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Go Ahead, Count Your Chickens: Cross-Hedging Strategies in the Broiler Industry

Leigh J. Maynard, Carl R. Dillon, and Joy Carter

ABSTRACT

Some suppliers of broilers without giblets (WOG) offer customers a choice between paying Urner Barry's WOG quote or a formula price based on futures prices. From a buyer's perspective, the formula price examined in this study is second-degree stochastic dominant. The formula price allows the seller to set perfect cross-hedges of WOGs with corn and soybean meal. Stochastic dominance and mean variance results suggested that the seller's dominant strategy would shift from the Urner Barry quote to the hedged formula price as risk aversion increased. Input-based formula pricing may be usefully extended to other industries.

Key Words: *broiler industry, formula pricing, hedging strategies, mean-variance analysis, stochastic dominance.*

Killing Two WOGs with One Stone

One of the primary variable inputs for poultry processors is broiler meat (Fryar). Whole broiler price risk contributes to processors' net revenue risk, but the absence of futures markets for poultry precludes direct hedging. On the other side of the transaction, firms that supply whole broilers also have incentives to manage output price risk. Some U.S. suppliers of whole broilers without giblets (WOGs) use a pricing mechanism that potentially offers a win-win solution. The supplier offers its customers a choice between paying an industry standard market WOG price reported daily by Urner Barry, or a formula price based on Chicago Board of Trade corn and soybean meal

futures prices. This study examines a specific formula used by one supplier.

The formula price serves two purposes, the details of which will be described in the next section. First, the supplier can offer its customers a price that is less volatile and no higher on average than the Urner Barry market quote. Competitors may offer discounts off the Urner Barry quote as a marketing inducement, but they will need to offer a larger discount to offset the greater volatility of the Urner Barry quote. Thus, the supplier using the formula price gains a competitive advantage. Second, the formula price is specifically designed to allow perfect cross-hedging with corn and soybean meal, providing the supplier with an effective output-price risk-management tool.

Aradhyula and Holt incorporated GARCH terms in a supply-demand model of the U.S. broiler industry, concluding that price variance is an important determinant of broiler supply. Holt and Aradhyula later established that output price risk stems primarily from the demand side, with production uncertainty con-

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tributing a minuscule portion of price variation. Knoeber and Thurman determined that integrators accept approximately 97 percent of the price and production risk associated with supplying broilers. Furthermore, price risk accounts for 84 percent of all risk. Knoeber and Thurman speculated that integrators are willing to accept risk (and the concomitantly higher returns) because they can reduce risk-bearing costs through diversification. This study picks up where Knoeber and Thurman left off by considering one supplier's strategy for reducing risk-bearing costs. The pricing mechanism considered here simply transfers price risk to speculators via futures markets; no diversification is required.

The objectives of the study are to (1) characterize price risk in the WOG market, (2) examine the buyer's optimal behavior using mean-variance and stochastic dominance criteria, (3) assess the potential for cross-hedging the industry standard Urner Barry WOG prices, (4) demonstrate how the alternative formula pricing mechanism allows one WOG supplier to eliminate a substantial portion of its net revenue risk, and (5) illustrate how stochastic dominance and mean-variance analysis can help guide the supplier's pricing strategy.

Price Risk in the WOG Market

Feed is the main input in broiler production, accounting for nearly 60 percent of total production cost on a liveweight basis (USDA). WOG suppliers face higher price risk in input prices than output prices. Coefficients of variation for annual corn and soybean prices are 16 percent and 18 percent, respectively, while the coefficient of variation for annual live broiler prices is 11 percent (Harwood *et al.*).

