Risk Management in Agricultural Markets: A Survey

William G. Tomek and Hikaru Hanawa Peterson1

prepared for presentation at

Producer Marketing and Risk Management: Frontiers for the 21st Century

A Conference Sponsored by the Food and Agricultural Marketing Policy Section of the American Agricultural Economics Association
January 13 and 14, 2000
Homewood Suites Hotel, International Drive,
Orlando, Florida

Copyright 2000 by William G. Tomek and Hikaru Hanawa Peterson. All rights are reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

---

1 Professor and graduate student in the Agricultural, Resource, and Managerial Economics Department, Cornell University. We gratefully acknowledge Loren Tauer's helpful comments. Cornell ARME Staff Paper 2000-01.

Risk Management in Agricultural Markets: A Survey

William G. Tomek and Hikaru Hanawa Peterson*

This paper surveys and evaluates the current state of knowledge about marketing strategies to manage price and revenue risk for farm commodities. What does existing research tell about the benefits and costs of alternative risk management strategies? What are the limitations of this research? What are the gaps in our knowledge?

Farm businesses confront a variety of risks, and they often have choices in managing risks. Each choice has its particular costs and benefits. Thus, the task of defining a menu of realistic marketing choices and specifying their benefits and costs is complex. In addition, a variety of ways of analyzing risk exist (Boehlje and Lins). In this paper, we use portfolio concepts to organize thinking about risk management choices (Markowitz).

Farmers are assumed to select a combination of marketing strategies that maximize (say) expected returns subject to the degree of risk, which they are willing to accept. The number of marketing alternatives is potentially large, but they can be grouped into three categories: spot market strategies, such as diversifying the frequency of marketing of annually produced crops; the use of forward (marketing) and deferred pricing contracts; and hedging via standardized options and futures contracts. Purchases of yield or revenue insurance are other possible constituents of a portfolio. To identify an optimal portfolio, which may include some combination of alternatives, we need to depict the net return and risk of each alternative.

A common simplification is to use means and variances of the probability distributions of the random variables in the portfolios to compare them, and a mean-variance framework is implicit in much of this paper. Another simplification is an emphasis on price risk, which is consistent with an emphasis on marketing strategies, although we briefly address yield risk. The magnitude of price risks can be large. Hog prices dropped over 25 cents per pound in 1998 and 24,000 hog producers were reported as likely to quit by the summer of 1999 (*Wall Street Journal*, November 1998, p. A2). Even if this estimate was exaggerated, it is clear that risk management is worthy of attention in research.

We start by discussing the sources of risks in agricultural commodity markets, i.e., price and yield behavior. Next, we discuss contributions to conceptualizing and implementing a portfolio framework. The issues include defining and estimating an objective function, factors influencing marketing choices, and linkages among choices and the associated data issues. Then, we touch on the empirical results that have come from past research. We conclude with a discussion of the implications for research.

* Agricultural, Resource, and Managerial Economics, Cornell University. We gratefully acknowledge Loren Tauer's helpful comments. Cornell ARME Staff Paper 2000-01.

Sources of Risks in Agricultural Markets

Cash Prices

In this section, we review the theoretical and empirical evidence related to the behavior of cash prices. The risk to be managed by farmers is that associated with the cash market. Use of derivative markets helps shift price-level risk to basis risk, which may be smaller, but the cash commodity is the asset which underlies futures and options markets. An understanding of cash price behavior is a critical element of price risk management.

The observed characteristics of commodity prices are well documented. A typical price series of varying frequencies exhibits considerable variability and positive autocorrelation. There are occasional spikes; i.e., prices jump abruptly to a high level relative to its long-run average. Thus, the distribution of observed prices is skewed to the right and in many cases displays substantial kurtosis (e.g., Myers; Deaton and Laroque, 1992). Price changes are nonlinearly dependent; namely, higher moments are correlated (e.g., analysis of daily prices by Yang and Brorsen).

Given the complexity of these time-series features, modeling commodity prices has been a daunting task. To date, economists have not reached a consensus about the "best" model for commodity prices. In the literature, time-series methods are commonly applied to data observed at high frequencies (e.g., daily or weekly) while structural models are commonly applied to data observed at lower frequencies (e.g., quarterly or annually). Linear models are predominant in time-series modeling, while it is more straightforward to incorporate nonlinearities in structural models. Since prices reflect the underlying structure of a given commodity market (i.e., supply and demand), prices for various commodities in respective markets (say, geographically) ought to be modeled differently.[2]

Fundamentally, commodity price behavior over time is a mixture of systematic intra- and inter-year fluctuations plus randomness. Seasonality in demand and/or supply is inherent in most agricultural commodity markets. Seasonality in demand is exemplified by examples of turkey at Thanksgiving or ice cream during summer time. For most major crops, production is seasonal and marketing takes place throughout the remaining year. It follows that prices are low around harvest, appreciate over the storage season to cover storage costs, and decrease prior to the subsequent harvest. Geographical dispersion in supply can have a similar effect as the crop being harvested more than once throughout the year. For example, soybeans are produced in both Northern and Southern Hemispheres.

In livestock, seasonality in supply reflects climatic, biological factors, and seasonality of feed supplies affecting production. With the industrialization of production and marketing, seasonality in some markets such as poultry and eggs has declined and seasonal price movements are reduced. Systematic shifts in seasonal price patterns can occur.

[2] Comovement in prices, where different commodity prices exhibit a tendency to move together, has been empirically observed (Pindyck and Rotemberg). The statistical results for cointegration are mixed (Myers).

Variability of prices depends on information flows regarding supply and demand, and hence is expected to exhibit systematic changes as well. Using grains as an example, available supply is known with relative certainty after harvest through the first half of the storage season. Once the new crop is planted, uncertainty regarding the yield of the new crop builds up during the growing season until it is resolved at harvest. Thus, we would expect that price be most volatile during the growing season and least volatile during the period following harvest.

The seasonality in price level and volatility is illustrated empirically by the distributions of monthly cash corn prices (at Chicago) for the period 1989/90 through 1997/98. In order to allow for skewness and non-zero kurtosis, a Gamma distribution is fitted to the sample by a method of moment estimation.[3] In Figure 1, the distributions for selected months are plotted in four separate diagrams, and the September price distribution is included in all for ease of comparison. Positive skewness is observed in all distributions. The modes increase over the storage period through April reflecting storage costs. After the new crop is planted and during the growing season, the modes revert to the level at harvest. The probability mass of prices during the months of harvest and post-harvest are relatively centered. Prices become more dispersed as planting approaches, and this trend continues through July. In August, the trend in dispersion is reversed in anticipation of the new crop.

A large literature has focused on inventory behavior to explain seasonal and inter-year price patterns. In the classic works of Brennan, Working, and Kaldor, inventory of a commodity is held up to the point where the price in the subsequent month is expected to appreciate sufficiently to cover storage and interest costs. More recently, the storage framework appends demand and supply functions to the original supply of storage equation and adopts Muth's rational expectations hypothesis. Williams and Wright synthesize the modern theory of storage and show that the framework is capable of explaining occasional spikes in the price series as a result of total or close-to-full stockouts.

A competitive storage model (Deaton and Laroque, 1992) was capable of replicating the degree of skewness and kurtosis in observed price distributions, but failed to account for the degree of autocorrelation.[4] Rui and Miranda impose a theoretical convenience yield (convex, decreasing function of storage) implying a convex increasing marginal storage cost that became infinitely negative at low inventory level. Their analysis showed that the different assumptions regarding the storage cost function explain the level of autocorrelation observed in the same deflated series used by Deaton and Laroque (1992).

---

[3] Let X be a random variable having a Gamma distribution with parameters α and β. Then, $\mathrm{E}[X] = \alpha/\beta$ and $\mathrm{Var}[X] = \alpha/\beta^2$. Method-of-moment estimators are obtained by equating theoretical moments to its corresponding sample moments. Thus, $\hat{\beta} = \overline{X} \Big/ \frac{1}{(n-1)} \sum_{i=1}^{n} \left(X_i - \overline{X}\right)^2$ and $\hat{\alpha} = \hat{\beta}\overline{X}$, where $\overline{X}$ is the sample average.

[4] They used deflated series for observed price series, and deflating could have introduced autocorrelation that did not exist in the nominal series.

Part of the validation attempt has focused on the framework's prediction that prices are a two-regime process depending on whether or not inventories are held. Deaton and Laroque (1996) and Chambers and Bailey explore this process by imposing varying assumptions regarding the stochastic nature of supply shocks. Ng provides evidence for regime-specific price behavior using threshold models.

These works apply a single framework to multiple commodity prices, regardless of their seasonality in production, marketing, and/or demand. Beck tests an implication of a nonnegative constraint on storage, i.e., the difference in asymmetry of price distributions between storable and non-storable commodities. Her results find no significant difference. In a different application of the competitive storage framework, Pirrong builds a quarterly model to explain a high correlation between new and old crop futures prices for seasonally produced commodities such as grains. More work is necessary to validate the applicability of the storage framework to model commodity price behavior.

Traditional time-series analysis assumes that current price is a linear function of past prices. In ARIMA models, price changes are assumed to be independently drawn from an identical normal distribution. Yet, the observed volatility of price changes varies over time as the series move between volatile periods. Time-varying volatility in commodity prices leads to autocorrelation patterns in the conditional variance of price innovations where the variance is conditional on an information set available at the time forecasts are being formed. Engle's autoregressive conditional heteroskedasticity (ARCH) model captures such effects, and it is generalized (GARCH) to include lagged conditional variances as well as lagged squared innovations in an equation explaining conditional variance movements (Bollerslev). ARCH and GARCH models capture part of the excess kurtosis in commodity prices. Yang and Brorsen examine daily cash prices of seven agricultural commodities, and their results support the non-normality of daily returns and a GARCH process with residuals following a student distribution as a superior model. Beck derives that Muth's rational expectations model of commodity markets implies an ARCH process in spot prices of storable commodities. She examines 19 different commodity prices at annual frequency and finds significant ARCH processes for most storable commodity price series. Barkoulas, Labys, and Onochie provide evidence of fractional orders of integration in several commodity price series and propose modeling them as autoregressive fractionally integrated moving average (ARFIMA) processes.

