RISK MANAGEMENT IN AGRICULTURAL MARKETS: A REVIEW

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This article surveys and evaluates the current state of knowledge about producers' marketing strategies to manage price and revenue risk for farm commodities. The review highlights gaps between concepts and their implementation. Many well-developed models of price behavior exist, but appropriate characterization and estimation of the probability distributions of commodity prices remain elusive. Hence, the preferred measure of price risk is ambiguous. Numerous models of optimal marketing portfolios for farmers have been specified, but their behavior appears to be inconsistent with most, if not all, of these models. In addition, some research suggests that farmers can earn speculative profits, which is inconsistent with notions of efficient markets. The conclusions discuss what academic research can and cannot accomplish in relation to assisting producers with risk-management decisions. © 2001 John Wiley & Sons, Inc. Jrl Fut Mark 21:953–985, 2001

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INTRODUCTION

Businesses confront numerous risks, and they have choices in managing them. The task of defining a menu of realistic choices and specifying their benefits and costs is complex. In addition, a variety of ways of analyzing risk exist (Boehlje & Lins, 1998). Various risk-management strategies can be justified based on theoretical analyses, and many corporations employ some financial tools to manage risks (Bodnar, Hayt, & Marston, 1998). Yet academics know little about corporate risk-management practices and how they relate to theory. Our knowledge about producers' risk-management practices also is incomplete, but considerable research has been conducted on the theory and practice of price risk management by agricultural firms.

This article surveys and evaluates the current state of knowledge about producers' marketing strategies to manage price and revenue risk for farm commodities. Typically, farmers are assumed to select a combination, a portfolio, of marketing strategies that, for example, maximize expected returns subject to the degree of risk they are willing to accept. Marketing alternatives 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 futures and options contracts. Yield or revenue insurance is another possible constituent of a portfolio.

The net return and risk of each alternative must be depicted in order to identify an optimal portfolio, and a common simplification is to use means and variances of the probability distributions of returns to identify the optimum. In analyzing returns, the literature has emphasized distributions of prices, but we also briefly address yield distributions. The consequences of price risks can be large. For example, as a consequence of a large decline in prices in late 1998, 24,000 hog producers were reported as likely to quit by the summer of 1999 (Wall Street Journal, 1998).

We start by discussing sources of risk in agricultural commodity markets, namely price and yield behavior. The next section surveys contributions to conceptualizing and implementing a portfolio framework for marketing commodities. We then touch on empirical analyses regarding risk management and the performance of producers' marketing strategies. The article concludes with a discussion of some implications for research.

Some of the earliest analyses of risk management occurred for agricultural firms, but an over-arching theme of this article is the gaps that exist between concepts and their implementation. Well-developed models of price behavior exist, but appropriate characterization and estimation of the probability distributions of commodity prices remain elusive. The literature contains numerous models of optimal marketing portfolios because so many alternative specifications of farmers' objective functions are possible, but these diverse models and results have not been unified in a way that provides useful generalizations for decision-makers. A considerable portion of the literature is empirical, emphasizing the comparison of returns from alternative marketing strategies. Some of this research assumes that returns can be enhanced by speculative strategies, which conflicts with the notion of efficient markets. In addition, the results from such studies are difficult to appraise because the costs of the alternative marketing programs are incompletely analyzed. The remainder of our article elaborates on these points.

PRICE AND YIELD BEHAVIOR

Cash Prices

The price risk to be managed by farmers is that associated with the cash market, and an understanding of cash price behavior is a critical element of risk management. In our view, the characteristics of commodity prices are well documented, but this has not made risk management easy. A typical price series, whatever the frequency, 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., Deaton & Laroque, 1992; Myers, 1994). Price changes are nonlinearly dependent; i.e., higher moments are correlated (e.g., Yang & Brorsen, 1992). Given the complexity of these time-series features, modeling commodity prices has been a daunting task. Economists have not reached a consensus about the best model for commodity prices. This is perhaps not surprising, as models are likely to differ depending on the research problem and the commodity being studied.

Fundamentally, commodity price behavior over time is a mixture of systematic intra- and inter-year fluctuations plus randomness, and the variability of prices depends on information flows regarding supply and demand. Traditional time-series analysis assumes that current price is a linear function of past prices. In autoregressive integrated moving average (ARIMA) models, price changes are assumed to be drawn independently from an identical normal distribution. Yet, as just noted, the volatility of price changes is not constant. 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.

