Managing Risk in Farming: Concepts, Research, and Analysis.
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Abstract

The risks confronted by grain and cotton farmers are of particular interest,
given the changing role of the Government after passage of the 1996 Farm
Act. With the shift toward less government intervention in the post-1996
Farm Act environment, a more sophisticated understanding of risk and
risk management is important to help producers make better decisions in
risky situations and to assist policymakers in assessing the effectiveness of
different types of risk protection tools. In response, this report provides a
rigorous, yet accessible, description of risk and risk management tools and
strategies at the farm level. It also provides never-before-published data
on farmers' assessments of the risks they face, their use of alternative risk
management strategies, and the changes they would make if faced with
financial difficulty. It also compares price risk across crops and time peri-
ods, and provides detailed information on yield variability.

Keywords: Crop insurance, diversification, futures contracts, leasing,
leveraging, liquidity, livestock insurance, marketing contracts, options con-
tracts, production contracts, revenue insurance, risk, vertical integration.

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Summary

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Risk is uncertainty that affects an individual's welfare, and is often associated with adversity and loss. There are many sources of risk in agriculture, ranging from price and yield risk to the personal risks associated with injury or poor health. In dealing with risky situations, risk management involves choosing among alternatives to reduce the effects of the various types of risk. It typically requires the evaluation of tradeoffs between changes in risk, changes in expected returns, entrepreneurial freedom, and other variables.

Several surveys have been conducted asking about the types of risk most important to farmers. These surveys reach similar conclusions. A 1996 USDA survey, for example, indicates that producers are most concerned about changes in government laws and regulations (institutional risk), decreases in crop yields or livestock output (production risk), and uncertainty in commodity prices (price risk). In general, producers of major field crops tend to be more concerned about price and yield risk, while livestock and specialty crop growers are relatively more concerned about changes in laws and regulations.

While concerns about risk vary across types of producers, other factors are also important in determining the risk inherent in a producer's situation. Yield risk, for example, varies regionally, and depends on soil type, climate, the use of irrigation, and other variables. Yield risk tends to be low in California, where irrigation is widespread, and higher in dryland producing areas in the Great Plains. In contrast to yield risk, price risk for a given commodity tends not to vary geographically, and depends on such factors as commodity stock levels and export demand.

Farmers have many options in managing agricultural risks. They can adjust the enterprise mix (diversify) or the financial structure of the farm (the mix of debt and equity capital). In addition, farmers have access to many tools—such as insurance and hedging—that can help reduce their farm-level risks. Off-farm earnings are a major source of income for many farmers that can help stabilize farm household income. Indeed, most producers combine the use of many different strategies and tools.

Because farmers vary in their attitudes toward risk, risk management cannot be viewed within a "one size fits all" approach. That is, it is not wise to say that "All Midwestern corn farmers should hedge 50 percent of their crop in futures," or that "No farmer should

plan to obtain more than two-thirds of his or her income from a single commodity." Different farmers confront different situations, and their preferences toward risk and their risk-return tradeoffs have a major effect on decisionmaking in each given situation. A large, industrialized operation, for example, may hire marketing expertise to directly use hedging and options, while a smaller farmer may prefer to forward contract with other parties better able to hedge directly.

Although farmers in similar situations can differ greatly in their response to risk, surveys provide an overall view of producer choices. The results of a 1996 survey, conducted shortly after passage of the 1996 Farm Act, indicate that operators in the largest gross income categories (more than $250,000 annually) are more likely to use virtually all risk management strategies than small-scale operators. Keeping cash on hand for emergencies and good buys was the number one strategy for every size farm, for every commodity specialty, and in every region.

Evaluating the effectiveness of different strategies and tools requires an understanding of the risk-return tradeoffs of individual producers. Several major points can be made, however, that generally apply to risk management. Most of the tools discussed in this report tend to reduce intrayear income uncertainty, but may have only small or negligible effects on multiyear uncertainties. In addition, some strategies—such as the combined use of insurance and forward pricing—tend to complement each other in reducing risks.

In short, understanding risk in farming is important for several reasons. First, most producers are averse to risk when faced with risky outcomes. Someone who is risk averse is willing to accept a lower average return for lower uncertainty, with the tradeoff depending on the person's level of risk aversion. Thus, strategies cannot be evaluated solely in terms of average or expected return, but also must consider risk. Second, understanding risk helps farmers and others develop strategies for mitigating the possibility of adverse events, and aids in circumventing extreme outcomes, such as bankruptcy.