The weekly data used in this analysis display similar price volatility levels. Daily WOG prices appear in *Urner Barry's Price-Current*, and represent weighted average spot prices obtained from telephone surveys of WOG suppliers by Urner Barry staff. The Friday price quote is used in this study because customers who elect to use the formula price use the Friday quote to contract the following week's price. The study period ranges from the week

ending January 5, 1995 to December 27, 1996 (i.e., 104 weeks). The dates were selected to encompass the period when a specific WOG supplier was known to have used a particular formula. While the supplier featured in this study has used a formula price since the mid-1980s (Fryar), the study period is limited to two years because the formula changed slightly over time to accommodate inflation and technological change, and information on formulas used in other years is not available. Historical Chicago Board of Trade corn and soybean futures prices were obtained from Knight Ridder Financial Services and from the *Wall Street Journal*. Thursday settlement prices for the spot month were used to maintain consistency with the Friday WOG quotes that reflect Thursday's market activity. Table 1 shows coefficients of variation for corn futures prices (25 percent), soybean meal futures prices (17 percent), and the Urner Barry WOG quote (10 percent). Corn and soybean meal prices were positively correlated (0.72 Pearson correlation coefficient), and the Urner Barry WOG quote was positively correlated with both corn and soybean meal prices (0.34 and 0.52 Pearson correlation coefficients, respectively).

The Buyer's Perspective: Choosing Between the Urner Barry Quote and the Formula Price

The integrator's customers include further processors, buyers for retail firms, and firms within the hotel, restaurant, and institutional sector. The formula price was typically offered as a year-long contractual commitment to the integrator's larger, well-established customers (Fryar). The formula WOG price (WOGFORM) offered by the supplier was calculated as:

$$(1) \quad \text{WOGFORM } (\$/\text{lb}) \\ = 0.38 + 0.000358P_c + 0.000322P_s,$$

where P_c denotes the corn futures price in cents/bushel, and P_s denotes the soybean meal futures price in dollars per ton. After converting P_c and P_s to common units, the formula assigns weights of 0.76 and 0.24 to corn and

Table 1. Descriptive Statistics of Input and Output Prices

	Mean	Std. Dev.	C.V.*	Min	Max
Corn futures (\$/bu.)	330.392	82.580	25.0%	231.750	548.00
Soybean meal futures (\$/ton)	211.263	35.597	16.8%	152.300	272.200
Urner Barry WOG quote (\$/lb.)	0.578	0.056	9.7%	0.470	0.680
Formula price (\$/lb.)	0.566	0.039	6.8%	0.512	0.660
Pearson Correlation Coefficients					
	Corn	Soymeal	UB WOG	Formula	
Corn	1.000	0.722	0.336	0.522	
Soymeal		1.000	0.979	0.847	
UB WOG			1.000	0.412	
Formula				1.000	

* C.V. (coefficient of variation) = (standard deviation)/(mean) * 100.

soybean meal prices, respectively. The weights are similar to the 70/30 feed ration assumed in previous broiler supply models (Chavas and Johnson; Aradhyula and Holt). The parameters on P_c and P_s reflect several factors. The corn parameter, for example, reflects conversion from cents per bushel to dollars per pound (0.000179), multiplied by the feed conversion rate (approximately 1.9 pounds feed per pound liveweight), multiplied by corn's share of the feed ration (approximately 76 percent), divided by the dressing rate (72 percent is typical). Similarly, the soybean meal parameter is approximately equal to the conversion from dollars per ton to dollars per pound (0.0005) multiplied by a 1.9 feed conversion rate, multiplied by soybean meal's 24 percent share of the feed ration, divided by a 72-percent dressing rate. The \$0.38 per pound base price represents the expected fixed and variable cost of non-feed inputs, plus a markup (Fryar). The base price would require periodic updating to account for inflation and technological change, and the formula parameters would require updating if technological progress reduced the feed conversion rate or increased the dressing rate. Other integrators in the broiler industry are known to use variants of the formula price examined in this study (Fryar), although specific information is difficult to obtain.

As Table 1 shows, the formula price is less volatile, with a 7-percent coefficient of variation, than the Urner Barry WOG price. The

substantial reduction in volatility relative to corn and soybean meal prices occurs because feed prices only account for 30 percent of the formula price on average; the \$0.38/lb base price remains constant. In addition to being more stable, the formula price is 1.12 cents per pound lower on average than the Urner Barry WOG price. After accounting for serial correlation, however, the difference between the two means is not statistically significant at a .10 level. For buyers using a mini-max decision rule, the formula price is *ex post* superior, with a maximum cost of \$0.66/lb. versus a maximum Urner Barry quote of \$0.68/lb. Thus, buyers of WOGs have risk-management incentives to patronize the supplier offering the formula price rather than competing suppliers who offer the industry standard Urner Barry quote.