When product prices are high, agricultural production tends to expand, leading to lower prices in the subsequent year, which in turn discourages production and enhances prices in the next year, and so on. For perennial crops, adjustment in production takes multiple years. Also, for livestock, lags in supply response take place in longer periods than a single year creating "cycles."

Lags between production decisions and the realization of output imply recursive models. Current supply is a function of expected price given information at the time of production decision, and the market-clearing condition (inverse-demand function) determines the current price. There are various hypotheses regarding expectation formation, representative ones being adaptive expectations, rational expectations, and quasi-rational expectations hypotheses. The recursive nature of the model implies autocorrelation in prices, but skewness may not be explained (Tomek and Myers). Structural models with supply shocks produce skewness and non-zero kurtosis in prices, but in order to account for autocorrelation, ad hoc distributed lags in supply shocks are necessary (e.g., Ghosh, Gilbert, and Hughes Hallett). The lag in agricultural production decisions or habit-formation in consumption may be accounted for by distributed lag specifications (Nerlove).

In livestock markets, the empirical evidence supports the existence of a commodity-specific cycle in quantities. There have been attempts to explain the cycle using variants of the cobweb theorem and delayed supply responses and linear models. In principle, prices move in cycles corresponding to the dynamics in quantities. Yet as Rucker, Burt, and LaFrance note, few studies have found a systematic empirical relationship between prices and beef supplies or stocks. Rosen demonstrates that supply responses to changing market conditions vary both in sign and magnitude according to whether demand and supply shocks are transitory or permanent. In his model, the distributed lags due to inventory management explain only a part of the cyclical nature in herd size.

The continuing existence of price cycles perhaps contradicts the notion of rational agents; if agents are rational and cycles are predictable, they should take advantage of more than normal profit and eventually price fluctuations would be smoothed out. The traditional premise in analysis of livestock cycles has been that producers' behavior is naïve. An alternative explanation is that price cycles are not perfectly predictable and hence it may be costly to take counter-cyclical actions. There has been exploration using a dynamic nonlinear process generating seemingly random behavior otherwise known as "chaos." Empirically, Chavas and Holt show that the dynamic process generating the pork cycle is nonlinear and that asymmetry exists between expansion and contraction phases, but their evidence for "chaos" is less conclusive.

Net of seasonality and cycles, cash prices may be considered to be mean-reverting to some long-run average or trend. Trends are generally associated with general inflation and deflation in the economy, changes in consumer preferences, increases in population and income, and technological changes in production. If marginal costs of production decline over the years, *ceteris paribus*, and agricultural markets are competitive, the price level for that commodity will trend downward.

A recent development in financial asset price modeling has been in modeling continuous time prices as stochastic processes. An infinitesimal change in a continuous random variable is described as a sum of deterministic and stochastic terms. The deterministic term could be a constant, a time-dependent trend, or a mean reversion to a constant (or a trend). The stochastic component is typically assumed to be an i.i.d. normal increment, but could also be an i.i.d. Poisson (jump) process.

Using the stochastic process modeling approach, a focus of empirical commodity price analysis has been on testing for mean-reversion. Bessembinder, et al. use the term structure of futures prices to test whether mean-reversion in commodity prices is expected in the market. Their evidence indicates significant mean-reversion in agricultural commodity prices (wheat, orange juice, sugar, and cattle) and crude oil. Schwartz analyzes three models of the stochastic behavior of commodity prices that take into account mean reversion in spot price, convenience yield, and stochastic interest rates. His work did not examine agricultural prices, but his results support a strong mean reversion in copper and oil prices. There have been applications, which incorporate seasonality in mean and volatility, to analyze agricultural prices (e.g., Fackler and Tian).

If economists could produce good commodity price forecasts (the systematic component understood), then price risk management could deal with the random deviation of cash prices around the known systematic pattern. Despite voluminous effort in commodity price analysis, however, we have yet to establish a consensus regarding the depiction of the systematic component of commodity price movements. It is very difficult to obtain "good" empirical models of commodity prices. Hence, much of price variability can be classified as risk, to be managed.

Formulating "good" models of cash prices would be a significant contribution to price risk management. Under exposure to price risk, hedgers value additional information regarding the mean and volatility of cash prices (Adam, Garcia, and Hauser). A useful role of models would be to provide an estimate of an entire distribution of price forecast at a given point in time. (As noted below, futures prices perhaps provide the best available forecasts of spot prices for the par grade at maturity.)

Futures Prices

Futures prices can be defined by the model $F_t = \mathrm{E}[F_T|I_t]$, where t is the current date, T is the maturity date, F is futures price, I is information set, and E is an expectation operator. That is, the current futures price is the expected value of the maturity price conditional on the information available at time t (e.g., see Carter; Fama and French). If there is no basis risk, then $F_t = \mathrm{E}[P_T|I_t]$, the expected spot price at maturity. If a risk premium exists, then the foregoing model needs to be modified by adding a term for an expected risk premium. In any case, price risk premiums, if they exist, are small.

One important application of the foregoing model is the theory of the price of storage (e.g., Working; Brennan), which is appropriate for seasonally produced crops with continuous inventories, such as corn and wheat. A futures price, observed at time t for delivery in time T, minus the cash price at time t, defines a price of storage for carrying inventory over the interval from t to T. With numerous maturity months, a number of prices of storage (bases) exist at any point in time, and storage theory emphasizes that the spot price and the futures prices for different maturity months are simultaneously determined. The array of temporal prices provides incentives (or disincentives) for storage. In effect, the information conditioning the expected value of the maturity month price includes the factors influencing the supply and demand for inventories.

As time passes, new information arrives in the market, and both the price level and the price differences (among the varying maturities) can change. In an efficient market, however, truly new information is a surprise and is rapidly incorporated into price changes. Arbitrage opportunities, related to new information, are fleeting. Indeed, most traders, including the vast majority of farmers, cannot profit from price forecasts *if markets are efficient*. Put another way, econometric models in the public domain cannot outperform efficient futures markets as forecasts of the maturity price (Tomek, 1997). This definition of efficiency permits the possibility of a few traders profiting by having better data and models; e.g., Bessler and Brandt found one expert that outperformed a livestock market. Moreover, as discussed below, models to forecast prices can have statistical significance but not economic significance.

Thus, assuming an efficient market and zero risk premiums, a futures price is an unbiased estimate of the contract's price at maturity. Futures prices for any individual contract in an efficient market are not mean reverting. A futures price is the expected value of a particular month's price, but spot prices, as discussed, can have systematic behavior. Empirical tests for mean reversion in futures prices are often confused by using prices for a sequence of nearby futures contracts, which is tantamount to using a series of spot prices. Also, previous analyses may suffer from statistical weakness (Irwin, Zulauf, and Jackson).

This point of view is not universally accepted. For example, Wisner, Blue, and Baldwin argue that pre-harvest marketing strategies can increase farmer's average returns. They attribute this potential return to a yield risk premium. Their hypothesis is that prices of the harvest-time futures are biased upward early in the growing season, because the market is reflecting a positive probability of a drought or other yield-reducing event. If so, selling a part of the crop in, say, June should increase average profits relative to selling at harvest (for a contrary view, see Zulauf and Irwin).

A related possibility is that marketing advisers (consultants) have superior information, which farmers can purchase. In this case, the questions are, do these firms really have private information that is not generally available, and if so, do the returns from the advice equal or exceed the costs of the advice? We explore the limited evidence on this point in a separate section below.

Another implication of the theory of the price of storage is that prices of contracts for delivery in the current crop year can be high relative to prices for new-crop delivery. This occurs when current inventories are small relative to demand and the expected future harvest is relatively large. In storage theory, a negative price of storage is commonly attributed to "convenience yield" (e.g., Telser). Inventories can have option-like values; i.e., inventories provide the benefit of meeting potential demands from uneven order flows. The smaller the total inventory, the larger the value, because of the larger probability of being out-of-stock. While Wright and Williams have questioned the convenience yield explanation of inverse carrying charges, it is clear that prices of old-crop, nearby futures can be very high relative to the prices of new-crop delivery months. This possibility was not well understood by firms writing hedge-to-arrive contracts with rollover provisions, and when a large negative price of storage occurred in 1995, the result was numerous defaults on forward contracts with rollover provisions.

Understanding the relationship of futures to cash prices – basis relationships and basis risk – is important for effective hedging. For example, if a cattle producer sells a June futures contract in December at 70 cents per pound, an implicit cash price is being "locked-in," which depends on the basis at the completion of the hedge. If, on May 25, the basis were one cent, then the assured cash price would be 69 cents; if the basis were five cents, the cash price would be 65 cents. Thus, the question arises as to whether this basis can be accurately forecast at the time the hedge is initiated. Sometimes, basis forecasts use naïve models; the expected basis equals, say, last year's basis or, say, the average basis over the previous three years. Econometric models have been developed to explain basis variability (e.g., Garcia and Good; Hauser, Garcia, and Tublin; Liu, et al.; Ward and Dasse). But, models that provide good *ex post* explanations of basis behavior may be difficult to use for forecasting, because it is difficult to make good *ex ante* estimates (ancillary forecasts) of the explanatory variables (Taylor and Tomek).