Autoregressive conditional heteroscedasticity (ARCH) and generalized autoregressive conditional heteroscedasticity (GARCH) models help explain conditional variance movements and capture part of the excess kurtosis in commodity prices (Bollerslev, 1986; Engle, 1982). Yang and Brorsen (1992) examined daily cash prices of seven agricultural commodities, and their results support the non-normality of daily returns. Beck (1998) derived that Muth's (1961) rational-expectations model of commodity markets implies an ARCH process in spot prices of storable commodities. Her analysis of 19 different commodity prices at annual frequency found significant ARCH processes for most storable commodity price series. Barkoulas, Labys, and Onochie (1997) provided evidence of fractional orders of integration in commodity price series and proposed mod-eling them as autoregressive fractionally integrated moving average (ARFIMA) processes.

Structural models are commonly applied to data observed at lower (e.g., quarterly or annual) frequencies and incorporate nonlinearities in a more straightforward way than do time-series models. Much of the literature focuses on inventory behavior to explain seasonal and inter-year price patterns. Building on the classic works of Brennan (1958), Working (1949), and Kaldor (1939), the framework adopts Muth's rational-expectations hypothesis and appends demand-and-supply functions to the original supply-of-storage equation. Williams and Wright (1991) synthesized the modern theory of storage and showed that it 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 & Laroque, 1992) was not capable of replicating the degree of autocorrelation in prices.[1] Rui and Miranda (1995) imposed a theoretical convenience yield (convex, decreasing function of storage), implying a convex increasing marginal storage cost that became infinitely negative at low inventory level, and showed that their assumption explained the level of autocorrelation observed in the same deflated series used by Deaton and Laroque (1992). Part of the validation of this model has focused on its prediction that

[1]They used deflated prices and deflating could have introduced autocorrelation, which did not exist in the nominal series.

prices are a two-regime process depending on whether or not inventories are held (Chambers & Bailey, 1996; Deaton & Laroque, 1996). Ng (1996) provided evidence for regime-specific price behavior using threshold models. Beck (1998) tested an implication of a nonnegative constraint on storage, that is, the difference in asymmetry of price distributions between storable and nonstorable commodities. Her results found no significant difference.

Longer cycles and trends are evident in some prices. Lags between production decisions and the realization of output imply recursive price behavior. Current supply is a function of expected price, given information at the time of the production decision, and a market-clearing condition (inverse-demand function) determines the current price. Various hypotheses exist about expectation formation: naïve, adaptive (Nerlove, 1958), rational (Muth, 1961), and quasi-rational (Feige & Pierce, 1976) expectations.

The recursive nature of the model implies autocorrelation in prices, but skewness may not be explained (Tomek & Myers, 1993). The particular nature of the autocorrelation depends on the specification of expectations formation. 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 and/or demand shocks appear necessary (e.g., Ghosh, Gilbert, & Hallett, 1987; Nerlove, 1958).

For perennial crops, adjustments in production take multiple years, and in livestock markets, the empirical evidence supports the existence of commodity-specific cycles in quantities. Attempts to explain cycles have used variants of the cobweb theorem, and, in principle, prices should move in cycles corresponding to the dynamics in quantities. Yet as Rucker, Burt, and LaFrance (1984) noted, few empirical studies have found this correspondence (though annual prices appear to be autocorrelated). Rosen (1987) demonstrated 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 existence of price cycles seemingly 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 analyses of livestock cycles has been that producers' behavior is naïve. An alternative and better explanation is that price cycles are not sufficiently predictable to make counter-cyclical actions profitable. Some research has explored dynamic, deterministic nonlinear processes that generate seemingly random behavior known as chaos. Empirically, Chavas and Holt (1991) showed that the dynamic process generating the pork cycle is nonlinear, but their evidence for chaos was less conclusive.

Net of seasonality and cycles, cash prices may be considered to be mean reverting to some long-run average or trend. Trends generally are 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.

Using the stochastic process-modeling approach of financial asset prices, a focus of empirical analysis has been on testing for mean reversion. Bessembinder, Coughenour, Seguin, and Smoller (1995) used the term structure of futures prices to test whether mean reversion in commodity prices is expected. Their evidence indicated significant mean reversion in agricultural commodity prices (wheat, orange juice, sugar, and cattle) and crude oil. There have been applications that incorporate seasonality in mean and volatility to analyze agricultural prices (e.g., Fackler & Tian, 1999).

For effective risk management, understanding the mean price level is not sufficient, since it is the extreme prices, which occur with low probability, that can bankrupt firms. If economists could characterize fully the systematic component of commodity price behavior and produce relatively accurate price forecasts, then price-risk-management techniques could deal with random deviations of cash prices around the known pattern of the mean. Despite voluminous efforts in commodity price analysis, however, it has proven to be very difficult to obtain good forecasts of commodity prices. Hence, much of price variability can be classified as risk.

