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Profit Margin Hedging

by

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Profit Margin Hedging

Some extension economists and others often recommend profit margin hedging in choosing the timing of crop sales. This paper determines producer's utility function and price processes where profit margin hedging is optimal. Profit margin hedging is shown to be an optimal strategy under a highly restricted target utility function even in an efficient market. Although profit margin hedging is not the optimal rule in the presence of mean reversion, it can still be profitable if prices are mean reverting. Simulations are also conducted to compare the expected utility of profit margin hedging strategy with the expected utility of other strategy such as always hedging and selling at harvest strategies. A variance ratio test is conducted to test for the existence of mean reversion in agricultural futures prices process. The simulation results show that the expected utility of profit margin hedging strategy is highest. The paired difference tests for the profit margin hedging and other two strategies shows that the expected utilities of profit margin hedging strategies are not significantly different from those of always hedging strategy, but are significantly different from those of selling at harvest strategy except when the transaction cost is considered. The results of variance ratio test indicate that there is little evidence that futures price of wheat follows mean reverting process.

Keywords: expected utility, mean reversion, profit margin hedging, target

Introduction

Some extension economists and others often recommend profit margin hedging, which sells crop preharvest, whenever prices are above a target. However, this strategy recommendation is without a research base. The strategy is also included in undergraduate text books such as Purcell and Koontz (pp. 329-330). The theoretical assumptions that would justify such a strategy have never been developed. Some empirical studies have found that a profit margin hedging strategy is profitable for producers or investors.

Leuthold and Mokler (1980) calculate the implied profit margin of feeding cattle by subtracting the cost of producing live cattle estimated from futures prices of feeder cattle and corn with an allowance for non-feed cost from total income estimated from the futures price of live cattle. They analyze hedging results when the implied profit margin varies from one to fifteen dollars in one dollar increments and found the optimal trigger level to be five dollars per cwt. Returns for the five dollar trigger level were \$3.11 per cwt compared to \$0.86 cwt for cash returns with the hedge reducing variance by fifty-seven percent.

Kenyon and Clay (1987) proposed a variable trigger level based on the expected profit margin determined by expected pork production and the cost of corn and soybean meal. They conclude that a producer could increase profits and reduce risk when the futures market offered an implied profit margin that exceeded the expected profit margin by 70 percent.

Johnson et al. (1991) used the moving average of the gross crushing margin as a proxy for all costs of crushing soybeans. Producers place a crush trade when the implied crushing/profit margin is above the moving average. If implied crushing/profit margin is below the moving

average, a reverse crush trade is placed. They find that the profits from these trades increase as the implied profit margin moves further from the moving average. However, these studies do not provide any theory deriving the assumptions where profit margin hedging is optimal.

This research will focus on answering the question, “What assumptions for producer’s utility and price process can justify profit margin hedging?” The purpose of this paper is to determine producer’s utility function and price processes where profit margin hedging is optimal. This study conducts a statistical test of mean reversion in agricultural futures prices process. The simulations are also conducted to compare the expected utility of profit margin hedging strategy with the expected utility of other strategies such as always hedging and selling at harvest.

Theory of Expected Target Utility

The mean-variance (E-V) model is a risk-return model which is the most commonly used to analyze choices under uncertainty. However, some previous studies argue that E-V analysis has several well-known theoretical shortcomings (Fishburn; Holthausen). Fishburn (1977) proposed a mean-risk model which generalized mean-target semivariance model (Markowitz; Mao; Hogan and Warren; Porter) to address the shortcomings of the E-V model which is that variance is not a suitable measure of risk. Fishburn’s model measured return as the mean of the outcomes, but defined risk as weighted deviations of outcomes below target and the model assumes risk neutrality above the target. Holthausen (1981) adapted Fishburn’s model by using the same measure of risk but defining return as weighted deviations above the target to avoid the risk neutrality restriction. To measure producer’s expected utility, this study adopts Holthausen’s model in which the utility function is:

$$(1) \quad U(p) = \begin{cases} (p-t)^b & \text{for all } p \geq t \\ -k(t-p)^a & \text{for all } p \leq t. \end{cases}$$

where p indicates profit, t represents the target, k is a positive constant, and a and b reflect the risk preferences. If $a < 1$ ($a > 1$), then the producer is risk seeking (averse) below target. Then, the expected target utility can be written as

$$(2) \quad EU(p) = \int_t^{\infty} (p-t)^b f(p)dp - k \int_{-\infty}^t (t-p)^a f(p)dp$$

where $f(p)$ is probability density function of p which is normally distributed with mean \bar{p} and variance S_p^2 ¹. If producers place hedge, then the profit is

$$(3) \quad p = p(1-F) + p_f^0 F$$

¹ The variance of profit, S_p^2 , equals $(1-F)^2 S_p^2$ where S_p^2 is variance of p .