In principle, it is possible to use hedges in futures to assure a return to storage, merchandising, or production decisions. The grain storage decision is a simple example. Competitive markets do not guarantee positive returns every year, but whenever they occur, producers need not wait to price the commodity until it is sold in the spot market. When the price of a futures contract is above the current cash price and when the expected convergence of the two prices is sufficient to cover the cost of storage over this time interval, producer/firm can sell futures, store, and expect to earn the convergence as a return (e.g., Heifner). The expected convergence can be forecast from the regression $B_t - B_{t+j} = a + bB_t + u_{t+j}$, where B is basis, t is the initial time period, $t+j$ is the end of hedge period, a and b are regression coefficients, and u is residual. If this is a stable relationship, then an equation can be fitted to historical period, and B for the current year can be inserted to forecast the change in the basis. This is a classical forecast problem, because B is observable at the time the forecast and the storage decision are being made. It is also possible to estimate the standard error of forecast – the basis risk – from the regression equation.

Clearly, hedging effectiveness depends on the magnitude and predictability of basis convergence, and in the simple regression model, only the initial basis is used as a regressor. All other variability in basis convergence is treated as a random error. Since the cost of arbitrage between cash and futures influences convergence and is difficult to measure, it may be necessary to treat it as an unobservable random influence. Work by Hranaiova and Tomek shows that the degree of convergence at contract maturity also depends on the value of the implicit options in futures contracts, such as providing sellers with choices about the timing of delivery. These options can have varying values which effect the futures price and hence the basis. It remains to be seen, however, whether this insight can improve forecasts of basis convergence.

We turn next to the nature of the probability distribution of futures prices, especially the behavior of the variance of the distribution. In discussing distributions, analysts typically have in mind changes in prices observed over some intra-year interval, like daily, weekly, or monthly prices. While these price changes may be roughly uncorrelated, based on the efficient market hypothesis, they need not have a constant variance. The variability of futures prices can be influenced by the flow of information and the uncertainty attached to the information, by the economic context within which the information arrives, and perhaps by the market structure of the traders interpreting the information (for a summary of this literature, see Streeter and Tomek).

The flow of information can have seasonality and trends. For crops, more information about expected yield arrives during the growing season, and hence other factors constant, prices should be more volatile in the growing season. Also, as the month of contract maturity approaches, more information arrives about the factors that influence the price at maturity (for an alternative interpretation, see Hennessy and Wahl).

The variability will also be influenced by current supply and demand conditions. A non-linear relationship exists between price and the stocks-to-use ratio (e.g., Westcott and Hoffman). If new information arrives in the context of a small stocks-to-use situation, the price effect will be larger than when stocks are large relative to use. Also, volatility may be influenced by the proportion of informed traders in markets, and this proportion may vary from market to market. For soybeans, Streeter and Tomek find that an increase in the proportion of scalpers in markets appeared to reduce volatility but that an increase in open interest held by the four largest longs tended to increase variability.

Other empirical evidence suggests that the distributions of changes in futures prices are not normal. The foregoing discussion of the variance implies that episodes of many small changes followed by episodes of large price changes are possible. Increasing the length of the sample period over which changes are observed, one is likely to find a larger proportion of small changes and of large changes (and fewer medium-sized changes) than implied by the normal distribution. Of course, the aggregation (sample length) problem is a difficult one. Should distributions be viewed as a sequence of normal distributions, with changing variances? Or, is the distribution better treated as (say) leptokurtic with constant variance and kurtosis?

A common approach is to analyze changes in the logarithms of prices, i.e., whether prices are log normally distributed. The evidence is mixed. Namely, whether or not price changes are well approximated by the log normal distribution depends on the commodity market and on the time period used for the analysis. For example, Hudson, Leuthold, and Sarassoro find that the log normal distribution was a good approximation for wheat, soybeans, and live cattle for daily prices for the years 1976–1982, but not if earlier years were included. Or, for example, Hilliard and Reis examine a set of intra-day prices – observations on every price change – for soybeans for the period July 1990 to June 1992, and they conclude that the logarithmic changes are not normally distributed. They believe that the departure from normality is caused by large price changes with the arrival of new information into the market.

The foregoing is important to decision-makers. First, optimal hedges in futures depend on the parameters of the underlying probability distributions, and the estimates of these parameters depend, in turn, on the analyst's assumed model of the distribution (e.g., Baillie and Myers; McNew and Fackler). Second, models of options prices make assumptions about the nature of the probability distribution of the underlying asset, and in the case of traded agricultural options, the underlying asset is a position in a futures contract. The famous Black-Scholes model, for example, assumes that the underlying asset price is log normally distributed with a constant variance. In addition, changes in volatility can influence the margin level for futures contracts and hence influence the cost of hedging, and of course, as noted in the next section, changes in volatility influence the level of options premiums.

A different question relates to the annual variability of the price of a futures contract at maturity compared with its variability earlier in the life of the contract. For example, how does the year-to-year variability of the December corn contract in April compare with the same contract's variance in December? This is an important question, because the routine sale of a crop at planting time will reduce the variance of returns only if the variability of prices is smaller at planting time than at the subsequent harvest and sale. Theory and the empirical evidence suggest that the variance is indeed smaller at planting time. Let F, t, and T be futures price, planting time, and harvest time, respectively, and $F_T = a + bF_t + e_T$. Then by definition, the variance of F_T is decomposed into two components: the variability of F at planting and of the error term. As discussed, more information arrives as time passes; this information causes prices to change; hence, F_t cannot be a perfect forecast of F_T. This implies that the variance of the planting-time price will be smaller than the variance of the harvest-time price. Evidence provided by Zulauf, et al. is consistent with this view.

To summarize, first, futures markets appear to be relatively efficient, but controversy continues about whether producers might enhance profits by using marketing strategies based on hedging (or speculating) in futures markets. Second, efficient futures markets can be used to "assure" profitable returns to storage and production decisions on those occasions when favorable prices arise in markets; producers need not wait to make a cash sale to obtain the return. Third, the literature has not provided a definitive answer about how to best model the probability distributions of futures prices, but as will be discussed in the empirical section, these ambiguities may not be very important for decision making on marketing programs. Nonetheless, basis risk faced by individual farmers is an important consideration in the use of futures contracts to manage price-level risk.

Options Prices

The trading of options on agricultural commodity futures contracts began in 1984. Options on futures contracts or "futures options" require the delivery of an underlying futures contract when exercised. Futures options are more attractive to investors than options on the underlying asset, since for most agricultural commodities, it is cheaper to deliver futures contracts rather than the commodity itself.

For a known price ("premium"), producers can acquire the right to sell (buy) their output (input), actual or anticipated, at a stated price ("strike price"). Unlike a futures contract, the right to sell places a floor under profits (or limits losses) from price changes, without putting a cap on them. An option contract, unlike futures or forward contracts, does not have a legal obligation to make or take delivery. Thus, it offers an alternative risk management mechanism. The main question for a potential buyer of an option is whether the cost (premium plus commission) is worth the right conveyed. The answer will likely differ for differently situated producers.

The model for pricing options on futures by Black is based on the underlying assumption that the futures price, F, follows geometric Brownian motion: $dF = \mu F dt + \sigma dz$, where μ is the expected growth rate in F, σ is its volatility, and dz is a Wiener process. This assumption leads to the futures price being treated in the same away as a security providing a continuous dividend yield equal to the risk-free interest rate. Then, the European call and put prices can be derived straightforwardly from the Black-Scholes formula, where the prices are functions of strike price, time to maturity, risk-free interest rate, current futures price and volatility of the futures price. There are no closed form solutions for American options premiums, but they can be calculated numerically.

Volatility is one of the critical factors that determine the option premium. Two types of volatility exist. Historical volatility is the variation in the underlying futures price, which can be estimated *ex post*. Implied volatility is a value that equates the market premium with the theoretical premium; i.e., given the interest rate, strike price, market price of the underlying futures, and time to maturity, the Black-Scholes model can be used to estimate volatility. It is regarded as a forecast. Thus, analogous to a futures market providing an estimate of an expected price, an options market provides an estimate of expected price volatility.

Considerable evidence in the empirical literature contradicts the Black-Scholes assumption that proportional changes in the underlying futures price are i.i.d. and normal. Specifically, there is evidence of excess kurtosis and time-varying volatility in commodity futures price movements and the distribution of price changes being not log normal. Evidence comparing Black-Schole's predicted prices with market option prices is mixed, but many studies have concluded that Black-Scholes' model results in systematic option pricing errors (Hauser and Neff). Hauser and Neff identified volatility forecasts and specification of the stochastic process of the underlying futures price as two major factors that impact premium estimate for agricultural options. Agricultural options premiums were found to be relatively insensitive to interest rate estimates.

As discussed above, expected price volatility depends on how information regarding future demand and supply resolve uncertainty with the passage of time. The results of empirical examination of whether implied volatilities exhibit time-to-maturity and seasonality effects have been mixed (Hauser and Neff). For example, implied volatility for corn and soybeans options is high during the growing season (May through August) and low during the storage season (October through March). For wheat, however, implied volatility is the highest in June and July and lowest during November through March. Fackler and Tian's work supports consistency between implied volatility and futures price volatility in terms of their seasonal variation. As a function of strike prices relative to a given market price, implied volatilities exhibit a curved (U-shaped) relationship, sometimes known as a "smile."

Closed form solutions for options premium have been found for returns that follow a poisson (jump) process (Cox and Ross) and a combination of the lognormal diffusion and a jump process (Merton). Alternative assumptions regarding the stochastic process of the underlying futures prices are possible. Myers and Hanson develop an option-pricing model where the underlying futures price is modeled as a GARCH process, allowing for time-varying volatility and excess kurtosis. Their empirical results suggest that the GARCH option-pricing model outperforms the standard Black option pricing, which uses historical volatilities. Hilliard and Reis compare Black's option pricing model and Bate's jump-diffusion model, where futures prices are assumed to follow a jump-diffusion process with systematic (seasonal) jump risk. Their results show that Bate's model performs better than Black's model.

