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Hedge Ratios and Basis
Behavior: An Intuitive
Insight?

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Theories on the purpose(s) of commodity hedging using futures markets have been formally partitioned among (1) traditional or pure risk minimization, (2) Working's (1953a; 1953b) profit motivated approach and (3) a combination of (1) and (2) presumably leading to the portfolio approach which may result in futures/physical commodity hedging ratios other than the traditional one to one (Ederington, 1979; Johnson, 1960). Working (1953b) criticized traditional theory as reflected in its naive tests of hedging effectiveness. He suggested more realistic motivations for merchants' or dealers' hedging by way of reacting to both varying inventory levels and expected basis changes. In contrast to much optimal hedge ratio research published in recent years, Working did not appear to be concerned with futures/cash hedging ratios of other than one associated with "discretionary hedging" based on predictable basis changes. Working found a fairly high association between the initial basis and the subsequent change in basis for specific seasonal periods during 1922-1952. Refitting Working's basis relations using 1971-1990 data suggests the behavior still exists.[1] His discretionary hedging prescribed cash speculation and low inventory if unfavorable basis changes were expected. If a favorable (profitable) basis change was expected, hedge 100 percent.

The application of the portfolio model, which includes price change expectations rather than Working's basis change expectations, to hedging yields a hedge ratio which maximizes profit subject to some risk averse weighted variance (Peck, 1975; Rolfo, 1980). However, absent some means of reliably forecasting changes in price over the hedge duration, the portfolio model is reduced to providing a price risk minimization hedge ratio (Heifner, 1972; Ederington, 1979; and Kahl, 1983). That is, we are back to the traditional or pure risk minimization approach but not necessarily with a 100 percent hedge.

Price risk minimizing hedge ratios based on regressing three alternative data forms have been proposed; (1) cash and futures price levels at the close of the hedge, (2) price changes over the duration of the hedge and (3) returns which occur over the life of the hedge (Witt, Schroeder and Hayenga, 1987). Brown (1985) suggested that the portfolio approach for hedging is not supported because he found hedge ratios of approximately one when regressing cash and futures returns over the duration of the hedge and ratios not equal to one regressing price levels at the close of the hedge. Kahl (1986) commented that finding a hedge ratio of one does not mean the portfolio approach is not relevant because the size of the hedge ratio is an empirical question. Brown (1986) replied that if empirical hedge ratios for returns, if not price levels, are typically one, then rational people will simply hedge 100 percent of stocks. No portfolio model is needed.

Others have preferred to use hedge ratios of one in evaluating hedging effectiveness. Hauser, Garcia, and Tumblin (1982) used alternative basis expectations models in measuring soybean effectiveness incorporating only 1:1 hedge ratios because they are "...more reasonable in risk preference terms, compatible with many previous studies..." and "...are easily understood by hedgers. While Kahl suggested Brown was in error on some points, Brown's idea that it is impractical "...to estimate hedge ratios based on subjective (price) expectations" has merit and suggests that the minimum price risk hedge ratio may frequently be the only practical application of the price regression derived ratios. In addition to the price forecasting problem, it appears that the "full" portfolio model is generally not appropriate because hedging as practiced is essentially either (1) an attempt at arbitrage via Working's anticipated change in relative prices (basis change) and/or (2) a zero return process where the objective is a minimum risk target price relative to some break-even price, probably in an anticipatory hedge. Portfolio models for hedging seem to have been applied only to Working's first two categories of hedges, carrying charge and operational, and not to hedges where stocks are not present; i.e., anticipatory hedges. Hartzmark (1988, p. 2) has suggested that even large commercial firms are generally risk minimizers rather than "nimble footed speculators" reacting to expected price changes.

The purpose of this paper is to suggest that, absent a reliable price expectation process, hedge ratios from the usual regression of cash on futures price levels or price changes merely reflect systematic basis behavior and are useful at the opening of the hedge in forecasting the net price expected from a hedge (Elam and Davis, 1990).