where p is the price of crop, F is a hedge ratio, and p_f^0 indicates the futures price at the placing point of hedge. Then, equation (2) is rewritten as

$$(4) \quad EU(p) = \int_A^\infty \{p(1-F) + p_f^0 F - t\}^b f(p) dp - k \int_{-\infty}^A \{t - p(1-F) - p_f^0 F\}^a f(p) dp$$

where

$$A = \frac{t - p_f^0 F}{1 - F},$$

and F is a choice variable. Equation (4) will be optimized when the first derivative with respect to F equals to zero. The first order condition of equation (4) is

$$(5) \quad \begin{aligned} EU'(p) = & - \int_A^\infty b \{p(1-F) + p_f^0 F - t\}^{b-1} (p - p_f^0) f(p) dp \\ & - \int_A^\infty \{p(1-F) + p_f^0 F - t\}^b \frac{\partial f(p)}{\partial S_p^2} 2(1-F) S_p^2 dp \\ & - \{A(1-F) + p_f^0 F - t\}^b f(p) \frac{t - p_f^0}{(1-F)^2} \\ & - k \int_{-\infty}^A a \{t - p(1-F) - p_f^0 F\}^{a-1} (p - p_f^0) f(p) dp \\ & + k \int_{-\infty}^A \{t - p(1-F) - p_f^0 F\}^a \frac{\partial f(p)}{\partial S_p^2} 2(1-F) S_p^2 dp \\ & + k \{t - A(1-F) - p_f^0 F\}^a f(p) \frac{t - p_f^0}{(1-F)^2} \end{aligned}$$

If a and b are equal, and k is one, then equation (5) can be rewritten as

$$(6) \quad \begin{aligned} EU'(p) = & - \int_A^\infty a \{p(1-F) + p_f^0 F - t\}^{a-1} (p - p_f^0) f(p) dp \\ & - \int_A^\infty \{p(1-F) + p_f^0 F - t\}^a \frac{\partial f(p)}{\partial S_p^2} 2(1-F) S_p^2 dp \\ & - \int_{-\infty}^A a \{t - p(1-F) - p_f^0 F\}^{a-1} (p - p_f^0) f(p) dp \\ & + \int_{-\infty}^A \{t - p(1-F) - p_f^0 F\}^a \frac{\partial f(p)}{\partial S_p^2} 2(1-F) S_p^2 dp. \end{aligned}$$

Then, the first and the third term in equation (6) cancel out. If the hedge ratio, F , equals one, then the second and the last term are deleted and equation (6) will be zero. Therefore, when a producer has the same level of risk preferences above and below target, and k equals to one, the expected target utility will be optimized if the producer places a hedge on all amount of a crop.

If the hedge ratio, F , is less than 1, then there is no interior solution and the optimum is the lower bound of zero. In case of dropping assumptions, a and b are equal and k equals one are dropped, we do not obtain analytical solution yet.

Theory of Mean Reversion

The dominant paradigm of the behavior of financial and commodity markets is the efficient market hypothesis which is that the market adjusts so quickly to new information that there exist no trading rules which consistently outperform the market in terms of expected returns. Therefore, under the efficient market hypothesis, buying and holding a diversified market portfolio rather than attempting to time investments to beat the market is best for investors in the stock market. In contrast to the efficient market hypothesis, some researchers suggested that asset prices are somewhat predictable. For example, stock market prices tend to follow a mean reversion process which is a tendency for a stochastic process to return over time to a long-run average value. The mean reverting price process can be written as

$$(7) \quad p_{t+1} - p_t = I(\bar{p} - p_t) + e_{t+1}$$

where p_t is stock price at time t , \bar{p} is the long-run average price, p_t always goes towards level \bar{p} with mean-reversion speed I which is greater than zero, and e_{t+1} is an error term with mean zero and variance S_e^2 . Producers' expected profit function can be defined as

$$(8) \quad E(p) = E[pq - C + (p_f^0 - p_f)F]$$

where p_f represents random futures price at the terminal point of hedge, and p_f^0 is the known futures price at the time of the hedge, and F is futures contracts. If futures random price follows mean reversion process, then equation (8) will be rewritten as

$$(9) \quad E(p) = E[pq - C + I(p_f^0 - \bar{p})F]$$

Since p_f^0 is greater than \bar{p} under profit margin hedging rule, and I is a positive value, the profit margin hedging is profitable with mean reverting futures price process.