We assume that options markets, like cash and futures markets, are efficient in general. There could be times when the market premium may not always be fairly valued; i.e., it could be undervalued or overvalued. In efficient markets, such discrepancy will be arbitraged away almost instantaneously. Yet, if a market is thin, the adjustment may take longer. Moreover, the price-effect of entering and exiting positions could be large. Agricultural options contracts have sometimes had low trading volume.

The major grains (corn, soybeans, and wheat) have had the largest trading activity. The closing total open interests for these commodities on December 17, 1999 were 328,566 (corn), 202,526 (soybeans), and 126,964 (wheat), compared to 10,005 (oats) or 20,410 (feeder cattle) (www.cbot.com; www.cme.com). Dairy contracts, introduced in 1993, have had low market participation. Options on the BFP milk futures contract had an open interest of 906 on December 17. Hence, despite its potential usefulness, dairy options may be costly to include in one's portfolio. Aggregate numbers for open interest and trading volume for a commodity do not provide information regarding liquidity of specific contracts by maturity months, strike prices, and puts and calls. Even for corn, some contracts are thinly traded.[5]

[5] On December 17, 1999, the March 2000 contract had the trading volume of 2402 calls and 1815 puts, while 889 calls and 114 puts of the May 2000 contract were traded. Of the 114 May puts traded, 102 traded for the strike price of 190.

Yield Behavior

Variability of the yield of a given crop can differ by location, because of differences in soil quality and climate, and of course different crops have differing degrees of variability (Harwood, et al., p. 8). With technological progress, yields grow and are commonly modeled as a function of trend and a random error term (e.g., Gallagher). The principal debate has been about whether the residuals can be treated as normally distributed. The common view is that the distributions, at least for crops, are skewed, with a larger probability of negative deviations than of positive deviations. "Bad" weather has a bigger effect on yields than does "good" weather.

Just and Weninger criticize the tests for normality on three grounds: the tests are conditional on the specification of the deterministic component of yields, i.e., the trend specification, and hence subject to misspecification bias; the tests misuse statistical significance, e.g., by not considering the correlation of related time series when multiple series are used to assess normality; and the tests typically use aggregate time-series, rather than farm-level yields. The latter criticism is perhaps the most important, because farm-level yield risk is usually the concept which we wish to measure.

Just and Weninger's analysis of farm-level and county-level data for five crops in four counties in Kansas illustrates the consequences of these concerns. For the farm-level data, normality typically cannot be rejected. They further show the implications of alternative specifications of the probability distribution of yields for the estimated probability of paying insurance indemnities.

Clearly the assumptions (and reality) of the distributions of yields can make a difference for evaluating yield and revenue insurance, and they also would make a difference in evaluating hedges using yield futures markets. Market prices likely provide a reasonable assessment of the basis risk faced by farmers for prices, because farmers face very similar market prices. In contrast, it is likely that farm-level data are required to assess the yield basis risk faced by farmers, because yields can vary from one location to another and from one manager to another. The basis risk for yields is more idiosyncratic, and the problem of adverse selection is an issue in developing yield insurance and yield futures products.

Optimal Marketing Portfolios

Conceptual Framework of Optimal Portfolios

The general principle of portfolio theory is well known (e.g., Huang and Litzenberger; Johnson); namely, the decision-maker selects the composition of her/his/the firm's portfolio to maximize expected utility. Utility depends on wealth, and future wealth depends on future returns from the portfolio. Future returns, however, are uncertain. Thus, utility is specified as a function of both the expected mean and the riskiness of the rate of return.

In the early literature on using futures markets, economists specified simple portfolios typically involving a commodity inventory and a short position in futures contracts. An optimal hedge was derived assuming that the quantity to be hedged was exogenously given, that only output price risk was important, and hence that the decision was about the optimal size of the futures position. The objective function maximized gross returns, subject to a risk constraint based on the variance. The resulting optimal futures position is identical to the position which minimizes the variance of returns, if the futures price is an unbiased forecast of the terminal price at the completion of the hedge (or if the hedger is extremely risk averse). If the problem is specified as a joint decision about the quantity to store and the size of the futures position, the optimum still simplifies to a ratio of futures to cash positions which minimizes the variance of returns and which is obtained as the ratio of a covariance of futures and cash prices to a variance of futures prices (Kahl).

A logical next step, taken by Feder, Just, and Schmitz, was to incorporate futures markets into a theory of the firm under uncertainty using the expected utility framework. This model ignores the riskiness of production. Yield risk is, however, a relevant issue in analyzing production and hedging decisions, and models have been developed to consider optimal positions in futures that take account of price and yield risk jointly. The simplest models abstracted from basis risk (Newbery); i.e., the futures price is assumed to converge exactly to the cash price at the completion of the hedge.

With the introduction of markets for options contracts, it was natural for the literature to consider positions in options contracts as part of the portfolio. If the model incorporates basis risk and options markets in a mean-variance framework and if the options premiums and futures prices are unbiased, then options turn out to be redundant hedging instruments; the optimal hedging strategy involves only futures (Lapan, Moschini, and Hanson). If production risk is introduced into the model, options enter the portfolio (Sakong, Hayes, and Hallam).

Considering three sources of risk (price level, basis, and yield), Lapan and Moschini derive the optimal hedge in futures using a constant absolute risk aversion utility function. In this model, the expected utility maximizing futures hedge does depend on risk attitudes even if the producer thinks that the futures price is unbiased. With yield uncertainty, the optimal hedge in futures depends on the conditional forecast of the harvest-time price, and since this forecast will change with the passage of time, the optimal hedge is inherently time-varying (Lapan and Moschini, p. 476).

Most of the literature on optimal hedging implicitly assumes a single production cycle, and in the standard model with nonstochastic production and unbiased futures and options prices, as mentioned above, it is optimal to sell the crop forward using futures and hold a zero position in options. (Quite a bit of the purely empirical literature also finds that crops should be forward priced.) If the assumption of a single production cycle is relaxed, however, it is usually optimal to change the futures position as the crop matures and to have a hedging role for options (Lence, Sakong, and Hayes). Forward-looking decision-makers “realize that this period’s (random) output prices will be associated in a nonlinear manner with prices in subsequent periods” (Lence, Sakong, and Hayes, p.294).

Still another issue in the conceptual (and empirical) literature is the nature of the probability distributions of the random variables; normality is the common assumption. If the distribution of returns is skewed, this is another reason for options contracts to enter optimal portfolios (Vercammen). In sum, optimal portfolios likely need to consider futures and options positions.

In recent years, crop-yield futures and yield or revenue insurance have been added to the list of instruments available to manage risky returns, and thus, optimal hedges that take account of these instruments have been considered. For example, Vukina, Li, and Holthausen derive optimal — variance-minimizing — positions in price and yield futures contracts. The possible negative covariance between price and yield may, depending on the location, create a partial natural hedge, but the simultaneous use of yield and price futures can reduce the variance of profits more than using price futures alone. The effectiveness of the hedges, not surprisingly, depends partly on the variability of the underlying yield; the greater the yield basis risk faced by the farmer, the less effective the hedge using yield futures (Vukina, Li, and Holthausen).

Crop insurance tends to dominate hedges in yield futures by farmers as a tool for managing revenue risk in empirical studies. This result is not surprising if yield basis risk is large, i.e., if individual farm yields vary substantially around the state average yield specified as the par yield in the futures contract. Also, premiums for crop insurance are subsidized. Coble and Heifner model farmer decisions, assuming they maximize expected utility defined over end-of-season wealth, to examine optimal combinations of positions in price futures and in insurance contracts. It is, however, difficult to consider complex insurance designs and futures hedging jointly, and Coble and Heifner use a numerical approach to appraise four insurance designs. They find that the existence of insurance products tends to reduce the optimal hedging positions by farmers, but does not drive them to zero. The nature of the particular insurance product influences the level of hedging in futures.

The foregoing models are rather weak in terms of explaining why different classes of firms have different hedging levels. For example, many farmers never hedge in futures or options markets (citations below). Thus, a question is, do the portfolio models correctly characterize the firm's risk? Collins says the answer is no and argues that the problem should be conceptualized as one of avoiding financial failure, not as one of reducing income variability. Thus, differences in cost and financial structure across firms cause the differences in hedging choices. Collins' model maximizes expected end-of-period *equity* subject to a *risk tolerance* constraint. He writes (p. 497), "Since prices are bounded from below by zero, this [the average farm equity in 1992] says it is not possible for a realization of cash price to cause the average farm to go bankrupt. As long as hedging costs money, there is no reason why it should be done..." Introducing the costs of hedging into the objective function greatly reduces the magnitude of the risk-minimizing hedge (Brorsen; Lence).

To summarize, the objective functions of individual farmers are potentially complex and difficult to specify appropriately. In principle, they have numerous tools to manage risk, and alternative specifications of objective functions make major differences in the conclusions reached about optimal portfolios. Portfolio concepts help us understand the roles of various risk management tools, but it is still unclear whether or not "generally applicable rules-of-thumb" can be developed from this background.

Implementing the Framework — "The devil is in the details"

In this section, we address selected issues in moving from a general framework to specific empirical applications to producer decision-making.