Stochastic dominance is an evaluative tool for decision making under uncertainty that is useful in comparing WOG pricing alternatives. In this study, Raskin and Cochran's (1986a) stochastic dominance software was used to perform the analysis. The results confirm that rational risk-neutral or risk-averse buyers would choose the formula price over the Urner Barry price. If the formula price is lower than the Urner Barry price for all levels of cumulative probability (i.e., the cumulative probability distributions do not cross), then the formula price is first-degree stochastic dominant (FSD) from the buyer's perspective. Second-degree stochastic dominance (SSD) is a

less-demanding criterion. Given two cumulative probability distributions that cross, the distribution that accumulates the largest area to the right (assuming dominant values lie to the right) of the other distribution is second-degree stochastic dominant (Hadar and Russell). All risk-neutral and risk-averse decision makers would rationally prefer a SSD distribution. If FSD and SSD fail to identify a dominant distribution, generalized stochastic dominance (GSD) allows the analyst to further refine the criteria by considering intervals bounded by upper and lower values of the Pratt-Arrow absolute risk aversion coefficient (Meyer). The coefficient measures local risk aversion (i.e., "risk aversion in the small"), but if it is assumed to be constant then changes in assets will not affect preferences among risks, and the distinction between local and global risk aversion becomes unnecessary (Pratt).

From the buyer's perspective, neither price distribution was first-degree stochastic dominant, but the formula price was second-degree stochastic dominant, as one would expect from a cost distribution with a lower mean and lower variance. If the base price in the formula were increased from \$0.38/lb., a risk-neutral decision maker would continue to choose the formula price until the base price reached \$0.3912/lb. A risk-averse decision maker with risk preferences described by a 0.0001 Pratt-Arrow absolute risk-aversion coefficient would place greater value on the stability of the formula price. The risk-averse decision maker would tolerate base price increases up to \$0.3919/lb. before switching to the Urner Barry quote.

The Seller's Perspective

Having determined that customers should prefer the formula price to the industry standard Urner Barry quote, the next issue of interest is the seller's motive for offering the formula price to its customers. The seller (an integrator) has absorbed all of the input price risk associated with feed and all of the output price risk through its growers' contracts. Knoeber and Thurman speculated that multiproduct

firms can reduce risk by diversification across enterprises, and that the shareholders of publicly owned firms can reduce risk by owning a diversified portfolio. These opportunities, however, may not be available to some decision makers in the broiler industry. Specifically, consider the risk-management alternatives of a firm producing either a single product or a line of products with positively correlated returns (e.g., processed meat products). Diversification across products will be of limited use to this firm.

Furthermore, consider the risk-reduction incentives facing the managers of a publicly owned firm. Among the top U.S. broiler companies, Tyson Foods, Con Agra Poultry, Pilgrim's Pride, Hudson Foods, Seaboard Farms, and Cagle's are publicly owned (Gold Kist is a cooperative, and Perdue Farms, Foster Farms, and Townsend's are privately-held corporations). Neoclassical theory predicts that shareholder portfolio diversification should induce integrators to maximize the firm's share price via risk-neutral behavior. Yet we observe that agribusinesses commonly engage in risk-averse behavior such as hedging. Principal-agent theory and alternative theories of the firm help explain incongruous risk preferences among principals and agents (Kreps). Holmstrom and Ricart i Costa suggest that a manager's decisions affect inferences about managerial competence in addition to the firm's financial returns. The manager's objective function is sensitive to both factors, while the firm's shareholders only value financial returns. A second motivation for risk management is that risk itself imposes costs. Lenders may impose higher capital costs on firms with more volatile returns, and the value of waiting to resolve downside uncertainty may delay otherwise profitable investments. Thus, even risk-neutral integrators have incentives to manage risk. The integrator's risk-management alternatives include hedging or forward contracting with customers, as noted by Knoeber and Thurman. Here we examine the case where the integrator wishes to limit the transfer of risk to its customers as a marketing inducement, and focuses on hedging as a price risk-management tool.