Data

The chosen agricultural commodity is hard red winter wheat. This study uses July futures contract prices from the Kansas City Board of Trade (KCBT). The sample period extends from June 2nd 1975 through May 26th 2006. In contrast to previous studies (Irwin, Zulauf, and Jackson; Yoon and Brorsen) which used a monthly or weekly data set to conduct mean reversion test for commodity price, this study uses daily data.

To test mean reversion in wheat futures prices, return horizons of 5, 20 days are examined. July observations are deleted since these observations are for delivery period. Markets are thin during this time and can be quite volatile.

To conduct simulation, Oklahoma monthly June average wheat cash prices and price for July futures contract at September 20th from 1975 to 2005 are used. The economic costs of wheat production from 1975 to 2005 are obtained from Economic Research Services (ERS), U.S. Department of Agriculture (USDA) website and targets are calculated as 70% of these economic costs. The data of wheat yield from 1975 to 2005 at Garfield County, Oklahoma, are obtained from the website of National Agricultural Statistic Service (NASS), USDA. To make hedging decision with price risk and yield risk, 5 year moving average of revenue are used.

Procedures

This paper has two main procedures – simulation to compare the expected utility of profit margin hedging strategy with the always hedging and the selling at harvest strategies, and mean reversion testing for wheat July futures price. The expected utility is measured by taking the average utility across 31 years. To test mean reversion, the variance ratio test is employed.

Measure of Expected Utility

To measure producers' expected utility, this study employs Holthausen's (1981) target utility function which is defined as

$$(14) \quad U(p) = \begin{cases} (p - t)^b & \text{for all } p \geq t \\ -k(t - p)^a & \text{for all } p \leq t. \end{cases}$$

where terms are the same as in equation (1). This study considers four cases which are no risk, basis risk, transaction cost, and yield risk for three hedging strategies. To measure the utility without any risk, this study used perfect foresight model which assumes actual harvest basis is known at the time of the decision. In this case, under profit margin hedging strategy, if the sum of futures price at the time of the decision and foresighted basis is greater than the target return then producers place hedge, otherwise they do not place hedge and sell the crop at harvest. If the basis risk were considered, producers place hedge when the sum of futures price at the time of the decision and average basis is greater than the target return. When the yield risk were considered, producers place hedge if the product of average yield and the sum of futures price at the time of the decision and the foresighted basis are greater than the target returns.

If producers place hedge, the July contract futures price at September 20th is used as profit to calculate utilities. If producers do not place hedge, June cash price is used as profit. Table 1 shows that how producers make decisions to place hedge and measure their utilities. In this study, we assume producers are risk averse above target and risk seeking below target and pick 0.5 as risk preferences a and b . Also, the study assumes the transaction cost is 1.2 cents per bushel. July futures contract prices at September 20th are used to calculate utilities. After

measure producer's utility, the study calculate the expected utility by taking an average of utilities such as

$$(18) \quad EU(\mathbf{p}) = \frac{1}{n} \sum_{i=1}^n U_i(\mathbf{p}).$$

Variance Ratio Test

The idea behind the variance ratio test is that if the natural logarithm of a price series P_t is a random walk, then the variance of k -period returns should equal k times the variance of one-period returns (Cochrane; Kim, et al.; Lo and MacKinlay; Poterba and Summers). The general k -period variance ratio, $VR(k)$ is defined as

$$(10) \quad VR(k) = \frac{s^2(k)}{ks^2(1)}$$

where $s^2(k)$ is the variance of the k differences and $s^2(1)$ is the variance of the first differences. The null hypothesis of interest is that $VR(k)$ equals one. That is, $VR(k)$ equal to one implies that futures price follows a random walk process, whereas a variance ratio of less than one implies a mean reversion process. Lo and MacKinlay (1988) show that the variance ratio estimator can be calculated as