Defining and Estimating the Objective Function. The broad issues are (a) specifying the choices open to the decision-maker (i.e., defining the objective function in ways that are consistent with the decisions), (b) specifying which variables are random and which can be treated as exogenous, and (c) estimating the parameters of the relevant probability distributions. Even if expected utility can be reasonably well characterized by the mean and the variance of returns (Levy and Markowitz), numerous problems still exist in specifying objective functions that are relevant to specific decision-makers. What is the appropriate definition of net wealth or returns? For example, to estimate the variance-minimizing hedge based on gross returns, the choice of the price level, the price change, or the percentage price change as the random variable makes a difference in the empirical outcome for the optimal hedge. For what choices should the returns be estimated? Further, as noted previously, introducing the costs of using futures markets reduces the size of the minimum variance hedge (Lence), although Brorsen shows that when the assumption of costless hedging is dropped, high-leveraged firms hedge more than low-leveraged firms.

Assuming for the moment that the random variables have been correctly specified, the analyst is still faced with estimating the parameters of the underlying probability distributions. The literature on estimating the parameters for optimal hedges is voluminous. A common approach, consistent with concepts discussed earlier, is to assume that futures markets are efficient, and therefore to assume that hedgers cannot profitably speculate in futures (i.e., the expected futures price change is zero).

In this context, a large portion of the literature, which we do not attempt to summarize, has concentrated on estimating variance and covariance parameters relevant to the decision. We need to note two points, however. First, the technically correct parameters to estimate are the conditional variances and covariances, which take account of possible systematic changes in the mean (at least of the spot prices). Second, since the conditional variances and covariances likely are not constants, empirical estimates should allow for this possibility (for an example and related references, see McNew and Fackler).

Using estimated parameters implies that the estimated returns from the associated decisions can have a large variance around the true (but unknown) optimum (see Chalfant, Collender, and Subramanian and references therein). Thus, even if we have a correct model (objective function), there is sampling error associated with the estimates of the parameters, and hence, estimates of the optimal portfolios should not be treated as certain. It is uncommon, however, to allow for this point in the applications.

Marketing Choices and Factors Affecting Choices. Empirical results in the older literature implied that optimal hedges are large relative to the cash position (Tomek, 1988), but in practice, the majority of farmers have not used futures or options markets. Moreover, those that do use them appear to take positions that are smaller than those suggested by estimates of optimal-size hedges. Recent evidence suggests that this — the limited use of futures and options — continues to be true (Harwood, et al., pp. 59f; Heifner, Wright, and Plato; Goodwin and Schroeder; Patrick, Musser, and Eckman).

In practice, marketing choices are analyzed in isolation from producers' other management decisions; this is perhaps a necessary simplification of a potentially complex portfolio specification. Strategies usually consider marketing and pricing a single crop or lot. Futures contracts for a few agricultural commodities are now being traded for more than one crop year into the future. Thus, it would be possible to sell next year's crop as well as this year's using futures. Another possibility, even when distant futures are not being traded, is to rollover positions from maturing to more distant contracts (Gardner). Some forward contracts have had rollover provisions.

It appears, however, that most farmers have relatively simple marketing programs. A study of Kansas grain producers found that 62 percent of wheat and corn farmers marketed their crops three or fewer times (Goodwin and Kastens). The mode was two times per year; however, a few farmers marketed as many as 20 times in a year. Goodwin and Kastens found that increased specialization led to increased marketing frequency, that older farmers marketed less often than younger farmers did, and that capital constraints cause producers to market less often. Interestingly, "Producers' risk attitudes appeared to have little effect on their frequencies of marketing" (Goodwin and Kastens, p. 584). These Kansas farmers apparently did not view frequency of marketing as a way of managing risk.

Consistent with the older studies, Goodwin and Schroeder found that only 10.4% of a sample of Kansas farmers hedged a portion of their production using futures markets. A more comprehensive study of U.S. farmers found a somewhat larger, but still rather small, percent of farmers used futures hedges in 1996 (Harwood, et al., p. 62). In the Kansas sample, farmers were about as likely to use options on futures as to use futures contracts, which would be logical for hedges placed during the growing season. A larger proportion of farmers forward contract than use futures and options (Harwood, et al.; Goodwin and Schroeder).

Statistical analyses of the Kansas data suggest that the adoption of forward-pricing marketing strategies increases with farm size and education, among other things. Participation in marketing educational programs significantly increased farmers' adoption of forward-pricing strategies (Goodwin and Schroeder). An unexpected result of the analysis was, however, that farmers who stated a preference for risk were more likely to adopt forward-pricing methods than were the risk-averse producers. This result is consistent with farmers' perceptions that forward-pricing is more risky (costly) than other marketing methods. It is also in line with a perception that farmers think of "hedging" in futures as a way to increase incomes rather than as a way to shift risk. Alternatively, it is consistent with a view that farmers regret delivering grain, previously priced at $2.50 per bushel, at a time when the market price is $3.

Large-scale Midwestern grain producers were found to use forward-pricing methods more often than the average farmers represented by random samples of producers (Patrick, Musser, and Eckman). But, again, these larger farmers appear to think of marketing tools as ways of enhancing profits rather than as ways of managing price risk. A fundamental question, which is addressed elsewhere at this conference, relates to whether or not farmers are risk averse. About 15 years ago, Tauer analyzed a sample of New York State dairy farmers and estimated that 26% preferred risk, 39% were risk neutral, and 34% were risk averse. This contrasts with a notion of dairy farmers as rather conservative managers. Of course, most of the foregoing analyses of farmer decisions and attitudes have potential measurement problems; their answers to questions may not be consistent with actual decisions.

If forward and futures contracts can be used to accomplish the same objectives, then the question becomes, which is the least cost alternative? If forward contracts were the least cost alternative for the majority of farmers, this would help explain the preference for the use of forward contracts. Few studies have estimated the costs of using forward contracts and compared this cost with hedging in futures. Brorsen, Coombs, and Anderson analyzed costs of forward-contracting hard red winter wheat and concluded that this cost ranged from two to seven cents per bushel. The estimated cost varied with the length of time to delivery (and also depended on the estimation method). These authors estimate that the equivalent cost of hedging in futures was two cents per bushel. They conclude, "...for about $0.02/bu. more, forward contracts lets a farmer not have to worry about margin calls or basis risk and allows pricing in increments other than 5,000 bu. Thus, it is easy to see why many farmers elect to forward contract..." (p. 353). So far as we know, this study (and others) did not impute a cost of default risk in forward contracts, which would be zero for futures contracts, and perhaps most farmers think that the cost of default is zero. The Brorsen, Coombs, and Anderson conclusion is consistent with the observed behavior of farmers.

Linkages and Data Availability. The problem of doing useful analyses is further complicated by a lack of easy access to data on some of the choices that could enter the portfolio. Data are available on market prices, and consequently it is relatively inexpensive to analyze portfolios involving cash, futures, and options positions. It is more difficult to analyze the benefits and costs of forward-contracting, although in principle it should be possible to construct appropriate data sets. When one introduces the possible use of yield futures and insurance products, research on optimal portfolios becomes more costly, as an understanding of the probability distributions of farm-level yields is important.

Still another complexity is the increasing opportunities for farmers to produce commodities with special attributes for niche markets. Thus, the "portfolio problem" becomes not only how to market, but what commodity attributes to produce and market. Often, niche markets involve forward contracts. These potential choices again imply the need for individual farm data, including an understanding of probability distributions of yields for the different outputs. There is the additional question of analyzing the relationship between yields and prices at the farm level.

Computer simulation software programs have, however, been developed to teach agricultural marketing tools to students and producers (e.g., Trapp; Dayton; King and Lev). These are potentially valuable for research purposes as well, when programs require farm-level marketing information, and thus, create databases that may serve as bases for marketing strategy evaluations. King, Lev, and Nefstead report development of a position report format used in their educational program for farm-level marketing management. The report includes cash resources and inventories, futures and options positions, and forward contract commitments.

In sum, useful research in this area requires the development of relevant data sets. This is not "flashy" research, but is important. Will the incentive system in academia produce such research (Brorsen and Irwin)?

Empirical Evidence on Marketing Strategies

In this section, we touch on research that provides empirical estimates of returns and the riskiness of returns from alternative marketing strategies. Some research compares simple "optimal" strategies with even simpler alternatives, such as only marketing at harvest. This type of research appears to be less common now than it was 10 to 20 years ago, and much of this type research appears to emphasize comparisons of *mean* returns from various strategies.

For "cash market only" strategies, research has compared harvest-time sales with diversification through storage. A study of post-harvest marketing of grain sorghum in a coastal region of Texas, using 1972-81 data, illustrates earlier research on "cash market only" strategies for one grain in one region (Rister, Skees, and Black). In this study, average returns, net of storage costs, were positive for the first six months of the storage period, but turned negative late in the storage season. (It perhaps should be noted that many empirical studies use commercial storage charges and do not impute an opportunity cost.) In a competitive market, the marginal revenue from storage should equal the margin costs of storage, but in practice, prices rise by more and by less than the cost of storage in individual years. Price risk exists, and costs of (unhedged) storage should make an allowance for risk. Thus, not surprisingly, Rister, Skees, and Black found that net returns from storage were variable and that the variability increased the further the sales month was from the harvest month. The authors did rank strategies by using stochastic dominance, i.e., by considering riskiness of choices, and they argue that outlook information was useful to many, but not all, decision-makers.

Regions facing large transportation costs to markets have a comparative advantage in storage, because of the lower local prices associated with distance to markets; consequently, the opportunity cost of holding stocks decreases with distance to markets (Benirschka and Binkley). Another line of research indicates that taxes are an important issue in grain storage decisions (Tronstad and Taylor; McNew and Gardner). Thus, optimal cash-marketing strategies likely vary by region and by individual farms within regions.