Elemental Hedge

In order to illustrate the connection between hedge ratio and basis behavior, consider the usual hedge process consisting of:

Date Opened		Date Closed		Change
F1	$ 2.90	F2	$ 2.60	$ -.30
C1	2.70	C2	2.50	-.20
B1	-.20	B2	-.10	+.10

Where:

F1 = the opening futures price in the appropriate delivery month.

F2 = the futures price at the close of the hedge.

C1 = the opening cash price or breakeven cost

C2 = the closing cash price

B1, B2 = the opening and closing bases, respectively, from C1 - F1 and C2 - F2.

The net price actually resulting from the hedge, whether long or short, using a ratio of one unit of physical commodity to one unit of futures, may be determined three ways:

(1) $NP = C2 + (F1 - F2)$

(2) $NP = F1 + B2$

(3) $NP = C1 + (B2 - B1)$

Formulas (1) and (2) are derived from (3). Each version of the net price formula is instructive. Formula (1) yields the actual net price at the close of the hedge because all values are known. Formula (2) can be used as a net price forecasting equation given some estimate of the closing basis, B2. Formula (3) reminds us that the net price is the beginning cash price plus the basis change, the process which interested Working. If a hedge ratio other than one is appropriate, equations (1a), (2a), and (3a) become operative where b is the hedge ratio:

(1a) $NP = C2 + b(F1 - F2)$

(2a) $NP = bF1 + (C2 - bF2)$

(3a) $NP = C1 + (C2 - bF2) - (C1 - bF1)$

Because the regression between closing cash price and futures price levels,

(4) $C2 = a + b\,F2 + e$

is, in essence, the closing basis relation, then the net price expected at the end of a hedge can be forecast by substituting equation (4) for C2 in equation (1a) and taking conditional expectations on both sides (Elam, 1988):

$$(5) \qquad NP = a + b\,F1 + e$$

Equation (5) can be used to forecast the net price resulting from a hedge because it incorporates the systematic basis behavior embodied in equation (4). Equation (5) does not forecast B2 or the change in basis but rather adjusts for the systematic basis change, if any, associated with various closing price levels. If b is +1, then a is the expected B2 value. If b is $\neq$ 1, then both a and b form the closing basis relation:

$$(6) \qquad B2 = a + (b-1)\,F2 + e$$

For a regression of closing cash and futures price levels, a hedge ratio < 1 implies a weakening basis as the futures price increases and vice versa. A hedge ratio > 1 indicates a strengthening basis as the futures price rises.

A price levels regression yielding a hedge ratio greater than one may result from a cross-hedge where the spot price changes more than the futures price. For example, lightweight cattle hedge ratios are typically greater than one while par and heavier weights are one and less than one, respectively (Elam, 1988; Schroeder and Mintert, 1988).

If price changes rather than price levels are used to determine a hedge ratio: i.e.,

$$(7) \qquad (C2 - C1) = c + d\,(F2 - F1) + e,$$

the embodied basis relationship is the change in basis. Since B2 - B1 = (C2 - C1) - (F2 - F1), then substituting equation (7) for (C2 - C1) yields

$$(8) \qquad B2 - B1 = c + (d - 1)\,(F2 - F1) + e$$

If the hedge ratio, d, from equation (7) is > 1, the basis will strengthen as price rises and weaken as price falls unless the intercept value, c, overrides the effect of the d value. If $d < 1$, then the basis weakens as price rises and vice versa, again depending on the size of the intercept value. If $d = 1$, the change in the basis is the c or intercept value in equation (7). This is the type of hedge ratio determination which would seem to have interested Working although the need for a forecast for F2 remains. Working's basis changes were independent of the closing level of price. Incidentally, contrary to Brown (1985, p. 510), a coefficient of determination of unity is possible with a narrowing basis, i.e., the hedge ratio d is one and the intercept value is the change (strengthen or weakening) in the basis using price changes.