Integrators can hedge feed production and/or purchases using futures and options contracts for corn and soybean meal. Futures markets do not exist for poultry, however, leaving the integrator completely exposed to output price risk. Given that the Urner Barry WOG price is positively correlated with corn and soybean meal futures prices, one might consider selling WOGs at the industry standard Urner Barry WOG price and cross-hedging with corn and soybean meal futures contracts. Such a strategy might allow the integrator to simultaneously manage output price risk and the input price risk associated with feed. Henceforth, we refer to output price less the prorated feed expense as "partial net revenue." The proration follows the formula in (1) to allow comparison between scenarios using the formula price versus the Urner Barry WOG price. Specifically,

(2) *partial net revenue*

$$= \text{output price} - 0.000358P_c \\ - 0.000322P_s,$$

where P_c and P_s are defined as in equation (1) but lagged six weeks from the time output is sold to reflect the commitment of inputs at the beginning of the production period. Given that the integrator featured in this study operated in Arkansas, weekly cash corn and soybean meal prices were obtained from Memphis Daily Grain Reports and Memphis Weekly Feed Reports compiled by the USDA-AR Extension Service in Little Rock, Arkansas. The corn and soybean meal cash prices were each 98 percent correlated with their corresponding nearby futures prices.

Estimates of risk-minimizing hedge ratios for corn and soybean meal are equal to the respective parameters α_1 and α_2 in the regression (Stoll and Whaley, p.57):

$$\Delta PNR_t = \alpha_0 + \alpha_1 \Delta P_{c,CBOT,t} + \alpha_2 \Delta P_{s,CBOT,t}$$

where Δ denotes first differences, PNR_t denotes partial net revenue at time t , $P_{c,CBOT}$ denotes the nearby futures price of corn, and $P_{s,CBOT}$ denotes the nearby soybean meal fu-

Table 2. Optimal Hedge Ratio Regressions Imply that Hedging the Urner Barry WOG Quote is Futile, but Hedging the Formula Price is Effective

	Dependent Variable	
	$\Delta PNR_{UB,t}$	$\Delta PNR_{formula,t}$
Intercept	-0.000117 (0.002177)*	-0.001524 (0.000665)
$\Delta P_{c,CBOT,t}$	0.000250 (0.000216)	0.000363* (0.000033)
$\Delta P_{s,CBOT,t}$	-0.000473 (0.000444)	0.000386* (0.000137)
Adjusted R^2	-0.0014	0.6733

* Standard errors in parentheses.

* Denotes statistical significance at .01 level.

tures price. Parameter estimates equal to zero imply that partial net revenue cannot be effectively hedged with a particular futures contract. The adjusted R-squared from the regression is a measure of hedging effectiveness, with a unit value implying a perfect hedge.

Optimal hedge ratios were estimated for two scenarios, in which the Urner Barry WOG quote and the formula price determined output prices. Table 2 shows the autocorrelation-corrected regression results. When output prices were based on the Urner Barry WOG quote, neither of the parameter estimates was significant at a .10 level, and the adjusted R^2 was negative. The results imply that, although hedging might be an effective way to manage input and output price risk separately, hedging would not help the integrator manage the risk of volatile partial net revenue when output prices are based on the Urner Barry WOG quote. The failure of cross-hedging to manage partial net revenue risk helps motivate the formula price that guarantees effective cross-hedging.

When output prices were based on the formula price, the parameter estimates were highly significant and similar in magnitude to the coefficients of the pricing formula. This result is expected, because the formula price is a linear combination of corn and soybean meal futures prices. The adjusted R-squared of 0.67 implies that 67 percent of the volatility in partial net revenue can be eliminated by hedging.

The remaining 33 percent of partial net revenue volatility is attributable to fluctuating basis levels over time.

Note that the formula price is specifically designed to allow perfect hedging of partial net revenue, assuming the integrator can purchase feed and set corn and soybean meal hedges in proportions consistent with the formula price parameters. Let $P_{c,1}$ and $P_{s,1}$ denote corn and soybean meal futures prices, respectively, on the WOG sale date. Likewise, let $P_{c,0}$ and $P_{s,0}$ denote corn and soybean meal futures prices, respectively, when feed is purchased and hedges are set. Let $B_{c,0}$ and $B_{s,0}$ denote the initial basis when hedges are set. Partial net revenue is thus the output price

