Perfect Cross-Hedging Opportunities via Formula Pricing: the Case of the Broiler Industry

Joy Carter
Central Plant Ingredient Buyer, Land O'Lakes, Inc.
2827 8th Ave. S.
Fort Dodge, IA 50501
phone: 515-574-2017
fax: 515-574-2037
email: jcart@landolakes.com

Leigh J. Maynard (contact author)
Assistant Professor, Dept. of Agricultural Economics
319 Ag. Engineering Bldg., University of Kentucky
Lexington KY 40546-0276
phone: 859-257-7286
fax: 859-257-7290
email: lmaynard@ca.uky.edu

Carl R. Dillon
Associate Professor, Dept. of Agricultural Economics
403 Ag. Engineering Bldg., University of Kentucky
Lexington KY 40546-0276
phone: 859-257-3267
fax: 859-257-7290
email: cdillon@ca.uky.edu

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Abstract
One supplier of broilers without giblets (WOGs) offers 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 is second-degree stochastic dominant, thus acting as a marketing inducement. The formula price allows the seller to set almost perfect cross-hedges of WOGs with corn and soymeal. Stochastic dominance results suggested that the seller's dominant strategy would shift from the unhedged Urner Barry quote to the unhedged formula price as risk aversion increased. The hedged formula price was prominent in optimal portfolios of pricing strategies.

Keywords: broiler industry, formula pricing, hedging strategies, mean-variance analysis, stochastic dominance

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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. One U.S. supplier of whole broilers without giblets (WOGs) uses 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.

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 both less volatile and lower 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 allows almost perfect cross-hedging with corn and soybean meal, providing the supplier with a highly 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. 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 the 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*. 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. 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 formula WOG price (WOGFORM) offered by the supplier was calculated as:

(1) $WOGFORM$ (\$/lb) = 0.38 + 0.000358 P_c + 0.000322 P_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 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.

As Table 1 and Figure 1 show, the formula price is less volatile, with a seven 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. The difference between the two means is statistically significant at a .10 level (z = 1.68). For buyers using a mini-max decision rule, the formula price is again superior, with a maximum cost of $0.66/lb. versus a maximum Urner Barry quote of $0.68/lb. Thus, buyers of WOGs have cost-cutting and 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) generalized 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 was lower than the Urner Barry price for all levels of cumulative probability (i.e., the cumulative probability distributions do not cross), the formula price would be first-degree stochastic dominant (FSD). 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, 1977).

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 (Pratt) 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: Cross-Hedging Fails to Manage Urner Barry Price Risk

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 in 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 management of a publicly owned firm. Portfolio diversification is relevant to the shareholder, but not to the corporate integrator's agents responsible for decision making. The integrator's remaining 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 instead 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.

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 and the 76/24 ratio implied in equation (1). The amount of feed involved in this hedge is enough to raise approximately 100,000 broilers to market weight (Chavas and Johnson).

Assuming that birds are on feed for six weeks, and that approximately 100,000 broilers reach market weight each week, an integrator might pursue a uniform weekly hedging strategy that attempts 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,

$$\textit{partial net revenue} = \textit{output price} - 0.000358\, P_c - 0.000322\, P_s, \qquad (2)$$

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.

In the interest of obtaining results that are not affected by site-specific basis patterns, futures prices are used to value the purchase price or opportunity cost of feed. Thus, the partial net revenue distributions do not reflect input basis risk. While the lack of input basis risk affects the volatility of the partial net revenue distributions, it does so equally across all of the distributions generated. Accordingly, the relative ranking of the various risk management alternatives should only be affected over narrow ranges of risk preferences.

Table 2 illustrates the outcome of a short cross-hedge when output is sold at the Urner Barry WOG price, given the assumptions of a zero basis and the ability to hedge in the proportions reflected in equation (1). The hedge essentially matches up the periods when revenue is earned and costs are incurred. If WOG prices fell between the time feed was committed and the time the WOGs were marketed, and if corn and soybean meal futures prices are positively correlated with the WOG price, then a futures gain should partially offset the loss in the cash market. The converse would hold if WOG prices rose, leading to a less volatile partial net revenue stream.

