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CROSS HEDGING WHOLESALE BEEF PRICES: AN APPLICATION OF VARYING PARAMETER REGRESSION

by

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Introduction

Previous studies have demonstrated the efficacy of livestock futures markets as risk management tools for livestock producers (e.g., Heifner; Leuthold; McCoy and Price). These studies commonly compare pricing strategies which involve a cash only strategy (no hedging), a fully hedged strategy (always hedge) and various strategies which use a decision rule to determine if the firm should or should not hedge. Price variance over time is used as the measure of price risk. Typically, the cash only, or no hedging strategy, produces a higher price risk (variance) and higher mean return than does the fully hedged strategy. The strategies which utilize decision rules sometimes improve the mean returns while producing a lower risk than the cash only strategy. Recently, it has been shown that the fed cattle futures market can also be used by food service institutions as a means of reducing the price risks associated with purchasing selected beef cuts (Miller). As discussed in more detail below, the effectiveness of fed cattle futures as a risk management tool in wholesale beef procurement is determined by the predictability of the relationship between wholesale beef and fed cattle futures prices in a regression framework. Miller utilized ordinary least squares (OLS) to test the feasibility of cross hedging selected beef cuts with live cattle futures. In this paper, we explore the potential of varying parameter regression for improving the predictive performance of that regression relationship.

In subsequent sections we provide discussions of the economic model, the varying parameter regression methodology, empirical results, and our conclusions.

Economic Model

The use of fed cattle futures to hedge wholesale beef purchases is an example of cross hedging.[1] By definition, cross hedging is the hedging of cash position in one commodity by using the futures market for a different commodity. Cross hedging is used to forward price commodities for which futures markets do not exist[2] (Hieronymus, p. 233).

We consider the following situation. The cross hedging institution purchases beef at time t + i in a competitive wholesale market. Cross hedges are placed at time t and are lifted at time t + i. The quantity of beef to be purchased at time t + i is known at time t.[3] Let

Q = quantity (cwt) of dressed beef to be purchased at time t + i,

R_{t+i} = price/cwt of dressed beef, a random variable with expected value of μ_R and variance σ_R^2,

C = quantity (cwt) represented by futures contracts held by the institution. The contracts are those which mature nearest to, but not before, t + i. The contracts are bought at t and are sold at t + i,

F_t = price/cwt of futures at t,

F_{t+i} = price/cwt of futures at t + i, a random variable with expected value F_t, and variance σ_F^2.

The value of dressed meat purchases and futures activity (ignoring futures' commissions and margin requirements) is given by

$$Y = R_{t+i}Q - (F_{t+i} - F_t)C \quad . \tag{1}$$

The expected value and variance of Y are given by

$$E(Y) = \mu_r Q \ , \tag{2}$$

and

$$\sigma_Y^2 = Q^2\sigma_R^2 + C^2\sigma_F^2 - 2CQ\sigma_{R,F} \ , \tag{3}$$

respectively, where $\sigma_{R,F}$ equals the covariance of R and F. With C as the choice variable, Equation (3) is minimized when

$$\frac{C}{Q} = \frac{\sigma_{R,F}}{\sigma_F^2} \quad . \tag{4}$$

The level of C relative to Q which satisfies Equation (4) is called the minimum risk cross hedge. The minimum risk cross hedge is not necessarily optimal for the institution. Determination of the optimal level would require knowledge of the institution's attitude toward risk, and is thus institution-specific. However, the minimum risk cross hedge provides a useful benchmark for comparison to risks encountered under alternative procurement strategies.

Following Heifner (p. 28), a consistent a posterior estimate of $\sigma_{R,F}/\sigma_F^2$ would be provided by the estimated regression coefficient from a regression of dressed beef prices on concurrent prices of futures contracts nearest maturity. The coefficient of determination (R^2) from such a regression also provides an *a posterior* measure of the effectiveness of minimum risk cross hedging in reducing price risk. If the minimum risk cross hedge is to be approximated *ex ante*, the regression relationship must be relatively stable so as to allow estimation at time t, when the cross hedge is to be placed.

Previous evidence by Breimyer indicates that marketing margins for meat "have exhibited a persistent short-run tendency to widen when supplies increase and narrow when supplies decrease" (p. 691). There is then reason to suspect that the regression relationship between dressed beef prices and fed cattle futures prices (as they reflect cash fed cattle prices) may not be constant over time. Thus, a statistical methodology which allows for regression coefficient variation over time may provide improved predictions of dressed beef prices relative to ordinary least squares (OLS), which assumes constant parameters. In the following section we introduce such a variable parameter model.