$$\$0.38 + 0.000358P_{c,1} + 0.000322P_{s,1}$$

less the cost of corn and soybean meal inputs

$$\begin{aligned} &-0.000358(P_{c,0} + B_{c,0}) \\ &- 0.000322(P_{s,0} + B_{s,0}), \end{aligned}$$

plus the gain from the corn and soybean meal hedges

$$\begin{aligned} &+0.000358(P_{c,0} - P_{c,1}) \\ &+ 0.000322(P_{s,0} - P_{s,1}), \end{aligned}$$

which equals

$$\$0.38 + 0.000358B_{c,0} + 0.000322B_{s,0}.$$

The formula price allows perfect hedging in the sense that, after setting the hedge, the integrator knows the future value of partial net revenue with certainty. Initial basis levels will fluctuate from one hedge to the next, however, causing volatility in the partial net revenue stream and justifying hedge ratios slightly different from the formula price parameters.

One futures contract of corn represents 280,000 pounds, and one contract of soybean meal represents 200,000 pounds. A ratio of two corn contracts per soybean meal contract produces a ratio of 74 percent corn to 26 percent soybean meal, which approximates the 70/30 rule-of-thumb feed ration, the 76/24 ra-

tio implied in equation (1), and the 72/28 ratio implied by the optimal hedge ratio estimates. The amount of feed involved in this hedge is enough to raise approximately 100,000 broilers to market weight (Chavas and Johnson). The 100,000-broiler scale was selected as a benchmark for further analysis, as it represents the minimum scale at which the formula price can be effectively hedged. A market weight of four pounds per bird was assumed.

Assuming that birds are on feed for six weeks, and that approximately 100,000 broilers reach market weight each week, three simulated partial net return distributions were developed. All three distributions assumed that the integrator realized input costs at the beginning of the six-week production period. The first distribution assumed that the integrator received the Urner Barry WOG quote at the end of the six-week production period. The second distribution assumed that the integrator received the formula price. The third distribution also used the formula price, but incorporated a uniform weekly short hedging strategy. Corn and soybean meal hedges were set at the beginning of the production period, and lifted at the end of the production period. The optimal hedge ratio results shown in Table 2 determined the quantity of futures contracts sold when setting each hedge.

Table 3 shows the descriptive statistics for each of the three scenarios. Partial net revenue based on the Urner Barry WOG quote showed the highest mean and the highest volatility, while the optimally hedged partial net revenue stream based on the formula price displayed the lowest mean and the lowest volatility. The Urner Barry quote produced a weekly average partial net revenue that was 3.7 percent higher than the hedged formula price, but the standard deviation of the Urner Barry series was seven times greater than that of the hedged formula price. In the case of the Urner Barry series, individual weekly observations covered a range of over \$82,000, while the hedged formula price covered a range of about \$24,000. The mean of the unhedged formula price series was less than 1 percent higher than its hedged counterpart, but it was 2.9 times as volatile.

Table 3. Descriptive Statistics for "Partial Net Revenue" Distributions at a 100,000-Broiler Scale Based on Alternative Pricing Strategies*

Output Price	Mean (\$)	Std Dev (\$)	C.V.	Min. (\$)	Max. (\$)
Urnar Barry WOG quote	156,877	20,011	12.8%	112,858	195,524
Formula price, unhedged	152,400	8,287	5.4%	129,236	170,898
Formula price, hedged	151,289	2,847	1.9%	137,763	161,698

* "Partial net revenue" refers to per-unit output price less the value of corn and soybean meal inputs, assuming Memphis basis, equation (1) accurately reflects feed conversion and dressing rates, and hedging is possible in the ratio implied by equation (1).

Stochastic dominance results appear in Table 4. The second-degree stochastic dominance criterion did not identify a single risk-efficient distribution, but a generalized stochastic dominance analysis suggested that the unhedged Urnar Barry WOG quote dominated for absolute risk-aversion coefficients lower than 0.000029. The unhedged formula price dominated over a narrow range of absolute risk-aversion coefficients from 0.000029 to 0.000033, and the hedged formula price dominated for absolute risk-aversion coefficients greater than 0.000033.