The definition of price risk, however, remains debatable. The commonly used risk measure includes both upward and downward deviations from the mean, but perhaps only downward (upward) deviations are relevant to farmers (processors). Alternatively, the level from which deviations are measured needs not coincide with the mean; estimated cost of production may be more appropriate. An implication is that not only the mean and variance, but also higher moments, are valuable information for risk management. Hence, there is a substantial role for good models of cash prices. They could provide estimates of an entire distribution of price forecasts at a given point in time and augment mean and variance estimates obtainable from derivative markets.

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, 1999; Fama & French, 1987). 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 model needs to be modified by adding a term for an expected risk premium.) Thus, futures prices for an individual contract in an efficient market are not mean reverting. Empirical tests for mean reversion often use prices for a sequence of nearby futures contracts, which is tantamount to using spot prices that, as discussed above, can have systematic behavior. In addition, previous analyses of futures prices may suffer from statistical weaknesses (Irwin, Zulauf, & Jackson, 1996).

An important application of the foregoing model is the theory of the price of storage (e.g., Brennan, 1958; Working, 1949), which is appropriate for seasonally produced crops with continuous inventories. 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. The spot price and the futures prices for different maturities provide incentives (or disincentives) for storage. An implication is that prices of contracts for delivery in the current crop year can be high in relation to prices for new crop delivery. This occurs when current inventories are small in relation to demand and the expected future harvest is relatively large. This possibility is not always understood by firms writing forward contracts with rollover provisions, and can result in defaults on such contracts (Lence & Hayenga, 2001).

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, 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 incorporated rapidly 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). Markets, however, may not be strong-form efficient, and some traders may profit by having better (private) data and models (for a possible example, see Bessler & Brandt, 1992).

Moreover, price-forecasting models can have statistical, but not economic, significance, that is, returns from using the forecasts are less than transaction costs.

This point of view is not accepted universally. Wisner, Blue, and Baldwin (1998) argued that preharvest marketing strategies can increase farmers' average returns. They attributed this potential return to a yield-risk premium. Their hypothesis was 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 June (preharvest) should increase average prices in relation to selling at harvest. An unpublished paper by O'Brien (2000) supports this idea. However, Zulauf and Irwin (1998) found that such results depended on the sample period used in the analysis and concluded that there was no evidence of a drought premium. Other research has searched for profitable speculative strategies, implicitly assuming that futures markets are inefficient, but typically this research does not contain hypotheses that justify the strategies used.

Another way to obtain above-average returns is to find a marketing adviser (consultant) who has 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? An on-going project at University of Illinois evaluates the recommendations of a group of advisory services for marketing soybeans and corn. Their results, based on 1995 to 1998 data, suggested that, on average, most market-advisory services could not outperform the market, and their performances rarely were consistent from year to year (Irwin, Good, Martines-Filho, & Jackson, 2000).

Futures contracts are used primarily to hedge storage, merchandising, or production decisions, and an understanding of basis relationships and basis risk are important for hedging effectiveness. For the grain-storage decision, 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, the firm can sell futures, store, and expect to earn the convergence as a return (e.g., Heifner, 1966). Thus, the question arises, can the relevant basis be forecast accurately at the time the hedge is initiated? Some basis forecasts use naïve models; the expected basis equals last year's basis. Econometric models have been developed to explain basis variability (e.g., Hauser, Garcia, & Tublin, 1990; Liu, Brorsen, Oellermann, & Farris, 1994; Ward & Dasse, 1977). However, 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 & Tomek, 1984).

Clearly, for the grain-storage decision, 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 (2000) showed that the degree of convergence at contract maturity also depended on the changing values of the implicit options in futures contracts, such as providing sellers with choices about the timing of delivery. It remains to be seen, however, whether this insight can improve forecasts of basis convergence.

In discussing the probability distributions of futures prices, analysts typically have in mind changes in prices observed over some intra-year interval, such as daily, weekly, or monthly prices. While these price changes may be uncorrelated roughly (the efficient market hypothesis), they need not have a constant variance (e.g., Streeter & Tomek, 1992). 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. Moreover, as the contract-maturity date approaches, more information arrives about the factors that influence the price at maturity. Alternatively, Hennessy and Wahl (1996) argued that the time-to-maturity effect arose from the resolution of uncertainty, since supply and demand responses become increasingly inelastic as decisions were made. In addition, a nonlinear relationship exists between price and the stocks-to-use ratio (e.g., Westcott & Hoffman, 1999). 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 in relation to use.

Analyses of probability distributions often use changes in the logarithms of prices. The evidence is mixed on whether price changes are well approximated by the log normal distribution. For example, Hudson, Leuthold, and Sarassoro (1987) found that the log normal distribution was a good approximation for wheat, soybeans, and live cattle for daily prices for the years 1976 through 1982, but not if earlier years were included. Or, for example, Hilliard and Reis (1999) examined a set of intra-day prices—observations on every price change—for soybeans for the period July 1990 to June 1992, and they concluded that the logarithmic changes were not distributed normally.