Diversification of sales in cash markets is, of course, more of a question for farmers producing annual crops. Producers of livestock, milk, and eggs have a natural diversification through frequency of marketing. Dairy farmers receive 24 milk checks per year, and consequently receive an "average" price. Nonetheless, hedging or forward contracting has the potential of reducing the variance of returns below those obtained via spot markets

While diversification of sales may be a way to manage price risk in some instances, diversifying sales of an annually produced crop over the storage season probably increases the variance of gross returns. As discussed above, cash prices have an increasing variance as the storage season progresses. Prices can rise (or fall) relative to the cost of storage in any particular year. Thus, unhedged storage should result in larger gross returns than from sales at harvest, but also result in larger variance of returns.

The same may be true for the variability of net returns, but this is less clear. The storage decision also depends on the costs of storage including opportunity costs, and opportunity costs are positively correlated with the price level. Presumably, price is inversely related to quantity, and this implies lower storage costs and larger storage amounts when prices are low, *ceteris paribus*, further implying in the aggregate (though not necessarily for the individual) that varying storage rates over a period of years could contribute to net revenue stability.

It is also possible to diversify by using futures markets to make pre-harvest (pre-production) sales of a commodity, and routine pre-harvest hedging of growing crops in futures probably can reduce the variance of returns (Zulauf, et al.). This occurs, however, at some cost of hedging, and with yield risk, the optimal pre-harvest hedge is likely small. Similarly, the use of simple strategies in options (like buying puts) can protect against price declines, but at a premium.

Relative to using rollover strategies in futures, Gardner found that sequential rollovers yield the same expected returns as cash sales and have little effect on the variability of returns. He suggests that rollovers can lock-in a price for a given n-year period (when this appears desirable), but this conclusion is based on the assumption that the year-to-year basis in futures is a constant. In fact, relative prices for different maturities can change.

Some research has addressed whether derivative markets can be used to raise average returns. Research by Wisner, Blue, and Baldwin, discussed above, is a good example. Their work suggests that pre-harvest use of futures and/or options market strategies can increase average returns for corn and soybeans relative to sales at harvest or thereafter. In a similar vane, pre-harvest forward contracting has been found to increase returns relative to harvest-time sales (e.g., Kolajo, Hurst, and Martin). However, a study in South Dakota, comparing pre-harvest with harvest-time marketing found that the mean and variance of returns depended on location (Tennyson). A problem in these comparative studies is the difficulty of including the full costs and risks of the alternatives; i.e., are the comparisons truly valid?

Rather than storing grain unhedged, it appears more logical to store grain and to hedge this position in futures only in those years when the expected price of storage covers the cost of storage (e.g., Heifner). A return to storage is approximately assured via the hedge, and risk is limited to the basis risk associated with the expected convergence not being realized. To realize the return, a hedge in futures is essential; the harvest-time basis is not a forecast of the potential seasonal increase in cash prices; at most, it is a forecast of the return from hedged storage, the convergence of the two prices (Heifner; Kastens and Dhuvetter).

Similarly, for livestock, it should be possible to use futures markets to assure profitable production when favorable relative prices appear in markets (i.e., by buying inputs and selling the output more or less simultaneously). Paul and Wesson called this the "price of feedlot services" which is analogous to a "price of storage." Research by Peterson and Leuthold found that cattle feeders could reduce risk and also lock-in returns when favorable prices occur. Recently, Kee and Kenyon question the value of futures markets in assuring profit margins for hog producers, because of the basis risk associated with the use of futures.

Harrison, et al. compare the profitability and risk management properties of grazing contracts to futures and option contracts for "backgrounding" operations (assemble and grow calves from weaning weights to feed-lot-ready weights) in the feeder cattle industry. Net return distributions from 28 different backgrounding production and marketing arrangements were evaluated under simulated cash, futures and options prices and animal performance, and ranked using stochastic dominance. They find that in general, pasture owners prefer grazing contracts to integrated production and marketing using traditional hedging strategies to manage price risk. The hedging strategies yielded negative net returns on average.

Farmers can purchase the services of marketing advisers. Jackson, Irwin, and Good and Good, et al. have evaluated the recommendations of a group of advisers for marketing soybeans and corn. The advice covers pre-harvest through post-harvest alternatives, typically involving the use of forward contracts, futures contracts, and options contracts. The advice can be viewed as a recommended portfolio for the given grain, but it appears that advisers stress the returns part of the outcome. Consistent with this, the evaluations by Good and his colleagues compare returns from the alternatives rather than analyze the risk.

The recommendations of the advisers are used to estimate returns and are based on prices net of brokerage fees and carrying charges. These net advisory prices then are compared with market benchmark prices: average price during harvest and the weighted average price received by farmers over a given crop year. One result is that the net prices for corn and soybeans, from the various advisers, have a wide range and that the advisers' performances are not always consistent from year to year. For the two crop years, 1995-96 and 1996-97, the majority of marketing programs for corn had returns less than the benchmark price, while the opposite was true for soybeans.

A recent study analyzed nationwide, cross-section data at the farm level in attempt to understand the incentives to participate in federal crop insurance (Just, Calvin, and Quiggan). The results suggest that farmers participate in the insurance program mainly to receive the associated subsidy or because of adverse selection. The risk-aversion incentive is small. While this empirical analysis is not directly related to marketing strategies, it is another piece of evidence that raises a question about the nature of risk aversion among U.S. farmers.

While the foregoing summary of empirical results is far from exhaustive, we interpret them as being largely consistent with theoretical predictions. Basically, no magic formula exists for increasing average returns. Strategies exist to manage risk, but these strategies have costs. The benefits relative to costs of the alternative strategies are not fully understood for the diversity of circumstances faced by different farmers.

Summing Up: Implications for Research Priorities

An important first question is, what is being optimized? That is, what objectives are marketing strategies expected to accomplish? Are marketing programs expected to raise the average net returns of producers? If so, is this a realistic objective? If the objective is to reduce or shift risk, what is the appropriate definition of risk? Analyses of marketing programs are necessarily conditioned by the objectives that the programs are expected to accomplish.

Risk analysis is also conditional on (hopefully correct) models of the random variables underlying the risky returns received by farmers. Agricultural economists have made important contributions to modeling price behavior in cash markets, but it has proven difficult to obtain good empirical models (Tomek and Myers). To evaluate marketing programs, we need estimates of how the mean of prices changes and also how the (conditional) variance changes with the passage of time. Indeed, we need to know whether the probability distribution is normal and whether skewness and kurtosis exist. If forecasts of spot prices are poor, however, the unconditional variance (or semi-variance) may be a reasonable proxy for the magnitude of risk. Research should review the adequacy of risk measures.

Further, a full analysis requires information about the costs of choices. For example, if the question relates to a comparison of harvest-time sale of corn versus storage, then the analyst should estimate seasonal changes in the mean of prices and in the variance of prices around the mean. Moreover, the costs of storage — especially the opportunity costs associated with the price level and interest rates which are not constant — should be estimated.

Analyses for livestock and for tree crops are especially complex. This is because the modeling of the "life cycle effects," which influence prices, is complex. For example, a reasonable hypothesis about why the hog cycle has persisted over many decades is that the difficulty of predicting the cycle makes taking counter-cyclical actions risky (costly). Thus, agricultural economists face a major challenge to improve the quality of empirical results and make them more cumulative.

A similar case can be made for estimating yield risk. The critique of Just and Weninger, discussed earlier, is apt. The yields of most agricultural commodities are influenced by improving technology and management, and estimates of yield risk are conditional on having an appropriate model of the changes in the means of the yields. Moreover, yield risk varies among farms, and these differences in risk need to be better understood. The issue is further complicated by farmers having more choices about the particular varieties of commodities which they can produce and which can have different trends in yields and different levels of risk.

Managing price and revenue risk can involve the use of derivative instruments. Agricultural economists have been quick to adopt the underlying theory of the price behavior of derivatives for applications to commodity markets. The theory of price behavior in efficient markets is reasonably well understood, but controversy persists about the efficiency of various derivative markets for commodities. Much research has been devoted to analyzing whether markets are efficient and whether risk premiums exist. The evidence suggests that most markets are relatively efficient and that risk premiums, if any, are tiny. This implies, in turn, that farmers cannot profit from speculation on price changes in derivative markets. Some analysts believe, however, that the mean of returns can be raised by using futures and options markets.

We face a dilemma in doing research on this topic. The market efficiency question is an important one, but it is unclear whether useful answers can be obtained based on existing data and methods. There are a lot of research results, related to market efficiency, that can be judged to have had little value, and weak-form or semi-strong form efficiency do not rule out profitable speculation by those with better private information. A few marketing advisers may have this better information.

The discussion of efficiency should, however, be separated from analyses of the use of derivatives to price production, merchandising, and storage returns. In principle, futures and options can be used to more or less assure profitable storage (production, etc.) in those years in which profitable relative prices exist. Research to support these decisions includes forecasts of basis relationships and of basis risk. In some cases, basis risk may be so large as to make the derivatives ineffective, and this needs to be understood as well.

Forward contracts are another way to lock-in prices. As noted above, it is important to understand the full costs of marketing choices and how these costs may change. We especially lack information about the costs of forward contracting. It is even uncommon to estimate the costs of hedging programs involving futures and/or options trading. If farmers are optimizers, as we assume, then their preference for forward contracting over using futures markets suggests that many farmers believe that forward contracting has a more favorable benefit-to-cost ratio. It would be useful to try to determine under what circumstances this is true (or not true). And, do farmers' "calculations" perhaps ignore costs, such as the risk of default on forward contracts?

What can academics reasonably do? We are poorly equipped to give specific marketing advice to individual farmers. Even in those cases where predictable changes in futures prices may have been discovered, it is important to translate statistical significance into economic significance. A statistically significant forecast does not necessarily result in profitable speculation because of transactions costs. This cost includes risk associated with the use of the forecast.

Another reason for not giving specific advice is that it should be based on an in-depth understanding of the farm business. Farmers differ in many ways, including their equity position and preferences for avoiding risk. They do not necessarily face the same production functions, nor have the same level of efficiency, nor the same utility functions.