The original analysis is time-specific and place-specific. Table 4 also reports results from two additional scenarios that were examined to test the sensitivity of the results to basis risk and to the unusual corn basis behavior during the summer of 1996. In the interest of obtaining results that were not affected by site-specific basis patterns, futures prices were used to value the purchase price or opportunity cost of feed in Scenario 2. Thus, the partial net revenue distributions did not reflect input basis risk.

Scenario 3 considered only the period from January, 1995 to mid-July, 1996. The shortened study period still encompassed dates when the formula in equation (1) was known

to be used, but it excluded the period beginning in mid-July, 1996 when Memphis corn basis ranged from \$0.77 under nearby futures to \$1.02 over nearby futures during the course of five weeks. This extreme basis variation resulted from the inverted old crop/new crop market following the drought-induced short crop year of 1995. A stochastic dominance analysis of the shortened study period may better represent "normal" market conditions.

As Table 4 shows, the absence of basis risk barely affected the stochastic dominance rankings relative to the baseline scenario. Given that Memphis corn and soybean meal cash prices were 98 percent correlated with their corresponding futures prices, the similarity between Scenarios 1 and 2 is not surprising. If corn and soybean meal markets are spatially integrated, one would expect similar results in other locales.

Although the formula price continued to dominate over the range of risk-averse preferences in Scenario 3, the period under consideration affected the stochastic dominance rankings. When the unusual behavior of July and August of 1996 was excluded, the formula price was much less volatile, with a coefficient of variation of only 2.8 percent. Thus, the unhedged partial net revenue risk was already so

Table 4. Range of Risk Preferences Over Which Each Strategy Dominates, for Three Scenarios

	Scenario 1 Memphis-Basis Risk Jan. 1995–Dec. 1996	Scenario 2 No-Basis Risk Jan. 1995–Dec. 1996	Scenario 3 Memphis-Basis Risk Jan. 1995–July 1996
Pricing Strategy			
Urnar Barry	$-\infty$ to 0.000029*	$-\infty$ to 0.000028	$-\infty$ to -0.000001
Formula Price	0.000029 to 0.000033	0.000028 to 0.000029	-0.000001 to 0.000569
Hedged Formula Price	0.000033 to $+\infty$	0.000029 to $+\infty$	0.000570 to $+\infty$

* Values represent Pratt-Arrow absolute risk-aversion coefficients.

low that hedging was not a dominant strategy at moderate levels of risk aversion.

One naturally wonders whether a certain risk-aversion coefficient (e.g., 0.000033) represents slight, moderate, or strong risk aversion in a given context. Raskin and Cochran (1986b) present a table of absolute risk-aversion coefficients (denoted r) elicited or assumed in previous studies. Most of the studies evaluated alternatives at the annual farm income scale. Of the studies that directly elicited risk preferences, the highest value representing the onset of "strongly risk averse" preferences was 0.0025 (Love and Robison). After accounting for differences in scale, the transition from dominance of the Urner Barry WOG quote to the hedged formula price appears to occur within moderately risk averse levels in Scenarios 1 and 2. In Scenario 3, the unhedged formula price dominates over all reasonably expected levels of risk aversion.

A more formal means of interpreting the stochastic dominance results is to identify an *a priori* upper bound on the Pratt-Arrow absolute risk-aversion coefficient (McCarl and Bessler). One method involves establishing the risk premium as a function of a given number of standard deviations (D) from the mean net revenue, thereby representing the attitude towards risk for the decision maker. This then provides the basis for a confidence interval around the mean net revenue and permits the calculation of the maximum risk-aversion coefficient consistent with that confidence interval as based on the relationship between the risk premium ($D\sigma_x$) and the risk-aversion coefficient established by Pratt (see, e.g., Dillon). Assuming a normally distributed risky prospect x , McCarl and Bessler then suggest an upper bound on the risk-aversion coefficient r such that $r(x) = 2Z_\alpha/\sigma_x$, where Z_α denotes the z -statistic associated with risky outcomes that occur with α cumulative probability, and σ_x denotes the standard deviation of the risky prospect. Consequently, the appropriate normal Z_α value reflects a decision maker who maximizes a target level of partial net revenues that is α percent likely, where $50 < \alpha \leq 100$ for a risk-averse individual. Thus, a risk-neutral individual will maximize the net rev-