The uniform hedging strategy fails, however, to reduce the volatility of partial net revenue when output is valued at the Urner Barry WOG price. As shown in Table 3, the descriptive statistics are nearly identical for the scenarios with and without hedging. Although the Urner Barry WOG price was positively correlated with corn and soybean meal futures prices, it was almost equally correlated with six-week lags of the futures prices, implying that no risk management benefits accrue to the seller by using a short hedge to replace lagged input costs with current input costs. The failure of cross-hedging to manage partial net revenue risk when using the Urner Barry WOG quote motivates the design of a formula price that guarantees effective cross-hedging.

The Seller's Perspective: Cross-Hedging the Formula Price Eliminates Price Risk

Cross-hedging the WOG output price with corn and soybean futures prices would be more effective as the correlation between them increases, and the ideal output price for price risk management would be one that is perfectly correlated with the linear combination of corn and soybean futures prices used for hedging. Table 4 illustrates that the formula price can allow perfect cross-hedging of the output price under certain conditions. If the formula parameters that translate feed prices into WOG values conform to the hedging proportions used (e.g., two corn contracts per soybean meal contract), then any fall in formula price values is perfectly matched by a gain in the futures market; not even basis risk remains.

Table 4 also demonstrates how the formula price can lock in a partial net revenue level, subject to basis risk not considered here. Any change in the value of feed's contribution to the WOGs value while the birds are on feed is completely offset by the change in the value of the short futures positions. The remaining partial net revenue equals the base price specified in the formula, in this case $0.38 per pound. Figure 2 graphically illustrates the relative volatility of partial net revenue under three pricing strategies: the unhedged Urner Barry quote, the unhedged formula price, and the hedged formula price.

One initially suspects that some risk averse suppliers must prefer its customers to choose the effective, yet simple, formula pricing mechanism over the Urner Barry WOG quote. Table 3 shows that, compared to the unhedged Urner Barry WOG quote, the hedged formula price eliminates most input price risk and all output price risk at an average cost of 1.4 cents per pound (3.6 percent of partial net revenue). While it is clear that a risk neutral or risk preferring supplier would prefer its customers to select the Urner Barry quote, stochastic dominance is a useful tool for evaluating the pricing mechanisms under risk aversion.

The alternatives considered were partial net revenue distributions resulting from the Urner Barry WOG quote with and without uniform weekly hedging, and from the formula price with and without hedging. The stochastic dominance analysis was performed at the 100,000-pound scale, approximately the minimum scale for effective hedging. Second-degree stochastic dominance did not identify a single risk-efficient distribution, but generalized stochastic dominance suggested that the unhedged Urner Barry WOG quote dominated for absolute risk aversion coefficients less than 0.0000127. The unhedged formula price dominated for absolute risk aversion coefficients from 0.0000127 to 0.00143, and the hedged formula price dominated for absolute risk aversion coefficients greater than 0.00143.

Regarding interpretation of the results, 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 boundary between "almost risk neutral" and "strongly risk averse" was 0.0025 (Love and Robison). After accounting for differences in scale, the transition from dominance of the unhedged formula price to the hedged formula price appears to occur at or near strongly risk averse levels.

A more formal means of interpreting the stochastic dominance results is to identify *a priori* bounds on the Pratt-Arrow absolute risk aversion coefficient (McCarl and Bessler). One method involves assuming a confidence interval around the risk premium and inferring the maximum risk aversion coefficient consistent with that confidence interval (see, e.g., Dillon). Assuming a normally distributed risky prospect *x*, McCarl and Bessler suggest an upper bound of the risk aversion coefficient *r* such that $r(x) = 2\, Z_{\alpha} / \sigma_x$, 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. Table 3 shows, for example, the standard deviation of the distribution based on the unhedged Urner Barry quote as $4,992 at the 100,000-pound scale. Assuming a confidence interval that occurs with .95 probability, for example, the appropriate one-tailed *z*-statistic is 1.645 and the resulting upper bound on the risk aversion coefficient is 0.000659, which is lower than the value at which the hedged formula price begins to dominate. McCarl and Bessler's approach thus offers further evidence that the unhedged formula price would dominate even for strongly risk averse suppliers.