Varying Parameter Regression

The variable parameter model which we employ is that developed by Cooley and Prescott, hereafter CP. Since the CP model is detailed elsewhere (see Cooley and Prescott; Ward and Myers), only a brief sketch will be given here.[4]

The CP model, in matrix form, is written $Y_t = X_t B_t$. It is assumed that the parameter vector is subject to transitory and/or permanent changes. These changes are written as

$$B_t = B_t^p + u_t \text{ (transitory changes), and} \tag{5}$$

$$B_t^p = B_{t-1}^p + v_t \text{ (permanent changes)} \tag{6}$$

where u_t and v_t are identically and independently distributed multivariate normal vector variables with zero mean vectors. Their covariance matrices are Σ_u and Σ_v, respectively. In particular, CP assume that $Cov(u_t) = (1 - \gamma)\sigma^2\Sigma_u$ and $Cov(v_t) = \gamma\sigma^2\Sigma_u$, where $\sigma_{11u} = \sigma_{11v} = 1$ if the regression intercept is subject to change. Here, γ, $0 \le \gamma \le 1$, measures the parameter variation due to permanent change; $(1 - \gamma)$ measures the parameter variation due to transitory change.

If regression parameters are subject to change, we wish to estimate those parameters for T + 1, where T is the last observation in the sampling interval used for estimation. We can write

$$B_{T+1}^p = B_T^p + v_{T+1} \text{ , or} \tag{7}$$

$$B_{T+1}^p = B_t^p + \sum_{s=t+1}^{T+1} v_s \ . \tag{8}$$

Also,

$$B_t = B_{T+1}^p + u_t - \sum_{s=t+1}^{T+1} v_s \ . \tag{9}$$

Now,

$$Y_t - X_t B^p_{T+1} + w_t \;, \tag{10}$$

where

$$w_t = X_t u_t - X_t \sum_{s=t+1}^{T+1} v_s \tag{11}$$

is normal with zero mean and covariance matrix

$$\mathrm{cov}(w) = \sigma^2[(1-\gamma)M + \gamma N] \equiv \sigma^2\Omega(\gamma) \;. \tag{12}$$

Here M is a diagonal matrix with

$$m_{ii} = (X_i' \, \Sigma_u \, X_i) \tag{13}$$

and matrix N is such that

$$n_{ij} = \min(T - i + 1,\; T - j + 1) X_i' \, \Sigma_v \, X_j \;. \tag{14}$$

The conditional maximum likelihood estimators of B and σ^2 for a given γ are, respectively:

$$\tilde{B}(\gamma) = [X'\Omega(\gamma)^{-1}X]^{-1}[X'\Omega(\gamma)^{-1}Y] \tag{15}$$

and

$$s^2(\gamma) = \frac{1}{T}[Y - X\tilde{B}(\gamma)'\Omega(\gamma)^{-1}(Y - X\tilde{B}(\gamma))] \;. \tag{16}$$

The estimation procedure for the CP model maximizes the likelihood function with γ as the choice variable. In the absence of previous information on Σ_u and Σ_v, it may be assumed that $\Sigma_u = \Sigma_v$. The covariance matrix of the estimated coefficients from OLS is used as an estimate of Σ_u and Σ_v.

The estimated B vector from this procedure applies to time T + 1, where T is the last observation in the sampling interval used for estimation. For the purpose of forecasting, accounting for parameter variation may lead to improved results relative to OLS which assumes parameter constancy. A possible shortcoming of the CP model arises when n-step ahead forecasts, $n > 1$, are desired. As noted above, the estimated B from the CP model applies to T + 1. If the parameters are subject to change prior to T, it would seem that change subsequent to T + 1 is likely. To the writers' knowledge, the CP methodology has not been extended to allow for the projection of parameter changes beyond T + 1.

Empirical Results

In this section, top sirloin butt price variances and mean price difference of returns associated with alternative procurement strategies are compared. These strategies are as follows:

I. Cross-hedged using OLS estimates of minimum risk levels.

II. Cross hedging using CP estimates of minimum risk levels.

III. No cross hedging.

It is recognized that Strategies I and II are naive in that they imply a firm would hedge each month even if there was an unfavorable price relationship. These strategies, however, allow us to achieve the objective of this paper which is to compare the predictive performance of OLS and varying parameter regression techniques. It is assumed that the institution makes butt purchases on the last week of each month, and that the purchased quantities are predetermined. Cross hedges may be placed 3, 6, or 12 months prior to butt purchase dates.

