined optimal hedge ratios generated through price level regressions, price change regressions, and percentage price change regressions, and found that none of the techniques are necessarily statistically superior to the others. They instead concluded that the appropriate hedge ratio estimation model depends on the objective function of the hedger in question. They concluded that price change models may be appropriate for storable commodities under certain circumstances, while price level models are usually more appropriate when dealing with nonstorable commodities.

Myers and Thompson (1989) argued that the hedge ratio estimates traditionally used in the literature are inappropriate except under special circumstances. This is due to the fact that the traditional literature calculates the slope coefficient as the ratio of the unconditional covariance between cash and futures prices (or cash and futures price changes) to the unconditional variance of cash prices (or cash price changes). The authors suggested a more generalized model that takes into account the information which is available at the time the hedge is placed. Viswanath (1993) developed a modified version of the Myers and Thompson model where the change in cash price is regressed on the change in futures price and the basis at the time the hedge is placed. He then compared his basis-corrected model to the traditional unconditional price change model, and found that his model yielded smaller hedged portfolio return variances in several cases. The generalized approach suggested by Myers and Thompson and tested by Viswanath makes sense for the case of storing and hedging in the soybean market. Specifically, it seems reasonable to include basis information available at the time the hedge is placed in the model.

Despite the intellectual appeal of the generalized approach to hedge ratio estimation developed by Myers and Thompson, simpler approaches may be attractive from a practical standpoint. Data requirements are fairly minimal for an elementary regression of cash price level on futures price level or of cash price change on futures price change. In addition, Viswanath's study showed that there were no statistically significant differences between the soybean hedge ratios calculated using a traditional unconditional price change model and those calculated using a conditional basis-corrected model. If this is the case, soybean hedgers may not gain much practical advantage from using hedge ratios calculated using the generalized framework.

The Decision to Store and the Storage Hedge

Producers often decide to store soybeans based on historical price patterns for the storage period in question. Many store without the price risk protection of a futures market position. These producers rely on the hope that cash prices will improve enough to cover their costs of storage.

Frequently, producers use the futures market to minimize the price risk involved with storing soybeans. While the hedge ratios discussed earlier are optimal in the sense that they are regression coefficients which minimize the variance around the cash price level or cash price change, there is no guarantee that their employment will lead to profitable marketing decisions.

There are periods within the marketing year during which storing soybeans may make sense. Soybeans are usually in abundant supply at harvest time, from the middle of September through the middle of October. Prices are generally low at this time in comparison with other times of the year. Thus, storage from October through February, for example, may make sense if March futures prices (less the expected basis) are sufficiently high to cover the cost of carry over the storage horizon. Conversely, cash prices tend to fall during the period from June through harvest. A producer or commercial agent who is holding soybeans in June would generally not want to store over a horizon where returns to storage tend to be negative.

In the price change method of hedge ratio estimation, hedge ratios are calculated by minimizing the variance around the change in cash price over the storage period. This technique may not make sense in situations where storage may not be rational in the first place (i.e., in situations where the expected cash price change is negative or situations where the expected cash price appreciation is too small to cover the cost of carry). Also, price change models may need to be modified to take into account alternative market conditions: periods of relative surplus versus periods of relative shortage. The remainder of this paper will look at possible modifications of the traditional minimum-variance hedge model which will attempt to capture the effects of alternative market conditions on storage hedge ratios. Hedge ratios calculated using the modified model will be compared with those calculated using the conventional unconditional models to determine whether this new specification offers any practical advantages for soybean hedgers.

Traditional Model Specifications and an Alternative Approach

The simplest storage hedge ratio estimation procedure is a regression of cash price levels on futures price levels. The hedge ratio is calculated as the ratio of the covariance of futures and cash price levels to the variance of futures price levels. It is interpreted as the percentage of the cash price position to hedge in the futures market. Traditionally, this ratio as been calculated in an unconditional model framework, with futures price level as the only independent variable in the regression equation. The unconditional price level model can be expressed as follows:

$$P_t = \alpha + \beta F_t + \varepsilon_t$$

where: P_t = the cash price level at the end of the storage period.
F_t = the futures price level at the end of the storage period.
α = the intercept term.
β = the hedge ratio.
ε_t = the error term.