An understanding of the probability distributions of futures prices 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 & Myers, 1991; McNew & Fackler, 1994). 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. In addition, changes in volatility can influence the margin level for futures contracts and hence influence the cost of hedging.

A different issue is how the annual variability of the price of a futures contract at maturity compares with its variability earlier in the life of the contract. For example, is the year-to-year variability of the December corn price in April smaller than the same contract's variability in December? This question is relevant 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 (Zulauf, Irwin, Ropp, & Sberma, 1999).

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, futures markets can be used to assure profitable returns to storage and production decisions, but this depends on accurate forecasts of the relevant basis. 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, 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. Additional research would be useful to improve our understanding of the basis risk faced by producers.

Options Prices

Trading in options contracts on agricultural commodity futures contracts began in 1984. Since futures options require the delivery of an underlying futures contract when exercised, basis risk exists, but options contracts offer an alternative risk-management mechanism. (The potential value of options contracts in farmers' portfolios is discussed in a subsequent section.)

The model for pricing options on futures by Black (1976) is based on the underlying assumption that the futures price, F, follows geometric Brownian motion: $dF/F = \mu\, dt + \sigma\, dz$, where μ is the expected growth rate in F, σ is its volatility, and dz is a Wiener process. Although the validity of this model is debatable, volatility is one of the critical factors determining option premiums. Volatility can be viewed in two ways: historical volatility is the variation in the underlying futures price, which can be estimated ex post; and implied volatility is a value that equates the market premium with the theoretical premium. The latter, which can be estimated from the Black model (1976) given the interest rate, strike price, market price of the underlying futures, and time to maturity, is regarded as a forecast.

Evidence comparing Black (1976) and Black and Scholes' (1973) predicted prices with market prices is mixed, but many studies have concluded that their models result in systematic pricing errors for agricultural options (Hauser & Neff, 1985). Hauser and Neff identified volatility forecasts and specification of the stochastic process of the underlying futures price as two major factors that impact premiums. These premiums were found relatively insensitive to interest-rate estimates.

Empirical results of whether implied volatilities exhibit time-to-maturity and seasonality effects have been mixed (Hauser & Neff, 1985). 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 (near harvest) and lowest during November through March. Fackler and Tian's (1999) work supports consistency between implied volatility and futures price volatility in terms of their seasonal variation.

Alternative assumptions regarding the stochastic process of the underlying futures prices are possible. Myers and Hanson (1993) developed an option-pricing model where the underlying futures price was modeled as a GARCH process, allowing for time-varying volatility and excess kurtosis. Their empirical results suggested that the GARCH option-pricing model outperforms the standard Black model. Hilliard and Reis (1999) compared the Black model and Bate's (1991) jump-diffusion model, where futures prices were assumed to follow a jump-diffusion process with systematic (seasonal) jump risk; Bate's model appears to perform better than Black's.

Options markets, like futures markets, generally are thought to be efficient. There could be times when the market premium is under- or overvalued, but such discrepancies are thought to be arbitraged quickly away. Still, if a market is thin, the adjustment may take longer, and the price-effect of entering and exiting positions could be large. Agricultural options contracts often have low trading volume.[2]

The performance of options markets for commodities has been studied less than markets for financials, and the potential costs and benefits of using options by farmers is not understood fully. The options contract concept fits farmers' seeming aversion for giving up high prices in order to reduce price risk, and off-exchange contracts with options-like features now are permissible. Thus, considerable scope exists for analyzing options premiums for exchange-traded and off-exchange contracts; this would provide guidance to pricing forward contracts with option-like features (Unterschultz, Novak, Bresee, & Koontz, 1998). Volatility estimates from options markets are potentially valuable information for risk management, and additional studies to examine the reliability of implied volatility forecasts in agricultural options markets, such as Fackler and King (1990), would be useful.

Yield Behavior

Variability of the yield of a given crop can differ by location because of differences in soil quality and climate, and naturally different crops have differing degrees of variability (Harwood et al., 1999, p. 8). With technological progress, yields increase and are commonly modeled as a function of trend and a random-error term (e.g., Gallagher, 1986). The principal debate has been about whether the residuals can be treated as normally distributed. The common view is that yield 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.