However, applied economists can assist farmers by providing a framework for evaluating choices and by improving the understanding of price and yield behavior, the full extent of costs, and the nature of the risks they face. It is important to clarify the principles that undergird individual decisions. These principles certainly can be applied to different kinds of "representative farmers" to illustrate their applications, but we need to guard against "over promising" what marketing programs can accomplish, especially in terms of improving net returns. Educational programs can help understand trade-offs among alternative marketing choices.

Past research has tended to look at relatively few alternatives with simple models and perhaps has been a bit naïve about our ability to model price behavior. Since depicting reality in its entirety is not feasible, simplification is inevitable. There are many potential portfolios. Each analysis of various (simplified) portfolios is bound to lead to different conclusions. The relevant question is, what can we hold constant to minimize deviations from reality? Hopefully, this can be done in a cumulative fashion so that future research can provide deeper insights about the consequences of realistic marketing choices.

References

Adams, B. D., P. Garcia, and R. J. Hauser. "The Value of Information to Hedgers in the Presence of Futures and Options." *Review of Agricultural Economics* 18(1996): 437-447.

Baillie, R. T., and R. J. Myers. "Bivariate GARCH Estimation of the Optimal Commodity Futures Hedge." *Journal of Applied Econometrics* 6(1991): 109-124.

Barkoulas, J., W. C. Labys, and J. Onochie. "Fractional Dynamics in International Commodity Prices." *The Journal of Futures Markets* 17(1997): 161-189.

Bates, D. S. "The Crash of '87: Was It Expected? The Evidence from Options Markets." *The Journal of Finance* 46(1991): 1009-1044.

Beck, S. "Autoregressive Conditional Heteroskedasticity." Working Paper, Department of Economics, University of Delaware, 1998.

Benirschka, M., and J. K. Binkley. "Optimal Storage and Marketing Over Space and Time." *American Journal of Agricultural Economics* 77(1995): 512-524.

Bessembinder, H., et al. "Mean Reversion in Equilibrium Asset Prices: Evidence from the Futures Term Structure." *The Journal of Finance* 50(1995): 361-375.

Bessler, D. A., and J. A. Brandt. "An Analysis of Forecasts of Livestock Prices." *Journal of Economic Behavior and Organization* 18(1992): 249-263.

Black, F. "The Pricing of Commodity Contracts." *Journal of Financial Economics* 3(1976): 167-179.

Black, F., and M. Scholes. "The Pricing of Options and Corporate Liabilities." *The Journal of Political Economy* 81(1973): 637-659.

Boehlje, M. D., and D. A. Lins. "Risks and Risk Management in an Industrialized Agriculture." *Agricultural Finance Review* 58(1998): 1-16.

Bollerslev, T. "Generalized Autoregressive Conditional Heteroscedasticity." *Journal of Econometrics* 31(1986): 307-327.

Brennan, M. J. "The Supply of Storage." *The American Economic Review* 48(1958): 50-72.

Brorsen, B. W. "Optimal Hedge Ratio with Risk-Neutral Producers and Nonlinear Borrowing Costs." *American Journal of Agricultural Economics* 77(1995): 174-181.

Brorsen, B. W., J. Coombs, and K. Anderson. "The Cost of Forward Contracting Wheat." *Agribusiness: an International Journal* 11(1995): 349-354.

Brorsen, B. W., and S. H. Irwin. "Improving the Relevance of Research on Price Forecasting and Marketing Strategies." *Agricultural and Resource Economics Review* 25(1996): 68-75.

Carter, C. A. "Commodity Futures Markets: A Survey." *The Australian Journal of Agricultural and Resource Economics* 43(1999): 209-247.

Chalfant, J. A., R. N. Collender, and S. Subramanian. "The Mean and Variance of the Mean-Variance Decision Rule." *American Journal of Agricultural Economics* 72(1990): 966-974.

Chambers, M. J., and R. E. Bailey. "A Theory of Commodity Price Fluctuations." *The Journal of Political Economy* 104(1996): 924-957.

Chavas, J.-P., and M. T. Holt. "On Linear Dynamics: the Case of the Pork Cycle." *American Journal of Agricultural Economics* 73(1990): 820-828.

Coble, K. H., and R. Heifner. "The Effect of Crop or Revenue Insurance on Optimal Hedging." In: *NCR-134 Conference Proceedings*, 1998, pp. 107-121.

Collins, R. A. "Toward a Positive Economic Theory of Hedging." *American Journal of Agricultural Economics* 79(1997): 488-499.

Cox, J. C., and S. A. Ross. "The Valuation of Options for Alternative Stochastic Processes." *Journal of Financial Economics* 3(1976): 145-166.

Dayton, J. "Policy and Risk Implications for an Individual Grain Farm." *Agribusiness: an International Journal* 5(1989): 181-195.

Deaton, A., and G. Laroque. "Competitive Storage and Commodity Price Dynamics." *The Journal of Political Economy* 104(1996): 896-923.

Deaton, A., and G. Laroque. "On the Behavior of Commodity Prices." *The Review of Economic Studies* 59(1992): 1-23.

Engle, R. F. "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of U.K. Inflation." *Econometrica* 50(1982): 987-1008.

Fackler, P. L., and Y. Tian. "Volatility Models for Commodity Markets." In: *NCR-134 Conference Proceedings,* 1999, pp. 247-256.

Fama, E. F., and K. R. French. "Commodity Futures Prices: Some Evidence on Forecast Power, Premiums, and the Theory of Storage." *The Journal of Business* 60(1987): 55-73.

Feder, G., R. E. Just, and A. Schmitz. "Futures Markets and the Theory of the Firm under Price Uncertainty." *The Quarterly Journal of Economics* 94(1980): 317-328.

Gallagher, P. "U.S. Corn Yield Capacity and Probability: Estimation and Forecasting with Nonsymmetric Disturbances." *North Central Journal of Agricultural Economics* 8(1986): 109-122.

Garcia, P., and D. L. Good. "An Analysis of the Factors Influencing the Illinois Corn Basis, 1971-1981." In: *NCR-134 Conference Proceedings*, 1983, pp. 306-326.

Gardner, B. L. "Rollover Hedging and Missing Long-Term Futures Markets." *American Journal of Agricultural Economics* 71(1989): 311-318.

Ghosh, S., C. L. Gilbert, and A. J. H. Hallett. *Stabilizing Speculative Commodity Markets*. New York City, NY: Oxford University Press, 1987.

Good, D. L., et al. "1995 Pricing Performance of Market Advisory Services for Corn and Soybeans." AgMAS Project Research Report 1997-01, 1997.

Goodwin, B. K., and T. L. Kastens. "An Analysis of Marketing Frequency by Kansas Crop Producers." *Review of Agricultural Economics* 18(1996): 575-584.

Goodwin, B. K., and T. C. Schroeder. "Human Capital, Producer Education Programs, and the Adoption of Forward-Pricing Methods." *American Journal of Agricultural Economics* 76(1994): 936-947.

Harrison, R. W., et al. "Analysis of the Risk Management Properties of Grazing Contracts Versus Futures and Option Contracts." *Journal of Agricultural and Applied Economics* 28(1996): 247-262.

Harwood, J., et al. *Managing Risk in Farming: Concepts, Research, and Analysis*. Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report 774, 1999.

Hauser, R. J., P. Garcia, and A. D. Tublin. "Basis Expectations and Soybean Hedging Effectiveness." *North Central Journal of Agricultural Economics* 12(1990): 125-134.

Hauser, R. J., and D. Neff. "Pricing Options on Agricultural Futures: Departures from Traditional Theory." *The Journal of Futures Markets* 5(1985): 539-577.

Heifner, R. G. "The Gains from Basing Grain Storage Decisions on Cash-Futures Spreads." *Journal of Farm Economics* 48(1966): 1490-1495.

Heifner, R. G., B. H. Wright, and G. E. Plato. *Using Cash, Futures, and Options Contracts in the Farm Business*. Economic Research Service, U.S. Department of Agriculture. Agricultural Information Bulletin 665, 1993.

Hennessy, D. A., and T. I. Wahl. "The Effect of Decision Making on Future Price Volatility." *American Journal of Agricultural Economics* 78(1996): 591-603.

Hilliard, J. E., and J. A. Reis. "Jump Processes in Commodity Futures Prices and Options Pricing." *American Journal of Agricultural Economics* 81(1999): 273-286.

Hranaiova, J., and W. G. Tomek. "The Timing Option in Futures Contracts and Price Behavior at Contract Maturity." Department of Agricultural, Resource, and Managerial Economics, Cornell University, Working Paper WP 99-12, June 1999.

Huang, C.-f., and R. H. Litzenberger. *Foundations for Financial Economics*. Englewood Cliffs, New Jersey: Prentice Hall, 1988.

Hudson, M. A., R. M. Leuthold, and G. F. Sarassoro. "Commodity Futures Price Changes: Recent Evidence for Wheat, Soybeans, and Live Cattle." *The Journal of Futures Markets* 7(1987): 287-301.

Irwin, S. H., C. R. Zulauf, and T. E. Jackson. "Monte Carlo Analysis of Mean Reversion in Commodity Futures Prices." *American Journal of Agricultural Economics* 78(1996): 387-399.

Jackson, T. E., S. H. Irwin, and D. L. Good. "1996 Pricing Performance of Market Advisory Services for Corn and Soybeans." AgMAS Project Research Report 1998-01, 1998.

Johnson, L. L. "The Theory of Hedging and Speculation in Commodity Futures." *The Review of Economic Studies* 27(1960): 139-151.

Just, R. E., L. Calvin, and J. Quiggin. "Adverse Selection in Crop Insurance: Actuarial and Asymmetric Information Incentives." *American Journal of Agricultural Economics* 81(1999): 834-849.