The stochastic dominance results are surprising in that a strategy that removes all price risk (the hedged formula price) does not dominate within the range of anticipated risk preferences. 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 or 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 do in fact suggest a strong role for the hedged formula price.

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:

$$MAX\ \overline{Y} - r\sigma^2_y$$

subject to:

(2a) $$\sum_p SELL_p \leq 1$$

(2b) $$-\sum_p NETREV_{p,WK} * SELL_p + Y_{WK} = 0 \qquad \forall\ WK$$

(2c) $$\sum_{WK} \frac{1}{N} Y_{WK} - \overline{Y} = 0$$

where activities include:

$\overline{Y}$ = 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
$NETREV_{P,KW}$	= 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 less the product of the Pratt-Arrow absolute risk-aversion coefficient (*r*) and the variance of net returns (σ^2_y). 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. 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 almost two thirds of the optimal portfolio, and at the 95 percent confidence level the hedged formula price made up seven eighths of the optimal portfolio. Even the poor-performing hedged Urner Barry quote appears in the optimal portfolio for some risk levels. This occurs due to the negative correlation (-0.35) between the hedged Urner Barry quote and the unhedged formula price. The unhedged Urner Barry quote and the unhedged formula price are not highly correlated (0.03).

The mean-variance analysis is consistent with the stochastic dominance results in that the formula price assumes greater importance as risk aversion increases, but the results of the two techniques are in stark contrast regarding the role of cross-hedging the formula price. The stochastic dominance and mean-variance results jointly imply that even strongly risk averse decision makers would be willing to incur some risk in return for higher net revenues, but the cross-hedged formula price offers the primary means of tailoring the risk level to the decision maker's risk preferences. Figure 3 illustrates the risk-efficiency frontier derived from optimal portfolios at confidence levels ranging from 50 to 95 percent.

Summary and Conclusions

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. On a broader level, 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.

The formula price consists of a fixed base price and a variable component tied to Chicago Board of Trade corn and soybean meal futures prices. The parameters of the variable component translate the value of feed ingredients into the value of whole broilers without giblets (WOGs). The formula price is not only lower on average than the industry standard Urner Barry WOG quote, it is less volatile. Thus, the formula price acts as a marketing tool to maintain and expand the integrator's clientele.

From the integrator's perspective the formula price allows, in principle, perfect cross-hedging with corn and soybean meal. Changes in the value of formula-priced WOGs during the hedging period can be offset by equal and opposite changes in the value of short futures positions. In practice, the hedging ratio must recognize that corn and soybean meal futures contracts trade in units of 5,000 bushels and 100 tons, respectively. Fortunately, the ideal hedging ratio implied by the formula's parameters closely matches a 2:1 corn:soymeal hedging ratio. Basing the formula on futures prices rather than cash prices even eliminates basis risk in the integrator's output price.

The integrator ultimately cares about price risk management at the net revenue level, which includes input and output price risk. "Partial net revenue" distributions were generated that subtract the value of corn and soybean meal inputs from the output's value. The formula price is designed such that, by placing short hedges on corn and soybean meal when the inputs are purchased for broiler production, the integrator can lock in a partial net revenue value of $0.38/lb. (the fixed base price in the formula), subject to basis risk in the input markets.

Although the formula price combined with a uniform cross-hedging strategy does a masterful job of managing price risk, stochastic dominance results suggested that almost risk neutral integrators would prefer the unhedged Urner Barry quote, while more risk averse suppliers would prefer the formula price but would not hedge. The role of the hedged formula price became clearer when optimal portfolios of pricing strategies were considered in a mean-variance framework. Even at moderately risk averse preferences, the hedged formula price comprised the majority of a risk-efficient portfolio.