Another simple storage hedge model specification is a regression of cash price changes against futures price changes. The appropriate price change to be considered is the change over the period when the hedge is in place. The unconditional price change model can be expressed as follows:

$$\Delta P_{tj} = \alpha + \beta \Delta F_{tj} + \varepsilon_{tj}$$

where: $\Delta P_{tj} = P_t - P_{t-1}$
$\Delta F_{tj} = F_t - F_{t-1}$
α = the intercept term.
β = the hedge ratio.
ε_{tj} = the error term.

The hedge ratio here is interpreted in the same way as it is in the price level model, but the estimation procedure differs slightly. In the price change model, the regression equation is estimated by minimizing the variance around a cash price difference. In the price level model, the regression equation is estimated by minimizing the variance around the price level at the time the hedge is lifted. In both the price change and the price level models, it is expected that the hedge ratio estimate will be close to one. This is due to the fact that we have a direct hedge of soybeans in the soybean futures market. It is not expected to be *exactly* one, because local cash prices will generally react slightly differently than futures prices.

There has been considerable debate concerning the suitability of the unconditional price change and price level models. There are two specific omissions in the traditional models which should be addressed by an improved storage hedge model specification. First, basis information known at the time the hedge is placed should be included in the model. Basis is defined as the difference between futures prices and cash prices (in this case, the difference between Chicago Board of Trade soybean futures and North Central Iowa soybean spot prices.) The hedger is generally concerned with the *current* basis (that is, basis at the time the hedge is placed) and the *expected* basis at the time when the hedge will be lifted. The current basis is readily available to the hedger, while the expected basis can be inferred using historical cash-futures price relationships at or near contract maturity. The current basis is important because it can help forecast spot price at the futures contract maturity. Expected basis for the time when the hedge is lifted is important because it tells the hedger what to expect at the time that they plan to lift the hedge.

In addition to ignoring basis information available at the time the hedge is placed, traditional unconditional hedge ratio estimation models also tend to ignore the question of profitability. It clearly does not make sense for a farmer or elevator operator to store soybeans when the cash price is far above the deferred futures price. Despite this fact, hedge ratios are generally calculated without differentiating between the inverted market scenario and the situation where a carrying charge is built into the market. This suggests the possibility that hedge ratios used when storage is rational may be "biased" in one direction or the other by the fact that they were calculated using some data from years when storage was not reasonable. Ideally, storage hedge models should attempt to capture the effect of these alternative market scenarios, and help decision makers arrive at a "true" hedge ratio based on data from years where storage is rational.

The following models are suggested for use in calculating hedge ratios for use in situations where storage is an option:

$$P_t = \alpha + \beta F_t + \gamma F_t * B_{t-1} + \delta B_{t-1} + \phi B_{t-2} + \varepsilon_t$$

or

$$\Delta P_{tj} = \alpha + \beta \Delta F_{tj} + \gamma \Delta F_{tj} * B_{t-1} + \delta B_{t-1} + \phi B_{t-2} + \varepsilon_{tj}$$

where: B_{t-1} = basis at the time the hedge is placed (average for prior month.)
B_{t-2} = average basis for the month when the hedge is lifted (last year's average basis for that month.)

$F_t * B_{t-1}$ and $\Delta F_{tj} * B_{t-1}$ are included to test whether an interaction effect between beginning basis and futures level or change is present. If significant, this variable would be useful in calculating an adjusted hedge ratio at the time the hedger is making his or her storage decision. This adjusted hedge ratio would be calculated as follows:

$$HR = \beta + \gamma (B_{t-1})$$

The adjusted hedge ratio would indicate the adjusted percentage of the farmer or commercial agent's cash position which should be hedged in the futures market.