Just, R. E., and Q. Weninger. "Are Crop Yields Normally Distributed?" *American Journal of Agricultural Economics* 81(1999): 287-304.

Kahl, K. H. "Determination of the Recommended Hedging Ratio." *American Journal of Agricultural Economics* 65(1983): 603-605.

Kaldor, N. "Speculation and Economic Stability." *The Review of Economic Studies* 7(1939): 1-27.

Kastens, T. L., and K. C. Dhuyvetter. "Post-harvest Grain Storing and Hedging with Efficient Futures." In: *NCR-134 Conference Proceedings*, 1999, pp. 335-358.

Kee, G. D., and D. E. Kenyon. "Hog Profit Margin Hedging: A Long-Term Out-of-Sample Evaluation." In: *NCR-134 Conference Proceedings*, 1999, pp. 379-394.

King, R. P., and L. S. Lev. *MarketTools, Version 1.0*. St. Paul, MN: Harvest States Cooperatives, 1992.

King, R. P., L. S. Lev, and W. E. Nefstead. "A Position Report for Farm-Level Marketing

Management." *Review of Agricultural Economics* 17(1995): 205-212.
Kolajo, E. F., J. R. Hurst, and N. R. Martin. "Available Crop Marketing Alternatives Valuable to Alabama Farmers." *Highlights of Agricultural Research.* Alabama Agricultural Experiment Station, 1988, pp. 6.
Lapan, H., and G. Moschini. "Futures Hedging under Price, Basis, and Production Risk." *American Journal of Agricultural Economics* 76(1994): 465-477.
Lapan, H., G. Moschini, and S. D. Hanson. "Production, Hedging, and Speculative Decisions with Options and Futures Markets." *American Journal of Agricultural Economics* 73(1991): 66-74.
Lence, S. H. "The Economic Value of Minimum-Variance Hedges." *American Journal of Agricultural Economics* 77(1995): 353-64.
Lence, S. H., Y. Sakong, and D. J. Hayes. "Multiperiod Production with Forward and Option Markets." *American Journal of Agricultural Economics* 76(1994): 286-295.
Levy, H., and H. M. Markowitz. "Approximating Expected Utility by a Function of Mean and Variance." *The American Economic Review* 69(1979): 308-317.
Liu, S., et al. "Forecasting the Nearby Basis of Live Cattle." *The Journal of Futures Markets* 14(1994): 259-273.
Markowitz, H. M. "Portfolio Selection." *The Journal of Finance* 7(1952): 77-91.
McNew, K. P., and P. L. Fackler. "Nonconstant Optimal Hedge Ratio Estimation and Nested Hypotheses Tests." *The Journal of Futures Markets* 14(1994): 619-635.
McNew, K. P., and B. L. Gardner. "Income Taxes and Price Variability in Storable Commodity Markets." *American Journal of Agricultural Economics* 81(1999): 544-552.
Merton, R. C. "Option Pricing When Underlying Stock Returns Are Discontinuous." *Journal of Financial Economics* 3(1976): 125-144.
Muth, J. F. "Rational Expectations and the Theory of Price Movements." *Econometrica* 29(1961): 315-335.
Myers, R. J. "Time Series Econometrics and Commodity Price Analysis: A Review." *Review of Marketing and Agricultural Economics* 62(1994): 167-181.
Myers, R. J., and S. D. Hanson. "Pricing Commodity Options When the Underlying Futures Price Exhibits Time-Varying Volatility." *American Journal of Agricultural Economics* 75(1993): 121-130.
Nerlove, M. *Distributed Lags and Demand Analysis for Agricultural and Other Commodities*. Agricultural Marketing Service, U.S. Department of Agriculture, Agricultural Handbook 141, June 1958.
Newbery, D. M. "Futures Trading, Risk Reduction, and Price Stabilization." In: *Futures Markets: Modelling, Managing, and Monitoring Futures Trading*. ed. M. E. Streit. Oxford, England: B. Blackwell, 1983, Ch.9.
Ng, S. "Looking for Evidence of Speculative Stockholding in Commodity Markets." *Journal of Economic Dynamics and Control* 20(1996): 123-143.
Patrick, G. F., W. N. Musser, and D. T. Eckman. "Forward Marketing Practices and Attitudes of Large-Scale Midwestern Grain Producers." *Review of Agricultural Economics* 20(1998): 38-53.

Paul, A. B., and W. T. Wesson. "Pricing Feedlot Services Through Cattle Futures." *Agricultural Economic Research* 19(1967):33-45.

Peterson, P. E., and R. M. Leuthold. "A Portfolio Approach to Optimal Hedging for a Commercial Cattle Feedlot." *The Journal of Futures Markets* 7(1987): 443-457.

Pindyck, R. S., and J. J. Rotemberg. "The Excess Co-movement of Commodity Prices." *Economic Journal* 100(1990): 1173-1189.

Pirrong, C. "Searching for the Missing Link: High Frequency Price Dynamics and Autocorrelations for Seasonally Produced Commodities." Working Paper, John M. Olin School of Business, Washington University, 1999.

Rister, M. E., J. R. Skees, and J. R. Black. *Evaluating Post-Harvest Marketing Strategies for Grain Sorghum in the Texas Coastal Bend*. Texas Agricultural Experiment Station Bulletin B 1488, August 1984.

Rosen, S. "Dynamic Animal Agriculture." *American Journal of Agricultural Economics* 69(1987): 547-557.

Rucker, R. R., O. R. Burt, and J. T. LaFrance. "An Econometric Model of Cattle Inventories." *American Journal of Agricultural Economics* 66(1984): 131-144.

Rui, X., and M. J. Miranda. "Commodity Storage and Interseasonal Price Dynamics." In: *NCR-134 Conference Proceedings*, 1995, pp. 44-53.

Sakong, Y., D. J. Hayes, and A. Hallam. "Hedging Production Risk with Options." *American Journal of Agricultural Economics* 75(1993): 408-415.

Schwartz, E. S. "The Stochastic Behavior of Commodity Prices: Implications for Valuation and Hedging." *The Journal of Finance* 52(1997): 923-973.

Streeter, D. H., and W. G. Tomek. "Variability in Soybean Futures Prices: An Integrated Framework." *The Journal of Futures Markets* 12(1992): 705-728.

Tauer, L. W. "Risk Preferences of Dairy Farmers." *North Central Journal of Agricultural Economics* 8(1986): 7-15.

Taylor, P. D., and W. G. Tomek. "Forecasting the Basis for Corn in Western New York." *Journal of the Northeastern Agricultural Economics Council* 13(1984): 97-102.

Telser, L. G. "Futures Trading and the Storage of Cotton and Wheat." *The Journal of Political Economy* 64(1958): 233-255.

Tennyson, L. "Tailoring a Grain Marketing Plan for Highest Revenue." *South Dakota Farm and Home Research* (1996): 6-7.

Tomek, W. G. "Commodity Futures Prices as Forecasts." *Review of Agricultural Economics* 19(1997): 23-44.

Tomek, W. G. "Effects of Futures and Options Trading on Farm Income." In: *Options, Futures, and Agricultural Commodity Programs, Symposium Proceedings.* ERS USDA Staff Report No. AGES870911, 1988, pp. 21-33.

Tomek, W. G., and R. J. Myers. "Empirical Analysis of Agricultural Commodity Prices: A Viewpoint." *Review of Agricultural Economics* 15(1993): 181-202.

Trapp, J. N. "A Commodity Market Simulation Game for Teaching Market Risk Management." *Southern Journal of Agricultural Economics* 21(1989): 139-147.

Tronstad, R., and C. R. Taylor. "Dynamically Optimal After-Tax Grain Storage, Cash Grain Sale, and Hedging Strategies." *American Journal of Agricultural Economics* 73(1991): 75-88.

Vercammen, J. "Hedging with Commodity Options When Price Distributions are Skewed." *American Journal of Agricultural Economics* 77(1995): 935-945.

Vukina, T., D. Li, and D. M. Holthausen. "Hedging with Crop Yield Futures: A Mean-Variance Analysis." *American Journal of Agricultural Economics* 78(1996): 1015-1025.

Ward, R. W., and F. A. Dasse. "Empirical Contributions to Basis Theory: The Case of Citrus Fruit." *American Journal of Agricultural Economics* 59(1977): 71-90.

Wescott, P. C., and L. A. Hoffman. *Price Determination for Corn and Wheat: The Role of Market Factors and Government Programs*. Economic Research Service, USDA Technical Bulletin 1878, 1999.

Williams, J. C., and B. D. Wright. *Storage and Commodity Markets*. Cambridge, MA: Cambridge University Press, 1991.

Wisner, R. N., E. N. Blue, and E. D. Baldwin. "Preharvest Marketing Strategies Increase Net Returns for Corn and Soybean Growers." *Review of Agricultural Economics* 20(1998): 288-307.

Working, H. "The Theory of Price of Storage." *The American Economic Review* 39(1949): 1254-1262.

Wright, B. D., and J. C. Williams. "A Theory of Negative Prices for Storage." *The Journal of Futures Markets* 9(1989): 1-13.

Yang, S.-R., and B. W. Brorsen. "Nonlinear Dynamics of Daily Cash Prices." *American Journal of Agricultural Economics* 74(1992): 706-715.

Zulauf, C. R., and S. H. Irwin. "Market Efficiency and Marketing to Enhance Income of Crop Producers." *Review of Agricultural Economics* 20(1998): 308-331.

Zulauf, C. R., et al. "A Reappraisal of the Forecasting Performance of Corn and Soybean New Crop Futures." *The Journal of Futures Markets* 19(1999): 603-618.

Figure 1. Monthly Price Distributions