Thus, minimum price risk hedge ratio equations measure systematic basis behavior, whether using price levels or price changes as data.[2] Relatively elaborate models such as Myers and Thompson's (1989) embody basis behavior but seem unduly complex if forecasting net price is the objective.[3]

Hedge Ratio/Basis Behavior Implications

Let us assume that a producer would be content to forward price his/her crop in the futures market at any time during the year at some price level equal to or greater than the breakeven cost per unit, an anticipatory hedge. Thus, the producer wishes to forecast the net price, subject to basis risk, which would be obtained at the end of the hedge for comparison with current bids or cash price forecasts.[4] The net price is not a forecast of the closing spot price, C2, but of the price expected to result from short hedging at the current futures price. The accuracy of the forecast net price is subject only to variation in the closing basis; i.e., basis risk. Since the producer using an anticipatory hedge is substituting basis risk for price risk, direct or primary evidence of basis behavior should be examined in addition to fitting regressions on price levels or price changes to obtain a hedge ratio; see Naik and Leuthold (1991).

The point is that the use of a hedge ratio based on C2 = f(F2), as has been the case in several hedge ratio papers, is pre-Working traditional theory or price risk minimization which neither attempts to maximize returns subject to variance via the portfolio approach, nor to capitalize on expected basis change. It is, of course, a price risk minimizing "portfolio." The process of producers seeking a profitable net price seems akin to Working's reported hedging on basis changes by middlepersons. However, in contrast to merchants' concern with profitable margins from favorable basis changes, regardless of price level, producers need a minimum level expected net price (i.e., basis adjusted futures price) before setting the hedge. This difference between merchants and producers regarding price level orientation may partially explain the relatively low volume of hedging participation by producers versus marketers. In an efficient market, significantly profitable forward price levels would not long endure while reasonable merchandising margins, being of necessity cost-plus but presumably competitively administered, may be established at various price levels.

Using a hedge ratio other than one in Working's scheme based on expected favorable basis change defeats the process. Success requires a 1:1 ratio since relative price change rather than absolute price change is the key. In contrast, seeking minimum risk net prices is neither a portfolio problem nor a Working-discretionary hedging situation. If one can consistently forecast changes in future price levels, the market is not efficient and 100 percent hedging is inappropriate. Speculate. Get rich. However, absent confident expectations on price change, the producer's problem is forecasting the net price, subject to basis risk, expected from a hedge. From a producer's standpoint, being able to forecast net prices with some degree of accuracy should be adequate for operating a profitable enterprise if these prices are equal to or greater than break-even costs with sufficient frequency. Such situations have been reported. Hayenga, et al., (1984) found profitable hedging opportunities for Midwest cattle and hogs were frequently available during the feed-out periods for 1972-1981. Russell, Ikerd, and Dickey (1984) determined that short hedge forward prices covering break-even costs were available within the feeding period for 64 of 101 pens of High Plains fed cattle during 1974-1982. While these two studies considered the frequency of profitable hedging opportunities within the feed-out periods, other studies have attempted to "lock in" margins before as well as after feeding started. Kenyon and Clay (1987) found profitable hedging situations for hogs both before and after feeding commenced. Shafer, Griffen, and Johnston (1978) found profit margins per head available (a) occasionally prior to the start of feed-out via a "paper feed" and (b) frequently within the feed-out period for Texas Panhandle feedlots during 1972 through 1976. Texas High Plains and Lower Rio Grande Valley cotton producers could have obtained profitable prices by short hedging before or during the growing season (Wood, Shafer and Anderson, 1989). Successful anticipatory short hedges depend on (a) either the predictability (Working) or the systematic behavior (hedge ratio) of the closing basis, and (b) an adequate price level at which to place the hedge.

Matching cash volume to futures volume due to crop yield uncertainty is a separate problem to be determined each season depending on expected yields or to simply cover variable costs. Grant (1989) has examined the yield problem and suggests that a much lower than usually reported hedge ratio may be warranted due to price levels being inversely correlated with yields. Nevertheless, a producer wanting to protect only variable costs by short hedging a part of the crop should be concerned with the net price expected from that part of the crop hedged regardless of yield risk.