Data

Daily prices from 1975 through 1993 were analyzed in this study. Cash soybean prices are each Thursday's North Central Iowa spot prices. Futures prices are the corresponding closing prices on various Chicago Board of Trade soybean futures contracts. The three storage periods selected are October-February, October-April, and June-October. The first two were chosen because they are periods over which soybeans are commonly stored both in on-farm storage facilities and in commercial elevators. (These are periods starting around harvest time and extending through a part of the marketing year normally characterized by cash price appreciation.) The third storage period, June-October, was chosen because it is often characterized by falling cash prices as harvest approaches. In cases where prices are expected to fall throughout the storage period, it seems to make sense to sell soybeans rather than to store and hedge. The relevant futures contracts used for the three storage periods are March, May, and November, respectively.

Results

The results from the unconditional price level and price change models are shown in tables 1-1 through 2-3. The unconditional price change model yields hedge ratio estimates of 0.79 for the October-February storage period, 0.87 for the October-April storage period, and 1.15 for the June-October storage period. The mean price changes for the three storage periods were 0.07, 0.43, and -0.51 respectively. These results indicate that hedge ratios using the price change model which are calculated from periods where storage may not be profitable (June-October) may be higher than those ratios which are found in a carrying charge market (October-February, October-April). All hedge ratios in this and in the unconditional price level model were found to be significantly different from zero at the 1% level. The estimates for the unconditional hedge ratios in the price level model show less variation from storage period to storage period. The estimates are 0.93, 0.96, and 0.92 respectively.

The results from the conditional price level and price change models are found in Tables 3-1 to 4-3. Coefficients on F_t in the conditional price level model are very close to one. Coefficients on B_{t-1} are insignificant in the two carrying charge periods and significant and positive in the June-October period. Coefficients on B_{t-2}, on the other hand, were found to be highly significant in all three storage periods, indicating a strong reverting effect. The interaction effect was found to be statistically significant in the June-October period, but not in either of the carrying charge periods. This result is to be expected. The two carrying charge periods are characterized by rising cash and futures prices in almost all instances. Without the presence of two distinct market scenarios, there is little chance of identifying an interaction effect. It makes sense for an interaction effect to be significant over the June-October period, because some years are characterized by falling prices as harvest arrives while others are marked by rising prices due to a short new crop.

Coefficients on ΔF_{tj} in the conditional price change model are also close to one. Coefficients on B_{t-1} are positive and significant in all three storage periods, while coefficients on B_{t-2} are negative in all cases and significant at the 5% level only in the October-April storage period. $\Delta F_{tj} * B_{t-1}$, the interaction effect, is negative in all cases, and is significant in both the October-April and October-February periods.

The hedge ratio in this model is equal to $\beta + \gamma (B_{t-1})$. Examples of adjusted hedge ratios for all three storage periods calculated under surplus and shortage market scenarios are found in Tables 7 and 8. Average basis figures for "normal" and "drought" years were used to test if alternative market conditions affected the hedge ratio estimate. There seemed to be a significant difference only in the June-October period in the price level model, and in the October-April period in the price change model.

The conditional price level and price change models were also estimated without the interaction term ($F_t * B_{t-1}$ or $\Delta F_{tj} * B_{t-1}$) in one case (see tables 5-1 through 6-3), and without the B_{t-1} term in another (see tables 7-1 through 8-3) to examine whether a multicollinearity problem arises with the inclusion of both variables in the main model (tables 3-1 through 4-3). It was discovered that t-ratios were often smaller in the main model, but that the magnitudes of the coefficients were not greatly affected by multicollinearity. The one notable exception is found in the price change model for the June-October storage period. Here, we expected a interaction effect which was significantly different from zero, and the coefficient estimate turned out to be -0.01 with a t-ratio under one. When we examine the results of the model without the basis variable (B_{t-1}), we find the coefficient on the interaction term to be -0.25 with a t-ratio of -7.76 (see table 8-3).