Tests for normality can be criticized on three grounds: the tests are conditional on the specification of the deterministic component of yields, that is, the trend specification, and hence are subject to misspecification bias; the tests misuse statistical significance by not considering the correlation of related time-series when multiple series are used to

[2]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 906 for BFP milk, 10,005 for oats, or 20,410 for feeder cattle (http://www.cbot.com; http://www.cme.com). Furthermore, aggregate numbers for open interest and trading volume do not provide information about the liquidity of specific contracts by maturity months, strike prices, and puts and calls. On December 17, 1999, the March 2000 contract for corn had a 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.

assess normality; and the tests typically use aggregate time-series, rather than farm-level yields (Just & Weninger, 1999). The last criticism is perhaps the most important because farm-level yield risk is usually the concept we wish to measure. Just and Weninger's (1999) analysis of farm-level and county-level data in 1973 through 1987, for five crops in four counties in Kansas, illustrated the concerns. For the farm-level data, normality typically could not be rejected. They further showed the implications of alternative specifications of the probability distribution of yields for the estimated probability of paying insurance indemnities.

An issue not addressed by Just and Weninger is the sensitivity of results to variations in the sample period. Conclusions about the normality of distributions of the error terms in a yield model are likely to be sensitive to whether or not one or two large residuals appear in the results. In addition, the decision "cannot reject normality" is not the same as concluding the distribution is normal.

Clearly the assumptions (and reality) of the distributions of yields can make a difference for evaluating yield and revenue insurance and hedges using yield futures markets. Market prices potentially can provide a reasonable assessment of the price basis risk faced by farmers because farmers face prices that are correlated highly with one another. In contrast, it is likely that farm-level, or at least county-level, data are required to assess yield basis risk 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 (Just, Calvin, & Quiggin, 1999).

OPTIMAL MARKETING PORTFOLIOS

Conceptual Framework of Optimal Portfolios

The general principle of portfolio theory is well known (e.g., Huang & Litzenberger, 1988; Markowitz, 1952); namely, the decision-maker selects the composition of 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 also a function of the riskiness of the rate of return.

In the early literature on using futures markets, simple portfolios involved a commodity inventory and a short position in futures contracts (e.g., Johnson, 1960). An optimal hedge was derived assuming that the quantity to be hedged was given exogenously, 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 is obtained as the ratio of a covariance of futures and cash prices to a variance of futures prices (Kahl, 1983).

A huge literature has grown out of these simple beginnings. Feder, Just, and Schmitz (1980) incorporated futures markets into a theory of the firm under uncertainty using the expected utility framework, but ignored the riskiness of production. Models have been developed to consider optimal positions in futures that take account of price and yield risk jointly. The more basic models abstracted from basis risk (Newbery, 1983).

A natural extension of the literature is 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, & Hanson, 1991). If production risk is introduced into the model, options enter the portfolio (Sakong, Hayes, & Hallam, 1993).

Considering three sources of risk (price level, basis, and yield), Lapan and Moschini (1994) derived 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 & Moschini, 1994, 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, it is optimal to forward price the crop using futures, holding 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 usually is optimal to change the futures position as the crop matures and to have a hedging role for options (Lence, Sakong, & Hayes, 1994). 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, & Hayes, 1994, p. 294). Another reason for options contracts to enter optimal portfolios is that the distribution of returns is skewed (Vercammen, 1995). In sum, optimal portfolios likely need to consider futures and options positions.

Crop-yield futures and yield or revenue insurance are relatively new instruments to manage risky returns, and thus, optimal hedges that take account of these instruments have been considered. For example, Vukina, Li, and Holthausen (1996) derived 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. Not surprisingly, the effectiveness of the hedges 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 et al., 1996).

In empirical studies, crop insurance tends to dominate hedges in yield futures by farmers as a tool for managing revenue risk. This result is not surprising if yield basis risk is large, that is, if individual farm yields vary substantially around the state average yield specified as the par yield in the futures contract. In addition, the federal government subsidizes premiums for crop insurance in the US. Coble and Heifner (1998) modeled farmer decisions, assuming they maximized expected utility defined over end-of-season wealth, to examine optimal combinations of positions in price futures and in insurance contracts. They appraised four insurance designs and found that the existence of insurance products tended to reduce the optimal hedging positions, but did not drive them to zero.

A criticism of the foregoing literature is that it is weak in explaining why different classes of firms have different hedging levels. For example, many farmers never hedge in futures or options markets (citations below), implying that the portfolio models do not correctly characterize firms' objective functions. Collins (1997) argued that risk should be conceptualized as avoiding financial failure, not as 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 . . ." Indeed, introducing the costs of hedging into the objective function greatly reduces the magnitude of the risk-minimizing hedge. In various studies, the costs analyzed have varied, but have included transaction costs, tax effects, and the risk of using suboptimal estimates of hedge levels (Arias, Brorsen, & Harri, 2000; Brorsen, 1995; Lence, 1995).