enues that are 50 percent likely ($Z = 0$ is associated with no risk premium) whereas a risk-averse individual would select an optimal strategy that returns a level of net revenues more likely to be achieved. Table 3 shows, for example, the standard deviation of the distribution based on the Urner Barry quote as \$20,011 at the 100,000-broiler scale. Assuming a confidence interval that occurs with 0.65 probability, for example, the appropriate one-tailed z -statistic is 0.385 and the resulting upper bound on the risk-aversion coefficient is 0.000038, which is approximately the level of risk aversion at which the hedged formula price begins to dominate in Scenario 1. McCarl and Bessler's approach thus offers further evidence that the hedged formula price would dominate for moderately risk-averse suppliers.

While stochastic dominance is an effective tool for identifying dominant pure pricing strategies, it fails to identify optimal portfolios of pricing strategies. Given that the supplier featured in this study offers some, but not all, of its customers a choice between pricing mechanisms, the likelihood of implementing a pure pricing strategy is small. A mean-variance analysis was thus performed to consider portfolio solutions, where the results suggest that risk-averse managers would prefer mixed pricing strategies.

A quadratic programming model within an expected value-variance (E-V) framework incorporates partial net revenues and risk considerations for various pricing strategies for the sale of WOGs. E-V, or mean-variance, analysis is a widely used and accepted method (e.g., Freund; Markowitz; Heady and Candler; McFarquhar; Lin, *et al.*; Weins). Further numerous references can be found in Boisvert and McCarl, Robison and Brake, and Robison and Barry.

The specification of the E-V model is:

$$\max \bar{Y} - r\sigma_y^2$$

subject to:

$$(3a) \quad \sum_p SELL_p \leq 1$$

$$(3b) \quad -\sum_p NETREV_{p,WK} \cdot SELL_p + Y_{WK} = 0$$

$$(3c) \quad \sum_{WK} \frac{1}{N} Y_{WK} - \bar{Y} = 0 \quad \forall WK$$

where activities include:

\bar{Y} = expected partial net revenues
(mean across weeks)

Y_{WK} = partial net revenues by week

$SELL_p$ = sales of WOGs under pricing
strategy p in 100,000 lb units

constraints include:

- (a) Total sales volume limitation
- (b) Net partial revenue balance by year
- (c) Expected net partial revenue balance

coefficients include:

r = Pratt-Arrow absolute risk-
aversion coefficient

$NETREV_{p,WK}$ = partial net revenues for
pricing strategy p in week
 WK in dollars for the
100,000-pound level

N = number of states of nature
(weeks, or 104)

and indices include:

WK = week

p = pricing strategy.

The objective function maximizes the certainty equivalent of partial net revenue, which is the expected partial net revenue less the product of the risk aversion coefficient and the variance of partial net revenues (σ_p^2). The upper bound on the risk aversion coefficient is calculated using the method described by McCarl and Bessler, wherein a decision maker is assumed to maximize the lower limit from a confidence interval of normally distributed net returns. The general formula for calculating the risk-aversion parameter is $r = 2Z_\alpha/S_y$,

where r denotes the risk-aversion coefficient, Z_α the standardized normal Z value of α level of significance and S_y the sample standard deviation of the risk-neutral profit maximizing base case. The data required to specify the pricing decision model are simply the partial net revenue distributions for each pricing strategy.

Table 5 shows optimal portfolios of pricing strategies for selected levels of risk aversion ranging from risk neutrality to strong risk aversion. The mean-variance analysis is consistent with the stochastic dominance results in that the hedged formula price assumes greater importance as risk aversion increases. A risk-neutral supplier (i.e., the 50-percent confidence level in Table 5) would prefer a pure strategy based on the unhedged Urner Barry quote. At the 65-percent confidence level, however, the hedged formula price made up over half of the optimal portfolio, and at the 95-percent confidence level the hedged formula price made up the vast majority of the optimal portfolio. Even at strongly risk-averse levels, the Urner Barry quote and the unhedged formula price remained in the optimal portfolio, albeit in low proportions.