Summary and Conclusions

Four procedures have been used to estimate soybean storage hedge ratios. Traditional unconditional price change and price level models were estimated for three storage periods and yielded hedge ratios which were fairly close to one. While these simple models are easy to estimate and may offer useful results for the farmer or commercial storer of soybeans, there are two problems with them from a theoretical standpoint. First, information known at the time the hedge is placed is not taken into account. Second, the question of profitability is ignored. The information question is addressed in the unconditional model by the inclusion of two lagged basis measures as explanatory variables. The profitability question is addressed by the introduction of an interaction variable($F_t * B_{t-1}$ or $\Delta F_{tj} * B_{t-1}$). This variable captures the effect of alternative market scenarios (surplus vs. shortage) on hedge ratio estimates. This effect was found to be significant in two of three storage periods in the price change model and one of three periods in the price level model. It is suggested that several more storage periods be tested to determine whether there is a strong interaction effect present in storage hedge models. If the effect is found to be significant and prevalent, it may offer risk mangers an alternative method for calculating adjusted hedge ratios using available basis information.

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Unconditional Price Level Model Results

Table 1-1: October-February Storage Period

Variable Name	Estimated Coefficient	T-ratio (16 DF)
F_t	0.93	46.86***
CONSTANT	0.06	0.49

R^2=0.9691

Table 1-2: October-April Storage Period

Variable Name	Estimated Coefficient	T-ratio (16 DF)
F_t	0.96	69.64***
CONSTANT	-0.13	-1.47

R^2=0.9858

Table 1-3: June-October Storage Period

Variable Name	Estimated Coefficient	T-ratio (16 DF)
F_t	0.92	52.54***
CONSTANT	0.05	0.41

R^2=0.9753

Unconditional Price Change Model Results

Table 2-1: October-February Storage Period

Variable Name	Estimated Coefficient	T-ratio (16 DF)
ΔF_{tj}	0.79	30.10***
CONSTANT	0.26	14.08***

R^2=0.9283

Table 2-2: October-April Storage Period

Variable Name	Estimated Coefficient	T-ratio (16 DF)
ΔF_{tj}	0.87	42.18***
CONSTANT	0.43	18.72***

R^2=0.9621

Table 2-3: June-October Storage Period

Variable Name	Estimated Coefficient	T-ratio (16 DF)
ΔF_{tj}	1.15	24.61***
CONSTANT	-0.15	-2.95***

R^2=0.8964

*** indicates significance at 1% level

Conditional Price Change Model Results

Table 4-1: October-February Storage Period

Variable Name	Estimated Coefficient	T-ratio (13 DF)
ΔF_{tj}	1.05	13.04***
$\Delta F_{tj}*B_{t-1}$	-0.25	-2.36**
B_{t-1}	0.42	2.87**
B_{t-2}	-0.45	-1.83*
CONSTANT	0.18	3.07***

R^2=0.9510

Table 4-2: October-April Storage Period

Variable Name	Estimated Coefficient	T-ratio (13 DF)
ΔF_{tj}	1.11	21.89***
$\Delta F_{tj}*B_{t-1}$	-0.26	-3.51***
B_{t-1}	0.62	6.63***
B_{t-2}	-0.44	-2.61**
CONSTANT	0.12	2.54**

R^2=0.9865

Table 4-3: June-October Storage Period

Variable Name	Estimated Coefficient	T-ratio (13 DF)
ΔF_{tj}	0.98	25.34***
$\Delta F_{tj}*B_{t-1}$	-0.01	-0.28
B_{t-1}	0.55	6.75***
B_{t-2}	-0.14	-0.79
CONSTANT	-0.24	-2.92**

R^2=0.9680

* indicates significance at 10% level
** indicates significance at 5% level
*** indicates significance at 1% level

Conditional Price Level Model Results
(without interaction term)

Table 5-1: October-February Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
F_t	1.00	42.25***
B_{t-1}	0.14	1.09
B_{t-2}	-0.96	-3.71***
CONSTANT	-0.13	-1.12

R^2=0.9771

Table 5-2: October-April Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
F_t	1.01	86.25***
B_{t-1}	0.16	2.50**
B_{t-2}	-0.99	-6.86***
CONSTANT	-0.19	-2.66**