A broader conceptualization of farmers' portfolios also suggests that the specification of objective functions should take account of income from off-farm jobs, returns from nonfarm investments, government payments, and the possible diversity of commodities produced on the farm (e.g., Arias et al., 2000). Most model specifications, however, take an incremental approach to analyzing such factors. For example, Adam, Betts, and Brorsen (2000) considered the effect of government deficiency payments on marketing strategies for wheat, where the marketing strategies included the use of futures and options contracts, as well as cash-marketing (storage) alternatives. The literature also contains analyses of hedges of multiple commodities, but typical applications involved related commodities like soybeans, soybean meal, and soybean oil, or live cattle, feeder cattle, and grain contracts in the cattle-feeding industry (e.g., Collins, 2000, and references therein).

To summarize, the objective functions of individual farmers are potentially complex and difficult to specify appropriately. In principle, farmers 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.

Implementing the Framework—The Devil Is in the Details

Next, we turn to problems of 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, (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 & Markowitz, 1979), 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? What marketing alternatives should be considered? How should random variables be measured?[3] Furthermore, as noted previously, introducing the costs of using futures markets reduces the size of the minimum variance hedge, although Brorsen (1995) showed that when the assumption of costless hedging was dropped, highly-leveraged firms hedged more than less-leveraged firms (also see Arias et al., 2000).

Even if the model is correctly specified, the analyst still must estimate 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 (Myers & Thompson, 1989). 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 & Fackler, 1994). Nonetheless, such time-varying covariance estimation is costly and often does not result in greater hedging effectiveness relative to unconditional hedge ratios (Garcia, Roh, & Leuthold 1995; Myers, 1991).[4]

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, & Subramanian, 1990, and references therein). Thus, even if we have a correct model (objective function), sampling error is associated with the estimates of the parameters,

[3]The use of the price level, the price change, or the percentage price change makes a difference in estimates of optimal hedges (e.g., Kahl, 1986; Witt, Schroeder, & Hayenga, 1987).
[4]Another literature, which again we do not survey, deals with measuring risks and returns from marketing strategies that use options (on futures) contracts (e.g., Hauser & Eales, 1986).

and hence estimates of the optimal portfolios should not be treated as certain. Applications rarely make this point (but see Lence, 1995). In addition, it should be noted that subjective distributions of returns held by managers need not correspond to empirical distributions.

Marketing Choices and Factors Affecting Choices

Empirical results in the older literature implied that optimal hedges are large in relation to the cash position, but the majority of farmers have not used futures or options markets. Moreover, those who have used them appeared to have taken positions that were smaller than those implied by estimates of optimal-size hedges. Recent evidence suggests that this—the limited use of futures and options—continues to be true (Goodwin & Schroeder, 1994; Harwood et al., 1999, pp. 59f; Heifner, Wright, & Plato, 1993; Patrick, Musser, & Eckman, 1998).

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 now are 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 roll over positions from maturing to more distant contracts (Gardner, 1989).

Most farmers appear to have relatively simple marketing programs. Sixty-two percent of Kansas grain producers marketed their crops three or fewer times (Goodwin & Kastens, 1996). The mode was two times per year. Goodwin and Kastens found that increased specialization led to increased marketing frequency, that older farmers marketed less often than did younger farmers, and that capital constraints caused producers to market less often. Interestingly, producers' risk attitudes appeared to have little effect on their frequencies of marketing (Goodwin & Kastens, 1996, p. 584). These Kansas farmers apparently did not view frequency of marketing as a way of managing risk.

Consistent with older studies, Goodwin and Schroeder (1994) 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., 1999, 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 (Goodwin & Schroeder, 1994; Harwood et al., 1999).

Participation in educational marketing programs significantly increased farmers' adoption of forward-pricing strategies (Goodwin & Schroeder, 1994). 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 also is in line with a perception that farmers think of hedging in futures as a way to increase income 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 use forward-pricing methods more often than the average farmers represented by random samples of producers (Patrick et al., 1998). However, 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 relates to whether or not farmers are risk averse. About 15 years ago, Tauer (1986) 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 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 identical objectives, then the question becomes, which is the least cost alternative? If forward contracts are the least cost alternative for the majority of farmers, this helps explain their preference for them. Brorsen, Coombs, and Anderson (1995) estimated that the cost of forward-contracting hard red winter wheat ranges from two to seven cents per bushel; the estimates varied with the length of time to delivery (and also depended on the estimation method). The equivalent cost of hedging in futures was two cents per bushel. These authors concluded, ". . . 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)." The Brorsen et al. (1995) conclusion is consistent with the observed behavior of farmers, but in another study, Townsend and

Brorsen (2000) placed more weight on the relatively high cost to farmers of forward contracting. So far as we know, these studies (and others) did not impute a cost of default risk, which would be essentially zero for futures contracts, but not for forward contracts.

Linkages and Data Availability

The problem of doing useful analyses is 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.[5] 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.