Pricing strategies designed to allow perfect hedging or cross-hedging 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 product, broiler parts, turkeys, and aquaculture products. Such a strategy would be less effective in the pork and beef industries, which are well-served by futures markets, and would be impractical in the highly administered fluid milk market where cash forward pricing is currently infeasible. 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). However, 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 business 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 Urner 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.

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	548.000
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

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

Table 2. Cross-Hedging the Urner Barry WOG Quote [a]

Date	Cash Corn	Cash Soymeal	Cash WOG	Corn Futures	Soymeal Futures
t_0	buy @ $P_{c,0}+B_{c,0}$ [b]	buy @ $P_{c,0}+B_{c,0}$		short @ $P_{c,0}$	short @ $P_{s,0}$
t_1			sell @ WOG_1	long @ $P_{c,1}$	long @ $P_{s,1}$

"Partial net revenue"$=WOG_1-.000358\,[(P_{c,1} + B_{c,0})+(P_{c,0}-P_{c,1})]-.000322\,[(P_{s,1} + B_{s,0})+(P_{s,0}-P_{s,1})]$

$$=WOG_1 - 0.000358\,(P_{c,1} + B_{c,0}) - 0.000322\,(P_{s,1} + B_{s,0})$$

[a] assuming equation (1) accurately reflects feed conversion and dressing rate, and assuming hedging is possible in the ratio implied by equation (1)

[b] $P_{c,t}$, $P_{s,t}$, $B_{c,t}$, $B_{s,t}$ denote corn futures price, soybean meal futures price, corn basis, and soybean meal basis at time *t*, respectively; WOG_t denotes the Urner Barry WOG quote at time *t*

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

	Mean ($)	Std Dev ($)	C.V.	Min. ($)	Max. ($)
Urner Barry quote, unhedged	39,366	4,992	12.7%	28,299	49,776
Formula price, unhedged	38,247	1,991	5.2%	31,373	43,121
Urner Barry quote, hedged	39,119	5,317	13.6%	27,438	50,841
Formula price, hedged	38,000	0	0.0%	38,000	38,000

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

Table 4. Formula Price Allows Perfect Cross-Hedging of the Output Price, and Eliminates Price Risk from "Partial Net Revenue" [a]

Date	Cash Corn	Cash Soymeal	Cash WOG	Corn Futures	Soymeal Futures
t_0	buy @ $P_{c,0}+B_{c,0}$ [b]	buy @ $P_{c,0}+B_{c,0}$		short @ $P_{c,0}$	short @ $P_{s,0}$
t_1			sell @ $WOGFORM_1$ [c]	long @ $P_{c,1}$	long @ $P_{s,1}$

Output price = $.38 + .000358\ P_{c,1} + .000322\ P_{s,1} + .000358\ (P_{c,0} - P_{c,1}) + .000322\ (P_{s,0} - P_{s,1})$

$= .38 + .000358\ P_{c,0} + .000322\ P_{s,0}$

"Partial net revenue" = $.38 + .000358\ P_{c,0} + .000322\ P_{s,0} - .000358\ (P_{c,0} + B_{c,0}) - .000322\ (P_{s,0} + B_{s,0})$

$= .38 - .000358\ B_{c,0} - .000322\ B_{s,0}$

[a] assuming hedging is possible in the ratio implied by equation (1)

[b] $P_{c,t}$, $P_{s,t}$, $B_{c,t}$, $B_{s,t}$ denote corn futures price, soybean meal futures price, corn basis, and soybean meal basis at time *t*, respectively