$$(11) \quad s^2(k) = \frac{1}{m} \sum_{t=k}^{nk} (P_t - P_{t-k} - k\hat{m})^2,$$

where

$$m = k(nk - k + 1) \left(1 - \frac{k}{nk}\right) \text{ and}$$

$$(12) \quad s^2(1) = \frac{1}{(nk - 1)} \sum_{t=1}^{nk} (P_t - P_{t-1} - \hat{m})^2,$$

in which

$$\hat{m} = \frac{1}{nk} \sum_{t=1}^{nk} (P_t - P_{t-1}) = \frac{1}{nk} (P_{nk} - P_0),$$

where P_0 and P_{nk} are the first and last observations of the price series. Lo and MacKinlay (1988) also derive asymptotic standard normal test statistic for their variance ratio.

$$(13) \quad z(k) = \frac{VR(k) - 1}{[f(k)]^{1/2}} \xrightarrow{a} N(0, 1)$$

where

$$f(k) = \frac{2(2k-1)(k-1)}{3k(nk)}$$

Results

Table 2 denotes that, for all cases, the average prices of profit margin hedging strategy are the highest, following always hedging and selling at harvest strategy, respectively.

Table 3 shows the expected utilities for hedging strategies. The expected utility of profit margin hedging strategy is higher than with the other two strategies. Especially, the expected utility of profit margin hedging without any risk or cost has the highest value, which confirms the theoretical findings. The expected utility of always hedging strategy is greater than that of selling at harvest strategy except with the case of transaction cost. Adding yield risk greatly reduces the advantage of profit margin hedging.

The results of the paired difference tests for the profit margin hedging and other two strategies are presented in Table 4. All of the expected utilities of paired profit margin hedging and selling at harvest strategies are significantly different from zero at 5% significance level except for the case of considering transaction cost. This implies that the expected utilities of profit margin hedging strategies are significantly different from those of selling at harvest strategies except for the case considering transaction cost. None of the expected utilities of paired profit margin hedging and always hedging strategies are significantly different from zero at 5% significance level. That is, the expected utilities of profit margin hedging strategies are not significantly different from those of always hedging strategies.

The result of the variance ratio test in table 5 shows little evidence of mean reversion in futures prices. None of the variance ratios, $VR(k)$, are significantly different from 1.0 at the 5% significance level. Both variance ratios are greater than 1.0, which would indicate positive correlation rather than mean reversion.

Summary and Conclusions

Some extension economists and others often recommend profit margin hedging in choosing the timing of crop sales. This paper determines producer's utility function and price processes where profit margin hedging is optimal. Profit margin hedging is shown to be an optimal strategy under a highly restricted target utility function even in an efficient market. Although profit margin hedging is not the optimal rule in the presence of mean reversion, it can still be profitable if prices are mean reverting.

Simulations are also conducted to compare the expected utility of profit margin hedging strategy with the expected utility of other strategy such as always hedging and selling at harvest strategies. A variance ratio test is conducted to test for the existence of mean reversion in agricultural futures prices process. The simulation results show that the expected utility of profit margin

hedging strategy is higher than selling at harvest and selling at harvest strategies. Therefore, this result suggests that the profit margin hedging gives the highest expected utility to producers. The paired difference tests for the profit margin hedging and other two strategies shows that the expected utilities of profit margin hedging strategies are not significantly different from those of always hedging strategy, but are significantly different from those of selling at harvest strategy except when the transaction cost is considered. With the variance ratio test, there is little evidence that futures price of wheat follows mean reverting process.

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Table 1. The Method of Producer's Decision Making and Utility Measure for Each Strategy