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 programs have, however, been developed to teach agricultural marketing tools to students and producers (e.g., Trapp, 1989; HedgeSim program developed by the University of Illinois, http://w3.ag.uiuc.edu/ACE/ofor/hedgesim/hsim3.htm; Marketeer program developed by University of Minnesota and Country Hedging, Inc., http://www.countryhedging.com/marketeer/default.htm). These potentially are valuable for research purposes when programs require farm-level marketing information, and thus, create databases that may aid marketing strategy evaluations. King, Lev, and Nefstead (1995) reported development of a position format, used in an educational program for

[5]The reliability of cash-price reports probably is declining. Transactions in cash markets always have reflected diverse attributes (terms of trade); with the passage of time, there has been a decline in the number of observable, market transactions. This stands in contrast to spot prices available in financial markets, and the potentially low quality of spot prices in commodity markets perhaps has been over-looked as a possible problem in estimating optimal portfolios.

farm-level marketing management, that 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 & Irwin, 1996)?

PERFORMANCE OF MARKETING STRATEGIES

Many research projects have attempted to estimate the 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, which seems less common now than it was 10 to 20 years ago, tends to emphasize comparisons of *mean* returns from various strategies.

A study of postharvest marketing of grain sorghum in a coastal region of Texas, using data from 1972 through 1981, illustrates earlier research on cash-market-only strategies for one grain in one region (Rister, Skees, & Black, 1984). 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.[6] 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. Not surprisingly, Rister et al. (1984) 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 ranked strategies by using stochastic dominance, that is, by considering riskiness of choices, and they argued that outlook information was useful to many, but not all, decision-makers.

Regions with relatively 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 & Binkley, 1995). Another line of research indicates that taxes are an important issue in grain-storage decisions (Tronstad & Taylor, 1991;

[6]It should be noted that many empirical studies use commercial storage charges and do not impute an opportunity cost.

McNew & Gardner, 1999). Thus, optimal cash-marketing strategies are likely to 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. For example, dairy farmers receive two milk checks per month, 24 per year.

Another way to diversify is by using futures markets to make preharvest (preproduction) sales of a commodity. Routine preharvest hedging of growing crops in futures probably can reduce the variance of returns (Zulauf et al., 1999). This occurs, however, at some cost of hedging, and with yield risk, the optimal preharvest 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 (1989) found that sequential rollovers yielded the same expected returns as cash sales and had little effect on the variability of returns. He suggested that rollovers could lock-in a price for a given *n*-year period (when this appears desirable), but this conclusion was based on the assumption that the year-to-year basis in futures would be a constant. In fact, relative prices for different maturities can change, with disastrous results for forward contracts with rollover provisions (Lence & Hayenga, 2001).

Can derivative markets be used to raise average returns? The answer remains a subject of debate. Research by Wisner et al. (1998), discussed above, found that preharvest use of futures and/or options market strategies could increase average returns for corn and soybeans in relation to sales at harvest or thereafter. In a similar vane, preharvest forward contracting has been found to increase returns in relation to harvest-time sales (e.g., Kolajo, Hurst, & Martin, 1988). However, a study in South Dakota comparing preharvest with harvest-time marketing found that the mean and variance of returns depended on location (Tennyson, 1996). A problem in these comparative studies is the difficulty of including the full costs and risks of the alternatives; that is, are the comparisons truly valid?

Rather than storing grain unhedged, it is 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, 1966). 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, 1966; Kastens & Dhuvetter, 1999).

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 (1967) called this the price of feedlot services, which is analogous to a price of storage. Peterson and Leuthold (1987) found that cattle feeders could reduce risk and also lock-in returns when favorable prices occur, but Kee and Kenyon (1999) questioned the value of futures markets in assuring profit margins for hog producers because of the basis risk associated with the use of futures.

Farmers can purchase the services of marketing advisers. The advice can be viewed as a recommended portfolio for the given grain, covering preharvest through postharvest alternatives that typically involve the use of forward contracts, futures contracts, and options contracts. One result, as noted above, is that the net prices for corn and soybeans, from the various advisers, have a wide range and that the advisers' performances are rarely consistent from year to year (Irwin et al., 2000).

Harrison, Bobst, Benson, and Meyer (1996) compared the profitability and risk-management properties of grazing contracts to futures and option contracts for backgrounding (or stocking) 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 found that, in general, pasture owners preferred grazing contracts to integrated production and marketing using traditional hedging strategies to manage price risk. The hedging strategies yielded negative net returns on average.

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 et al., 1999). The results suggested that farmers participated in the insurance program mainly to receive the associated subsidy or because of adverse selection. The risk-aversion incentive was small. While this empirical analysis was not directly related to marketing strategies, it was another piece of evidence that raised 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 consistent with theoretical predictions. No magic formula exists for increasing average returns. Strategies exist to manage risk, but these strategies have costs. The benefits in relation to costs of the alternative strategies are not understood fully 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? Should questions be framed in terms of price, revenue, or income risk? Analyses of marketing programs are conditioned necessarily by the objectives that the programs are expected to accomplish.