[c] $WOGFORM_t = 0.38 + 0.000358\ P_{c,t} + 0.000322\ P_{s,t}$

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

Pr(Exceeds Confidence Interval Bound)*	50%	65%	80%	95%
Absolute Risk Aversion Coefficient	0.000000	0.000154	0.000337	0.000659
Relative Risk Aversion Coefficient	0.000000	5.896044	13.109974	25.086153
	Optimal Portfolios			
Urner Barry - Unhedged	100%	17.54%	0%	0%
Urner Barry - Hedged	0%	0%	8.02%	4.11%
Formula Price - Unhedged	0%	18.83%	16.63%	8.51%
Formula Price - Hedged	0%	63.63%	75.35%	87.38%
	Descriptive Statistics of "Partial Net Revenue"			
Mean ($)	39,366	38,286	38,902	38,067
Standard Deviation ($)	4,992	963	440	225
Coefficient of Variation	12.68%	2.52%	1.15%	0.59%
Min ($)	28,299	36,047	37,107	37,543
Max ($)	49,776	39,973	38,902	38,462

* 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.

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Figure 1. Buyers Prefer the Lower Mean and Lower Variance of the Formula Price

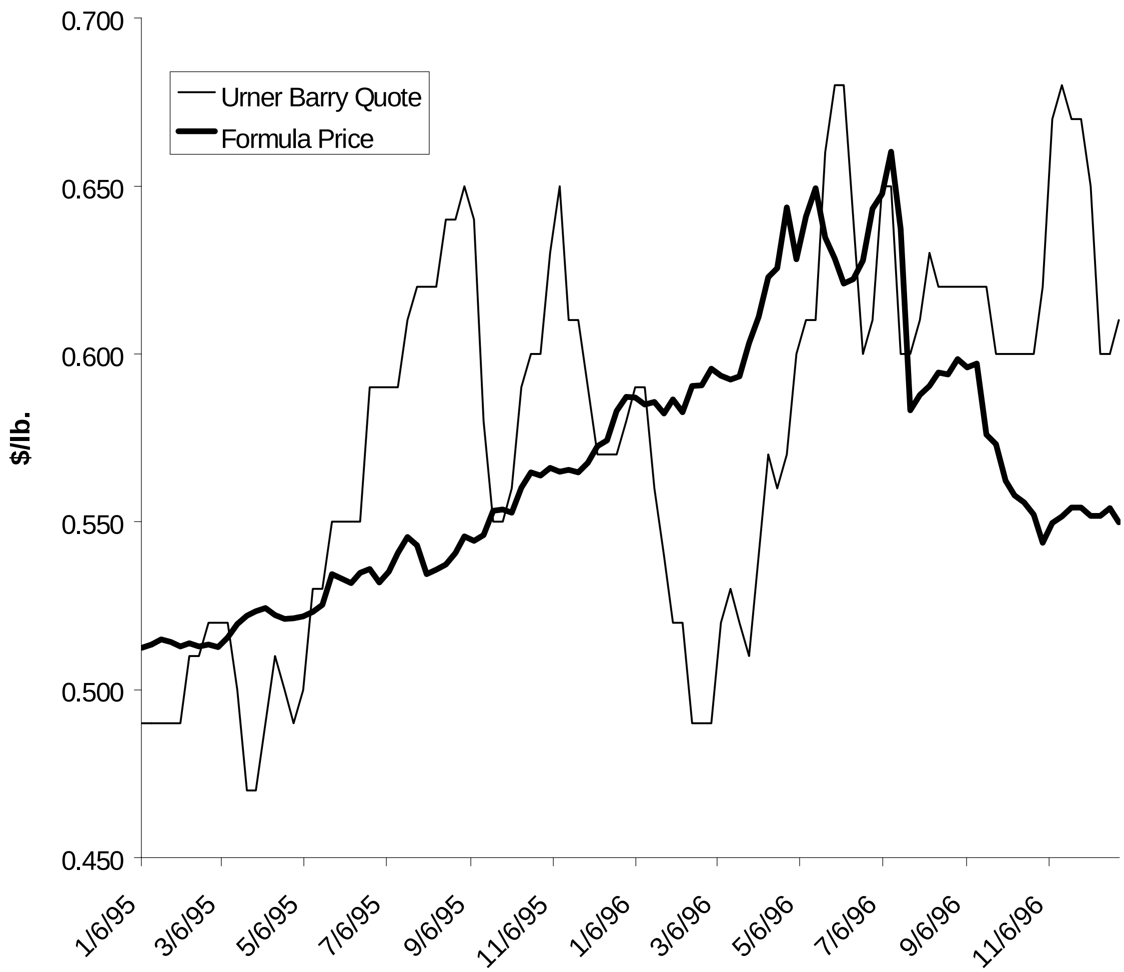


Figure 2. “Partial Net Revenue” Under Alternative Pricing Strategies

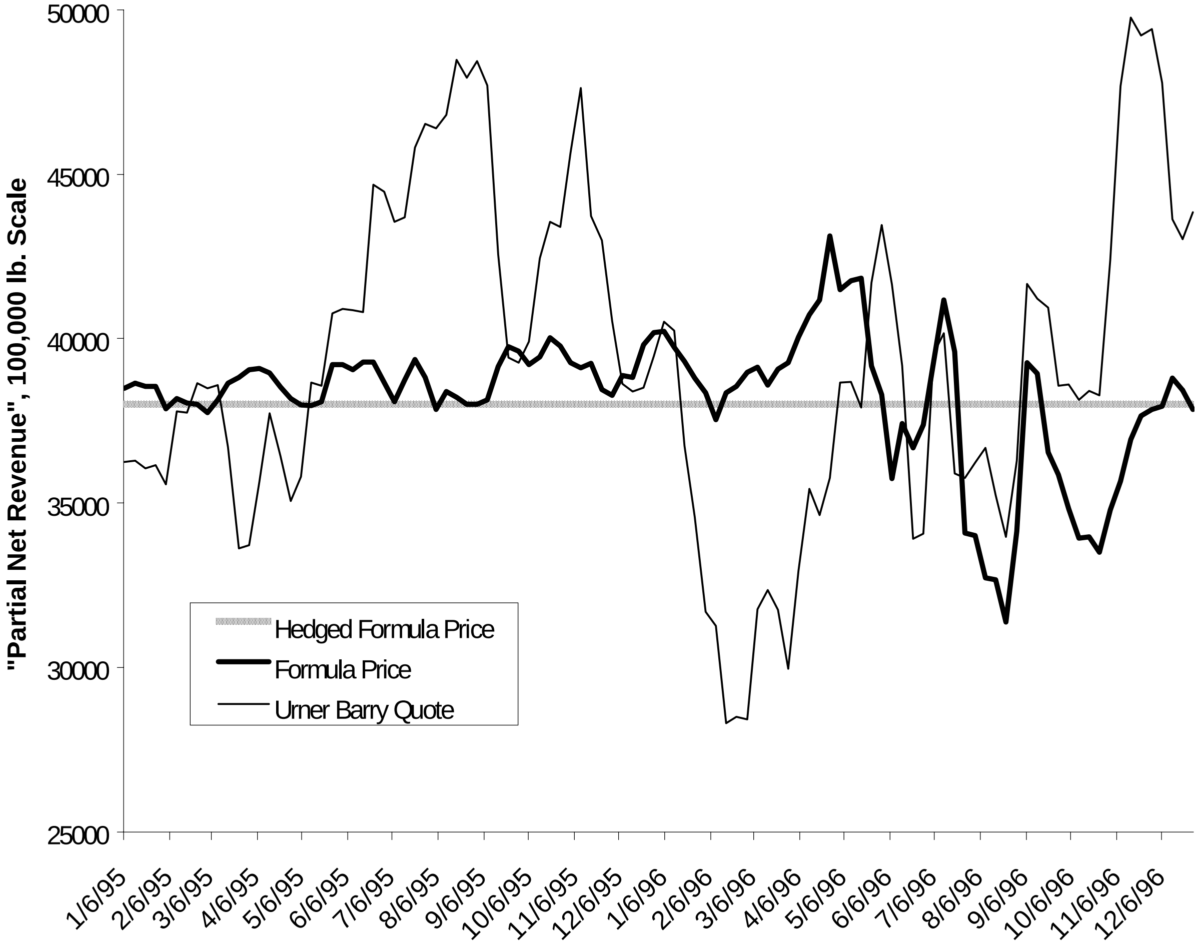
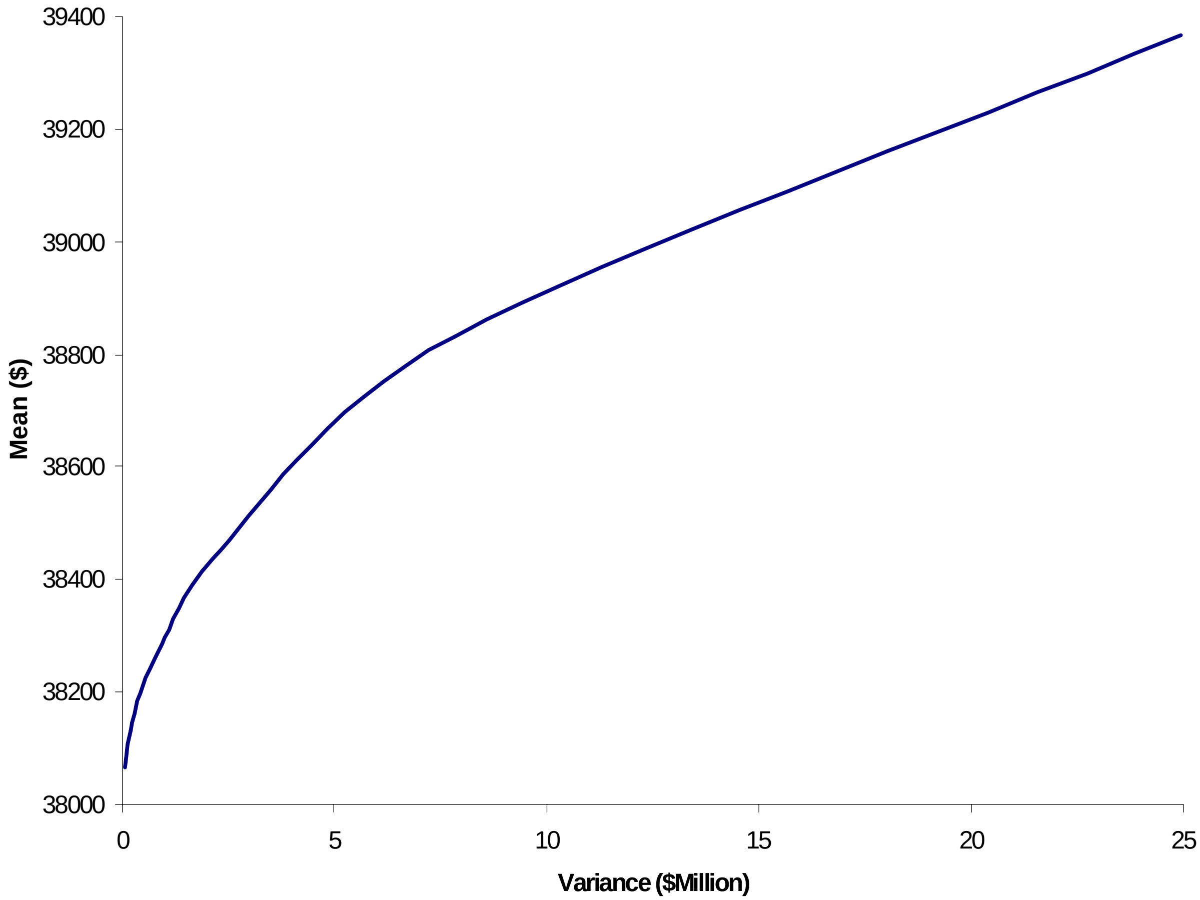


Figure 3. Risk-Efficiency Frontier Derived from Optimal Portfolios of Pricing Strategies *



* movements up and to the left are relatively risk-efficient