Discussion

Production contracts in the broiler industry typically shift input and output price risk from the grower to the integrator (Knoeber and Thurman). Integrators thus face incentives to reduce risk-bearing costs. This study focuses on one price risk management strategy by which an integrator's customers may choose between two pricing mechanisms: an industry standard Urner Barry quote or a formula price based on futures prices. The formula price is interesting because it allows the integrator to transfer virtually all price risk to speculators in a commodity not directly served by futures markets.

The formula price is no higher on average than the industry standard Urner Barry quote, and it is less volatile. Thus, the formula price acts as a marketing tool to maintain and expand the integrator's clientele. From a risk-management perspective the formula price

Table 5. Optimal Portfolios of Pricing Strategies and Descriptive Statistics at Selected Levels of Risk Aversion, at a 100,000-Broiler Scale

Pr(exceeds Confidence Interval Bound)*	50%	65%	80%	95%
Absolute Risk-Aversion Coefficient	0.000000	0.000038	0.000084	0.000200
Relative Risk-Aversion Coefficient	0.00	5.87	12.79	30.34
Optimal Portfolios				
Uner Barry	100%	18.58%	8.91%	4.93%
Formula Price-Unhedged	0%	24.74%	14.39%	10.14%
Formula Price-Hedged	0%	56.68%	76.70%	84.93%
Descriptive Statistics of "Partial Net Revenue"				
Mean (\$)	156,877	152,602	151,947	151,678
Standard Deviation (\$)	20,011	4,852	3,337	2,952
Coefficient of Variation	12.76%	3.18%	2.20%	1.95%
Min (\$)	112,858	136,072	136,736	137,010
Max (\$)	195,524	162,287	158,919	159,830

* Probability represents the likelihood of exceeding a maximized lower confidence limit on "partial net revenue". Assuming normally distributed returns, risk neutrality corresponds to a 50-percent probability that observed partial net revenue exceeds the expected value (Dillon). A risk-averse decision maker requires greater certainty in net revenue. McCarl and Bessler provide details.

also allows, in principle, perfect cross-hedging with corn and soybean meal. Results from stochastic dominance and mean-variance analyses suggested that risk-neutral integrators would prefer the unhedged Uner Barry quote, while more risk-averse suppliers would prefer the hedged formula price.

The risk-management strategies of the broiler industry may provide useful examples as other agricultural sectors coordinate vertically, rely more on contracts to transfer goods between market levels, and potentially face more volatile commodity prices as a result of policy reforms. Input-based formula pricing strategies could be effectively used for agricultural commodities that meet three criteria. First, the output must not be traded on a futures exchange or effectively hedged (e.g., cash feeder cattle prices in Kentucky and Tennessee are often not highly correlated with feeder cattle futures prices that are cash-settled based on Midwest market conditions). Second, a set of inputs must be traded via futures contracts. Third, that set of inputs must be used in stable proportions within the production process, and it must account for a substantial portion of price risk in the commodity.

Input-based formula pricing could be easily extended to shell eggs, egg products, broiler

parts, turkey products, and aquaculture products. Such a strategy would be less effective in the pork and beef industries, which are well-served by futures markets, and might be impractical in the highly administered fluid milk market where cash forward pricing is in its infancy. Input-based formula pricing could, however, be effective in manufactured dairy products such as ice cream, butter, and cheese. Futures markets exist for butter and cheese, but they are currently too thin to be effective hedging instruments (Prosi). Futures markets for the primary input, milk, are more liquid and are potentially superior hedging tools. Similar opportunities may exist in manufactured cereal products. If input basis risk were sufficiently high to warrant attention, the strategy could be extended to contracts with input suppliers such that even input basis risk could be eliminated.

Limitations of the analysis should be recognized. The stochastic dominance and mean-variance analyses fail to measure the increase in sales attributable to use of the formula price, and data are not available with which to measure the effectiveness of the formula price as a marketing inducement. Discounts off the Uner Barry quote are used to attract customers in the egg industry (Maynard). If the same strategy is common in the broiler industry, it

might be more appropriate to compare the formula price to a discounted Urner Barry quote. A selective hedging program has the potential to yield higher average net returns than the uniform hedging strategy assumed in this study. A selective strategy would attempt to leave the integrator exposed to output price risk if rising output prices were expected during the growing period, but short hedges would be set if falling output prices were expected. Put options also offer a potentially risk-efficient hedging strategy in combination with an input-based formula price.

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