Method	Risk	Strategy		
		Profit Margin Hedging	Always Hedging	Selling at Harvest
Decision Making	No risk or cost	If $p = p_f^0 + B \geq t$ then $F=1$ If $p = p_f^0 + B \leq t$ then $F=0$	Always $F=1$	Always $F=0$
	Basis risk	If $p = p_f^0 + \bar{B} \geq t$ then $F=1$ If $p = p_f^0 + \bar{B} \leq t$ then $F=0$	Always $F=1$	Always $F=0$
	Transaction cost	If $p = p_f^0 + B \geq t$ then $F=1$ If $p = p_f^0 + B \leq t$ then $F=0$	Always $F=1$	Always $F=0$
	Yield risk	If $p = (p_f^0 + B)\bar{q} \geq t\bar{q}$ then $F=1$ If $p = (p_f^0 + B)\bar{q} \leq t\bar{q}$ then $F=0$	Always $F=1$	Always $F=0$
Utility Measure	No risk or cost	For $p \geq t$, $U(p) = [(p_f^0 + B) - t]^b$ For $p \leq t$, $U(p) = [p - t]^b$ when $p \geq t$ $U(p) = -k[t - p]^a$ when $p \leq t$	For $p \geq t$, $U(p) = [(p_f^0 + B) - t]^b$ For $p \leq t$, $U(p) = -k[t - (p_f^0 + B)]^a$	For $p \geq t$, $U(p) = [p - t]^b$ For $p \leq t$, $U(p) = -k[t - p]^a$
	Basis risk	For $p \geq t$, $U(p) = [(p_f^0 + B) - t]^b$ For $p \leq t$, $U(p) = [p - t]^b$ when $p \geq t$ $U(p) = -k[t - p]^a$ when $p \leq t$	For $p \geq t$, $U(p) = [(p_f^0 + B) - t]^b$ For $p \leq t$, $U(p) = -k[t - (p_f^0 + B)]^a$	For $p \geq t$, $U(p) = [p - t]^b$ For $p \leq t$, $U(p) = -k[t - p]^a$
	Transaction cost	For $p \geq t$, $U(p) = [(p_f^0 + B) - t]^b - TC$ For $p \leq t$, $U(p) = [p - t]^b$ when $p \geq t$ $U(p) = -k[t - p]^a$ when $p \leq t$	For $p \geq t$, $U(p) = [(p_f^0 + B) - t]^b - TC$ For $p \leq t$, $U(p) = -k[t - (p_f^0 + B)]^a - TC$	For $p \geq t$, $U(p) = [p - t]^b$ For $p \leq t$, $U(p) = -k[t - p]^a$
	Yield risk	For $p \geq t$, $U(p) = [(p_f^0 + B) - t]^b$ For $p \leq t$, $U(p) = [p - t]^b$ when $p \geq t$ $U(p) = -k[t - p]^a$ when $p \leq t$	For $p \geq t$, $U(p) = [(p_f^0 + B) - t]^b$ For $p \leq t$, $U(p) = -k[t - (p_f^0 + B)]^a$	For $pq \geq tq$, $U(p) = [pq - tq]^b$ For $p \leq t$, $U(p) = -k[tq - pq]^a$

Note: B represents perfect foresighted basis, \bar{B} is average basis, \bar{q} indicates average yield, TC denotes transaction cost, and other terms are same as equations (1) and (3).

Table 2. Average Prices for Hedging Strategies at September 20th (1975-2005)

Risk	Strategies		
	Profit Margin Hedging	Always Hedging	Selling at Harvest
No risk or cost	330.72	320.98	311.03
Basis risk	327.86	320.98	311.03
Transaction cost	330.10	319.78	311.03
Yield risk	329.23	320.98	311.03

Note: Unit is cents per bushel.

Table 3. The Expected Utilities for Hedging Strategies at September 20th (1975-2005)

Risk	Strategy		
	Profit Margin Hedging	Always Hedging	Selling at Harvest
No risk or cost	1.81	0.60	0.57
Basis risk	1.29	0.60	0.57
Transaction cost	1.76	0.50	0.57
Yield risk	1.08	0.60	0.57

Table 4. Results of Paired Differences Test, *t*-Ratio (1975-2005)

Risk	Paired Difference	
	Profit Margin Hedging vs. Always Hedging	Profit Margin Hedging vs. Selling at Harvest
No risk or cost	1.58	2.57*
Basis risk	1.17	1.36
Transaction cost	1.64	2.52*
Yield risk	0.48	2.78*

Note: *t*-critical value with 29 degree of freedom at 5% significance level is 1.699.

* indicates that it is significant at 5% level.

Table 5. Results of Variance Ratio Tests of Wheat Futures Price (1975-2006)

Commodity	Return Horizon (k days)	No. of Observations	Variance Ratio [$VR(k)$]	Z-statistic
Wheat	5	7070	1.01	0.49
	20	6633	1.06	1.00

Note: July Contract futures prices are used and July observations are deleted.