The butt prices ($/cwt) are for Choice grade butts weighing 10 to 15 lbs in central U.S. markets. The prices are weekly averages reported by the Agricultural Marketing Service. Wednesday closing futures prices ($/cwt) are used in order to economize on data collection. The futures prices are from Yearbooks of the Chicago Mercantile Exchange.[5]

Minimum risk cross hedging levels for dressed beef purchases (Strategies I and II) at month t + i (i = 3, 6, 12) are estimated using information available at month t, when the cross hedges are placed. The estimates are the slope coefficients from regressions (OLS for Strategy I, CP for Strategy II) of dressed beef prices during the last week of the month on concurrent near term fed cattle futures prices, where the last observation is for month t. Based on previous evidence of seasonal differences in wholesale and live beef price relationships (Hacklander), quarterly intercept shifters (with January to March as the base period) are included as regressor in both the OLS and CP regressions. Within the CP model, only the base intercept and slope coefficient are treated as varying parameters. That is, the seasonal shifters are treated as constant parameters.

December 30, 1970 was arbitrarily selected as the first observation in estimation. The initial sampling interval is comprised of 36 monthly observations, with the first estimated minimum risk cross hedges being placed in November,

1973. Subsequent estimates are based on sampling intervals from December 30, 1970 to t. Final cross hedges are lifted on May 30, 1979. Figure 1 displays estimates of minimum risk cross hedging levels from the CP and OLS models.

The mean net prices/cwt of beef purchases at time t with cross hedging at estimated minimum risk levels (Strategies I and II) and mean prices/cwt without cross hedging (Strategy III), along with the corresponding variances of those strategies, are displayed in Table 1. These results motivate the following comments.

The variances associated with Strategies I and II are less than the corresponding variances associated with Strategy III for all values of i. Further, the F-ratios indicate that the differences in variances with and without cross hedging are statistically significant at or below the 5% level. Although Figure 1 indicates considerable differences in the levels of estimated minimum risk cross hedging levels between Strategies I and II, these differences are not reflected in the variances of those strategies. Strategy I has a lower variance for i = 3 and 6, and Strategy II has a lower variance for i = 12. However, the differences in variances between Strategies I and II are relatively small and are not statistically significant. In all instances (i = 3, 6, and 12), Strategy I produces a lower mean price than does Strategy II. Also, the mean prices of both Strategies I and II are lower than that for Strategy III. The results of t-tests at