R^2=0.9926

Table 5-3: June-October Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
F_t	0.95	58.22***
B_{t-1}	-0.22	-0.85
B_{t-2}	-0.56	-5.56***
CONSTANT	0.09	0.94

R^2=0.9833

* indicates significance at 10% level
** indicates significance at 5% level
*** indicates significance at 1% level

Conditional Price Change Model Results
(without interaction term)

Table 6-1: October-February Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
ΔF_{tj}	0.87	30.30***
B_{t-1}	0.52	3.49***
B_{t-2}	-0.34	-1.36
CONSTANT	0.09	2.00*

R^2=0.9470

Table 6-2: October-April Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
ΔF_{tj}	0.94	57.00***
B_{t-1}	0.69	7.09***
B_{t-2}	-0.31	-1.74
CONSTANT	0.05	1.08

R^2=0.9841

Table 6-3: June-October Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
ΔF_{tj}	0.98	32.65***
B_{t-1}	0.57	12.13***
B_{t-2}	-0.16	-0.96
CONSTANT	-0.24	-2.94**

R^2=0.9680

* indicates significance at 10% level
** indicates significance at 5% level
*** indicates significance at 1% level

Conditional Price Level Model Results
(without B_{t-1} variable.)

Table 7-1: October-February Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
F_t	0.99	37.44***
F_t*B_{t-1}	0.02	1.01
B_{t-2}	-0.94	-3.65***
CONSTANT	-0.06	-0.42

R^2=0.9771

Table 7-2: October-April Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
F_t	1.00	80.35***
F_t*B_{t-1}	0.02	2.12*
B_{t-2}	-0.93	-6.67***
CONSTANT	-0.09	-1.32

R^2=0.9924

Table 7-3: June-October Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
F_t	0.96	55.75***
F_t*B_{t-1}	-0.01	-1.14
B_{t-2}	-0.55	-5.50***
CONSTANT	0.07	0.65

R^2=0.9835

* indicates significance at 10% level
** indicates significance at 5% level
*** indicates significance at 1% level

Conditional Price Change Model Results

(without B_{t-1} variable.)

Table 8-1: October-February Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
ΔF_{tj}	1.07	12.65***
$\Delta F_{tj}*B_{t-1}$	-0.33	3.07***
B_{t-2}	0.10	0.59
CONSTANT	0.21	3.55***

R^2=0.9450

Table 8-2: October-April Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
ΔF_{tj}	1.13	17.47***
$\Delta F_{tj}*B_{t-1}$	-0.37	-4.08***
B_{t-2}	0.35	2.30**
CONSTANT	0.25	4.68***

R^2=0.9777

Table 8-3: June-October Storage Period

Variable Name	Estimated Coefficient	T-ratio (14 DF)
ΔF_{tj}	1.18	34.30***
$\Delta F_{tj}*B_{t-1}$	-0.25	-7.76***
B_{t-2}	0.38	1.83*
CONSTANT	-0.26	-2.44**

R^2=0.9463

* indicates significance at 10% level
** indicates significance at 5% level
*** indicates significance at 1% level

Table 9: Examples of Adjusted Hedge Ratios in Conditional Price Level Model

Storage Period	Basis	β	Adjustment	Hedge Ratio
October-Feb	0.65	1.01	-0.01	1.00
October-Feb	0.57	1.01	-0.01	1.00
October-Apr	0.80	1.05	-0.05	1.00
October-Apr	0.37	1.05	-0.02	1.03
June-Oct	0.55	0.99	-0.04	0.95
June-Oct	-0.84	0.99	+0.06	1.05

Table 10: Examples of Adjusted Hedge Ratios in Conditional Price Change Model

Storage Period	Basis	β	Adjustment	Hedge Ratio
October-Feb	0.65	1.05	-0.16	0.89
October-Feb	0.57	1.05	-0.14	0.91
October-Apr	0.80	1.11	-0.21	0.90
October-Apr	0.37	1.11	-0.10	1.01
June-Oct	0.55	0.98	-0.01	0.97
June-Oct	-0.84	0.98	+0.01	0.99