A related issue is the economic context and environment faced by the firm. What is the firm's equity? What is the importance of nonfarm sources of income? Etc. Clearly, firms vary in their tolerance of risk, and this, in turn, can influence risk-management strategies. Thus, it is important to specify more-realistic objective functions, both for conceptual and empirical analyses. However, increased reality implies increased complexity. If the objective is to consider a "global" risk-management strategy for a firm, then research should give more attention to the question of the effects of "separability" of marketing decisions. What are the consequences of analyzing alternative marketing strategies for corn without simultaneously considering strategies for soybeans? What are the implications of introducing off-farm income into the analysis?

In this context, it is important to have accurate measures of risks and returns. The issue is both the overall income risk faced by farmers and the riskiness of individual enterprises. As Collins (1997) suggested, the choice of the risk measure—the variance of returns from one crop versus the probability of a deviation in income that would result in bankruptcy—makes a large difference in the decision of whether or not to hedge, and the sensitivity of results to these choices deserves further analysis. Value at risk (VaR) is a procedure for specifying the minimum amount of money a firm could expect to lose with a given probability over a specified period, and is a concept used in nonfarm businesses. Perhaps it has a wider applicability to farm businesses (see Manfredo & Leuthold, 1999).

As noted earlier, however, it has proven difficult to obtain good empirical models of prices and yields that are relevant for decision-makers. To evaluate marketing programs using probability-distribution techniques, high quality estimates are needed of the moments of conditional probability distributions of prices of the spot commodity and of their derivative instruments. If, for example, the choice set includes storage and postharvest sales, then the decision-maker requires information about changes in the mean, variance, and skewness of price distributions as time passes. Moreover, the distributions likely are conditional on such factors as the size of inventories. That is, the magnitudes and probabilities of risks faced by producers can vary from one crop year to the next, and consequently questions—such as whether or not to store—and the degree to which to use futures and options markets are conditioned by circumstances. Research, therefore, should strive to improve measures of price (and yield) risk.

Analyses for livestock and for tree crops are especially complex. This is because the modeling of the life-cycle effects, which influence prices, adds another dimension to the problem. For example, a reasonable hypothesis about why the hog cycle has persisted over many decades is that the difficulty of making precise forecasts of changes in prices makes taking counter-cyclical actions risky (costly). Sarmiento and Allen (2000) illustrated the difficulty of estimating supply responses in the livestock sector.

A similar case can be made for estimating yield risk. The critique of Just and Weninger (1999), discussed earlier, is apt. Improving technology and management influences the yields of most agricultural commodities, 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 understood better. The issue is complicated further by farmers having more choices about the particular varieties of commodities they can produce and that can have different trends in yields and different levels of risk.

Controversy persists about the efficiency of various derivative markets for commodities; this controversy relates to the question of whether marketing strategies exist that can provide producers with speculative profits. The evidence suggests that, on the one hand, some farmers perceive "hedging," by using futures contracts, as a way to increase returns, but, on the other hand, that these strategies do not improve consistently returns relative to simple alternatives like selling the entire crop at harvest. There continues to be an inconsistency between academic research that finds relatively efficient markets and the beliefs of some farmers and marketing advisers that the mean of returns can be raised by speculative strategies.

Economists 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, but we doubt that academic researchers are likely to find models or other information that can be exploited profitably by producers.

The discussion of efficiency, however, should be separated from analyses of the use of derivatives to price production, merchandising, and storage returns. In principle, futures and options more-or-less can be used to assure profitable storage (production, etc.) in those years in which profitable relative prices exist. Research to support these decisions includes forecasts of both basis relationships and 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.

Furthermore, a full analysis of marketing alternatives 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 costs of storage—especially the opportunity costs associated with the price level and interest rates that are not constant—should be estimated. Likewise, forward contracting is popular with farmers, but the limited evidence suggests that forward contracting is relatively costly. Still, farmers' preferences for forward contracts over futures contracts suggest that they believe 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). In addition, do farmers' calculations perhaps ignore costs, such as the risk of default on forward contracts? Notable defaults have occurred.

What can academics reasonably do? We are poorly equipped to give specific marketing advice to individual farmers, nor should we. 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 face necessarily 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, but we need to guard against overpromising what marketing programs can accomplish, especially in terms of improving net returns.

Past research has tended to look at relatively few alternatives with simple models and perhaps has been naïve about our ability to model price behavior. Since depicting reality in its entirety is not feasible, simplification is inevitable, and 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.

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