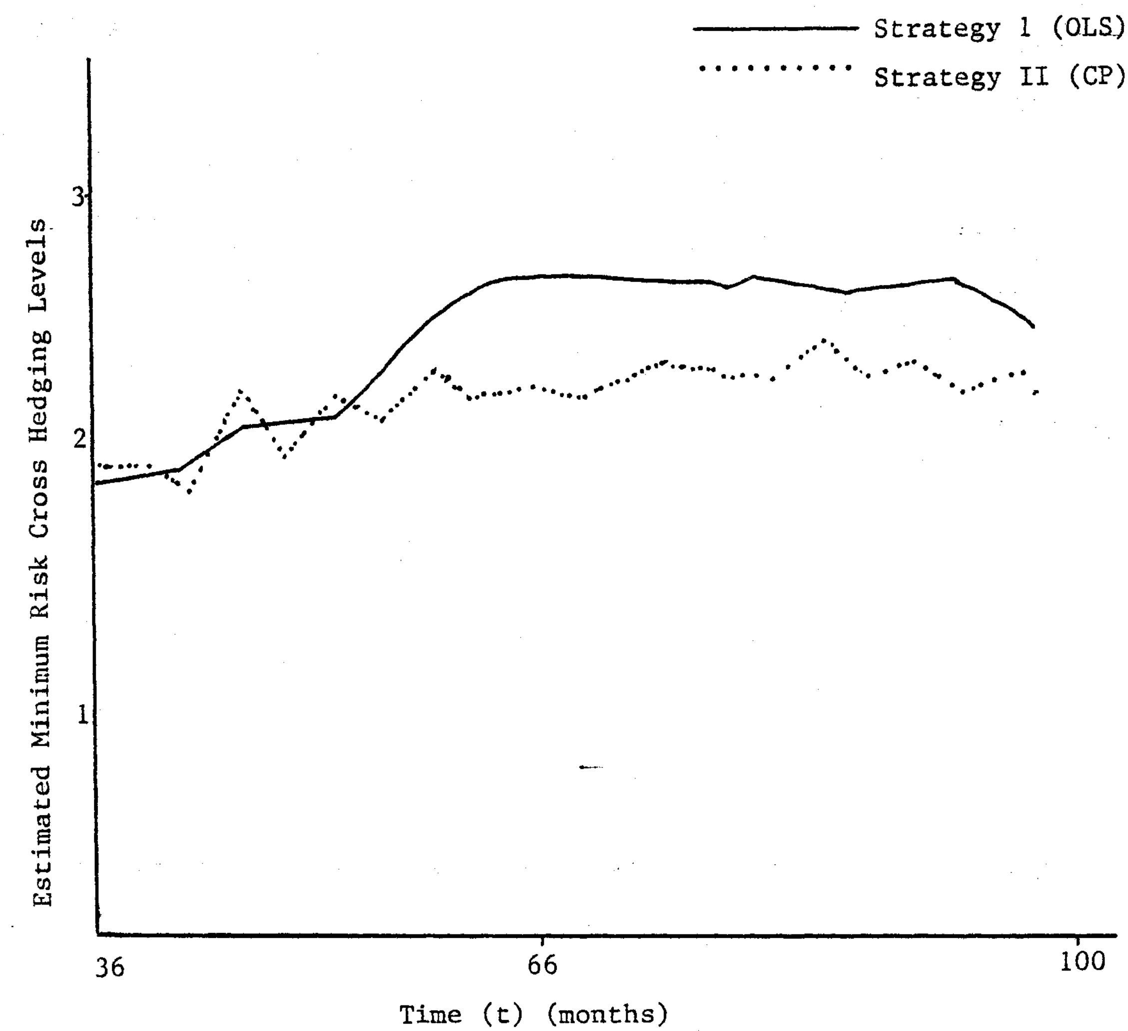

Figure 1. Estimated Minimum Risk Cross Hedging Levels, Top Sirloin Butt.

Table 1. Results of Purchasing Top Sirloin Butts Using Alternative Purchasing Strategies.

Strategy	Number of Observations	Mean Cross Hedging Level	Mean Price ($/cwt)	Variance $(\$/cwt)^2$	F-Ratio[a]
		3-month hedges (i = 3)			
I	64	2.45	156.51	461.33	1.64*
II	64	2.21	156.70	466.36	1.62*
III	64	--	159.00	757.49	--
		6-month hedges (i = 6)			
I	61	2.45	154.76	379.86	2.08**
II	61	2.21	155.21	396.79	1.99**
III	61	--	159.25	790.96	--
		12-month hedges (i = 12)			
I	51	2.45	151.63	374.42	2.25**
II	51	2.21	152.42	370.38	2.27**
III	51	--	159.44	841.25	--

[a]Note: *(**) denotes significance at the 5%(1%) level.

the 5% level indicate there are no significant differences in the mean prices associated with Strategies I through III. This observation continues to be true even when hedging costs are considered. The implication is that a significant reduction in price risk can be achieved without a corresponding reduction in returns.

Conclusions

The purpose of this paper is to determine whether the varying parameter technique developed by Cooley and Prescott may be successfully applied in estimation of the relationship between wholesale beef prices and fed cattle futures prices for the purpose of determining minimum risk cross hedging levels. The rationale for applying varying parameter regression is previous evidence (Breimyer) that the margin between wholesale and live beef can cause price changes over time.

Comparison of the results from estimating cross hedging levels via varying parameter and OLS regressions indicates that the former technique does not provide superior results. A possible explanation for the failure of the varying parameter technique to produce superior results relative to OLS in estimating minimum risk cross hedging levels is that the technique only produces parameter estimates for T + 1. We have used those estimates for 3, 6, and 12 step ahead predictions. Should the requisite methodology become available for projection of parameter estimates for n-step ahead predictions, the results from the varying parameter technique might be improved.

While this study uses naive hedging strategies to compare two regression techniques, further study is needed to analyze more sophisticated hedging techniques. These strategies could employ some type of decision rule to indicate if and when a firm should hedge in order to achieve a price advantage. The basis of the decision rule may be some type of econometric model or an arbitrary price relationship.

Footnotes

[1]Fed cattle, rather than imported lean beef futures are considered as the cross hedging medium since the latter market has not achieved a substantial trading volume. As a consequence, hedges on the imported beef market might suffer from bulges and dips in futures prices when placing and lifting hedges, respectively.

[2]Cross hedging is also employed when existing futures markets do not provide sufficient liquidity for direct hedging, and when the basis from direct hedging is unsatisfactory.

[3]An analysis of cross hedging when the quantity to be purchased at time t is unknown at t - i is not presented here. The lack of secondary data does not allow an empirical analysis of this situation (Miller, pp. 4-5).

[4]The following discussion draws heavily upon Cooley and Prescott, and Ward and Myers.

[5]On dates when butt or futures prices were not reported due to holidays, etc., the nearest previous prices are used. When a futures contract maturing at time t + 12 had not traded by time t, the future price on the first trading day is used provided that the contract traded for more than 6 months; otherwise, the contract was excluded from the analysis of 12-month hedges.

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