The importance of hedge ratios (< and > 1) derived from regression of price levels and price changes is that they embody basis behavior. While price level hedge ratio equations forecast neither absolute basis nor the basis changes examined by Working, they incorporate historic basis changes so that the resulting net price will be the forecast net price subject to basis risk.

The hedging ratios reported by numerous studies are relevant but are a step removed from the basis behavior they reflect. The basis behavior for particular futures delivery months at specific cash sale locations should be observed directly. Standard deviations and ranges on bases by delivery months are important. Further, does the basis behavior implied by the estimated hedge ratio make sense? Weaker bases at higher price levels seem reasonable, hence the frequently reported hedge ratio of less than one.

A Case

An example of net price forecasting with a hedge ratio using Lubbock, Texas, cash cotton prices and N.Y. March cotton futures prices provides an indication of basis or hedging risk associated with minimum risk forecast net prices, Table I.[5] This is a cross-hedge because 15/16" staple cotton is not deliverable. Regressing Lubbock mean cash prices (column I) for the period nine days prior to first notice day of the New York March cotton futures contract on the mean of cotton futures settle prices for the same contract (column II) over the 1979-1988 period yielded the typical price level hedge ratio equation:

$$(9) \quad C2 = 7.0529 + 0.73354\ F2,$$
$$\text{(t-values)} \quad (1.06) \qquad (7.68)$$

$$\bar{r}^2 = .86 \quad \text{D-W} = 1.82 \quad \text{SEE} = 3.05 \quad \text{SEF} = 2.22$$

The net price forecasting equation is

$$(10) \quad NP = 7.0529 + 0.73354\ F1 + e$$

which suggests that the futures price was more variable than cash price and the strength of the closing basis varied inversely with the level of the closing futures price as shown in the derived closing basis equation:

$$(11) \quad B2 = 7.0529 - 0.26646\ F2.$$

The actual closing basis, B2, in column III is the cash price in column I minus the futures price in column II. The "expected" basis in column IV is from equation (11) using the actual closing futures price in column II. The conditionally "forecast" net price in column VI is from equation (10) using actual March "opening" futures prices from March of the previous year (column V). The actual or expost net price in column VII resulting from the hedge of 0.7335 units of futures per unit of cash was computed from

$$(12) \quad NP = C2 + 0.73354\ (F1-F2)$$

which is equation (1a) with the 0.7335 hedge ratio.[6] Actual and expected closing bases were correlated. The actual basis was clearly inversely associated with the level of the closing futures price as implied by the 0.7335 hedge ratio. The 100 percent hedge (hedge ratio of one) expost net price in column VIII was higher than the ratioed net price if futures price fell during the hedge and lower if futures price increased.

Hedging efficiency (see Hauser, Garcia and Tumblin, 1982) could be measured as the goodness of fit between forecast and actual net prices. The difference between the forecast net price and actual net price is the difference between actual basis and derived or expected basis, the basis risk. Forecast net prices from equation (10) based on the March futures price from the previous year were clearly more closely related to the actual net prices column IX, than to the actual closing cash price, column X. Further, the standard deviation for the error between forecast net prices and expost net prices for the ratio hedge was considerably smaller (2.72¢) than that for the forecast 100 percent hedge net prices and the expost net prices (3.78¢). Thus, while basis adjusted March futures prices were not necessarily good forecasts of the closing cash prices, they did a reasonable job of "forecasting" the actual net price associated with a short hedge. Given the hedge ratio, Lubbock area cotton producers presumably could have forecast short hedge net prices for March sales rather closely during the 1979-1988 period, disregarding the effect of yield risk on the operational hedge ratio.

A brief out-of-sample evaluation using equation (10) to forecast net prices for the 1989, 1990 and 1991 seasons provided results similar to those for the in-sample period; compare tables I and II. The closing basis in 1990 was exceptionally strong but varied as expected in 1989 and 1991, being strong and weak in line with low and high closing futures prices, respectivley. The net prices from the ratio hedge averaged higher than the 100% hedge due to the rise in futures prices over the 12 month short hedge periods.

Conclusions

The purpose of this paper was to relate the traditional or price risk minimization approach to the use of hedge ratios derived from price level and price change regressions. These regression derived hedge ratios are a remnant of the portfolio approach absent expectations on the direction of price change. They reflect systematic basis behavior which permits the forecast of the minimum risk net price expected from the hedge (Ederington, 1979). This type of hedge ratio is not compatible with Working's approach to hedging which presumed reliable forecasting of basis changes leading to hedging 100 percent or, possibly, not at all; i.e. discretionary hedging. While the hedge ratios derived from simple regression of price levels facilitate forecasting the net price expected from a short or long hedge, they do not forecast the direction of price change, the closing basis, or the change in basis. A hedging ratio other than one implies that the closing basis depends on whether prices rise or fall during the course of the hedge. If, in fact, the market is efficient and forecasts are not reliable, then one is stuck, so to speak, with forecasting the net price based on the estimated hedge ratio. Given a fairly strong relation between closing cash and futures prices, using the net price forecasting process should provide a better estimate of end of hedge net price, subject to basis risk, than simply using a 100% hedge unless, of course, the ratio is 1:1 (Elam and Davis, 1990). Producers can use the hedge ratio equation (5) to examine daily futures prices for expected net prices during the entire crop year; i.e., the expected net price from anticipatory hedging.

If there is a relationship between closing price level and closing basis, the net price forecasting equation should provide useful estimates of the price which will result from the hedge. If strong (and reliable) price change expectations are held, perhaps the portfolio approach maximizing profit subject to some level of risk is useful. A forecast price increase suggests reduced short hedging, possibly to the point of "a Texas hedge," and vice versa. Absent confident forecasts of price change, we are left with the price risk minimizing hedge ratio net price forecast. If reliable basis change models like those reported by Working are available, discretionary hedging on a one to one ratio is appropriate for merchants and other handlers of commodities. Further, effort may be well spent on basis forecasting models and costs of delivery rather than the more remote hedge ratio measures (Garcia, Leuthold and Sarkan, 1984; Naik and Leuthold, 1991; Tilley and Campbell, 1988). Last but not least, Grant and Eaker (1989) suggest that too much emphasis has been placed on complex hedges including the estimation of hedge ratios.

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Endnotes

[1] Working (1953b) found the Kansas City December wheat basis typically strengthened between September and December and the July wheat basis generally weakened between May and July during the 1922-1952 period. His regressions of change in basis on opening basis were:

September to December

$$DBSD = 2.87 - 0.861BS \qquad r^2 = .703$$

May to July

$$DBMJ = 0.98 - 0.946BM \qquad r^2 = .95$$

A weak or negative basis in September led to a positive change or strengthening in the basis from September to December. A strong or positive basis in May led to a negative change or weakening in the basis from May to July, old crop to new.

An updating of Working's basis relations using 1971-1990 data on Kansas City cash and futures prices from the *Wall Street Journal* yielded similar results:

September to December

$$\underset{\text{t-values}}{DBSD} = \underset{(8.92)}{10.958} - \underset{(-7.77)}{.7269BS} \qquad \bar{r}^2 = .757 \qquad DW = .95$$

May to July

$$\underset{\text{t-values}}{DBMJ} = \underset{(2.05)}{3.379} - \underset{(-15.43)}{.8337BM} \qquad \bar{r}^2 = .925 \qquad DW = 1.82$$

The updated regressions appear to fit some better than Working's orignals and convey essentially the same relationship between initial and the change in basis during the selected periods. The May to July basis behavior seems to have been more consistent because of the usually strong bases which existed on May 1.

[2] Hayenga and DiPietre (1982) mention the basis/hedge ratio relation, but do not pursue the further implications.

[3] The effect of the conditional or generalized hedge ratios proposed by Myers and Thompson (1989) on implications for basis behavior are not clear. However, the conditional hedge ratios would also embody basis behavior. They argue (p. 861) that "Both common sense and empirical evidence reject ... the use of simple regression with price levels to estimate optimal hedge ratios."

[4] Elam and Davis (1990) have presented a detailed illustration of ratio hedged basis risk versus a 100 percent hedge basis risk using feeder cattle. They also derived a generalized basis formula but did not pursue the basis behavior aspect (p. 212).

[5] Hedging ratios should be derived for each futures delivery month because of seasonal influences. Thus, five hedging ratios are needed for Lubbock, Texas, cotton since there are five delivery months for N.Y. cotton futures.

[6] Forecast net price was a good "explainer" of the actual net price with the simple regression being

$$NP = 13.597 + 0.755\ \hat{NP}$$

(values) (3.02) (9.50)

$\bar{r}^2 = 0.91$ DW = 2.35 SEE = 2.02 SEF = 1.47

Table I. **Actual Closing Cash and Futures Prices, Expected and Actual Closing Basis, Forecast and ExPost Net Prices with Hedge Ratio and ExPost Net Price with 100% Hedge, Lubbock Cash and New York March Cotton Futures Prices, 1979-1988.**

	Closing Values[1]				Opening Futures Price	Net Prices			Forecast Net Price as Proportion of	
						Ratio Hedge[2]		100% Hedge expost [3]		
	Cash Price	Futures Price	Actual Basis	Expected Basis		Forecast	ExPost		Expost Net Price	Closing Cash Price
Year	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
1979	52.69	64.47	-11.78	-10.12	62.10	52.61	50.95	50.32	1.032	0.998
1980	67.54	84.74	-17.20	-15.53	66.50	55.83	54.16	49.30	1.031	0.827
1981	74.40	88.41	-14.01	-16.50	74.12	61.42	63.92	60.11	0.961	0.825
1982	49.27	63.13	-13.86	-9.77	83.90	68.60	64.51	70.04	1.063	1.384
1983	52.70	66.07	-13.37	-10.55	72.90	60.53	57.71	59.53	1.049	1.148
1984	64.06	74.98	-10.92	-12.93	70.43	58.72	60.72	59.51	0.987	0.917
1985	51.63	64.16	-12.53	-10.04	75.70	62.58	60.09	63.17	1.041	1.212
1986	54.12	62.24	-8.12	-9.53	66.00	55.47	56.88	57.88	0.975	1.025
1987	52.55	55.85	-3.30	-7.83	44.30	39.55	44.08	41.00	0.897	0.753
1988	54.55	61.64	-7.09	-9.37	53.00	45.93	48.21	45.91	0.953	0.842
Mean	57.35	68.57	-11.22	-11.22	66.89	56.13	56.00	55.68	0.999	0.993
SD	8.31	10.63	4.04	2.83	11.52	8.45	6.66	8.80	0.053	0.202

1 Closing values are mean values prior to first notice day.
2 The hedge ratio was 0.734 for the Lubbock cash price - N.Y. Futures contract during the first notice period.
3 A 100% ratio means futures contracts used equal the volume of physical cotton.

Table II. Actual Closing Cash and Futures Prices, Expected and Actual Closing Basis, Forecast and ExPost Net Prices with Hedge Ratio and ExPost Net Price with 100% Hedge, Lubbock Cash and New York March Cotton Futures Prices, Out of Sample 1989-1991.

	Closing Values[1]				Opening Futures Price	Net Prices			Forecast Net Price as Proportion of	
						Ratio Hedge[2]		100% Hedge expost [3]		
	Cash Price	Futures Price	Actual Basis	Expected Basis		Forecast	ExPost		Expost Net Price	Closing Cash Price
Year	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
1989	49.42	58.03	-8.61	-8.38	57.75	49.44	49.14	49.14	1.004	1.000
1990	61.01	68.33	-7.32	-11.12	64.23	54.19	58.00	56.91	.934	.888
1991	68.17	84.60	-16.43	-15.33	66.48	55.84	55.19	50.05	1.012	.819

1 Closing values are mean values prior to first notice day.
2 The hedge ratio was 0.734 for the Lubbock cash price - N.Y. Futures contract during the first notice period.
3 A 100% ratio means futures contracts used equal the volume of physical cotton.