Summary

Managing Risk in Farming

Concepts, Research, and Analysis

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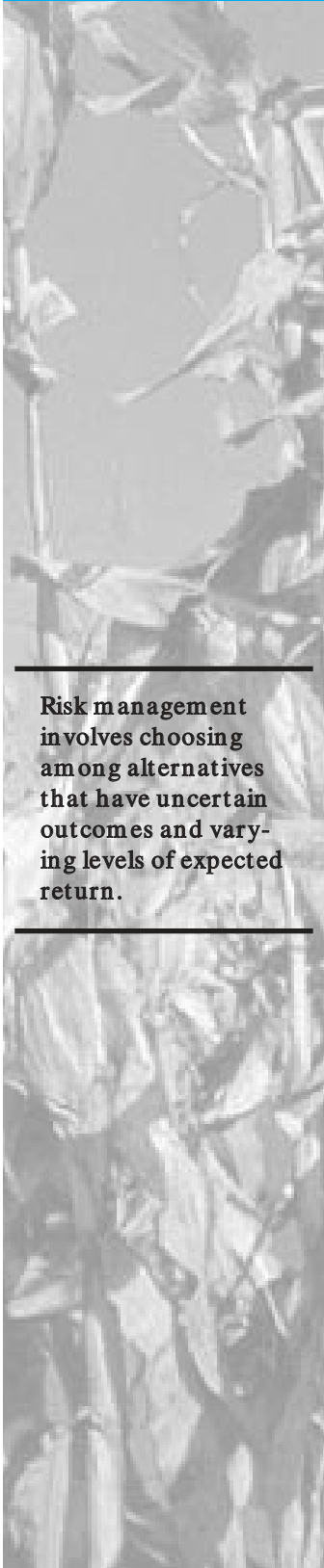
Farming is a financially risky occupation. On a daily basis, farmers are confronted with an ever-changing landscape of possible price, yield, and other outcomes that affect their financial returns and overall welfare. The consequences of decisions or events are often not known with certainty until long after those decisions or events occur, so outcomes may be better or worse than expected. When aggregate crop output or export demand changes sharply, for example, farm prices can fluctuate substantially and farmers may realize returns that differ greatly from their expectations.

The risks confronted by grain and cotton farmers are of particular interest given the changing role of the Government after passage of the 1996 Farm Act. The Act eliminated deficiency payments which, between 1973 and 1995, provided program crop producers with price and income support in years of low prices. Now, participating crop producers instead receive contract payments, which are fixed amounts scheduled to decline over time between 1996 and 2002. Unlike deficiency payments, these contract payments do not vary inversely with market prices. The 1996 Farm Act also eliminated annual supply management programs, providing producers with the flexibility to plant any crop (with certain restrictions for fruits and vegetables) on any acre. The Act also reduced government intervention in dairy markets.

This shift toward less government intervention in the post-1996 Farm Act environment creates a need for a more sophisticated understanding of risk and risk management. In response, this report provides a rigorous, yet accessible, description of risk and risk management tools and strategies. It describes risk at the farm level, examining situations facing individual producers. It is designed for risk program managers, extension educators, farmers and other business people, and others interested in risk and risk management issues. Understanding risk is a key element in helping producers make better decisions in risky situations, and also provides useful information to policymakers in assessing the effectiveness of different types of risk protection tools.

What Is Risk?

Risk is the possibility of adversity or loss, and refers to "uncertainty that matters." Consequently, risk management involves choosing among alternatives to reduce the effects of risk. It typically requires the evaluation of tradeoffs between changes in risk, expected returns, entrepreneurial freedom, and other variables. Understanding risk is a starting point to help producers make good management choices in situations where adversity and loss are possibilities.

Risk management involves choosing among alternatives that have uncertain outcomes and varying levels of expected return.

Risk is uncertainty that affects an individual's welfare, and is often associated with adversity and loss (Bodie and Merton). Risk is uncertainty that "matters," and may involve the probability of losing money, possible harm to human health, repercussions that affect resources (irrigation, credit), and other types of events that affect a person's welfare. Uncertainty (a situation in which a person does not know for sure what will happen) is necessary for risk to occur, but uncertainty need not lead to a risky situation.

For an individual farmer, risk management involves finding the preferred combination of activities with uncertain outcomes and varying levels of expected return. One might say that risk management involves choosing among alternatives for reducing the effects of risk on a farm, and in so doing, affecting the farm's welfare position. Some risk management strategies (such as diversification) reduce risk within the farm's operation, others (such as production contracting) transfer risk outside the farm, and still others (such as maintaining liquid assets) build the farm's capacity to bear risk. Risk management typically requires the evaluation of tradeoffs between changes in risk, expected returns, entrepreneurial freedom, and other vari-

ables. The following examples illustrate risk management in farming and the types of tradeoffs faced by farmers:

- *Enterprise Diversification*— Consider Farmer Smith, who is debating the most appropriate enterprise mix on his operation. In particular, Smith is contemplating switching 200 acres from corn to soybeans within his existing operation of corn, hay, and dairy. By adding this new crop, Smith is less at risk that the farm will generate low revenue because, in his location, income from soybeans is less variable than income from corn, and because individual commodity returns do not move exactly in tandem (they are less than perfectly correlated). Smith must consider this risk reduction against the expected net returns associated with the new enterprise, weighing any potential decline in net returns against the lower income variability that he believes will be provided by such an additional crop.

- *Crop Insurance*—Consider Farmer Jones, who farms where the potential for drought is a constant worry and yield variability is high. Jones can purchase insurance to cover a large portion of the potential loss, or can self-insure and absorb any

losses caused by low yields. In investigating the purchase of crop insurance, he finds that the annual premium is quite high due to the significant yield variability in his area. As a result, Farmer Jones must consider the risk-return tradeoffs in deciding whether or not to purchase insurance and, if he decides to buy insurance, the level of coverage that best suits his risk management needs.

- *Production Contracting*— Consider Farmer Johnson, who is considering whether to enter into a production contract with a large broiler integrator. The integrator retains control over the chicks as they are raised by the producer, and prescribes specific feeds, other inputs, and special management practices throughout the production cycle. In return for handing over management decisions, the producer's income risk is greatly reduced, market access is guaranteed, and access to capital is ensured. Johnson must weigh these potential benefits against his reduced entrepreneurial freedom and the risk of contract termination on short notice.

As can be seen through these illustrations, managing risk in agriculture does not necessarily involve avoiding risk, but instead, involves finding the best available combination of risk and return given a person's capacity to withstand a wide range of outcomes (Hardaker, Huirne, and Anderson). Effective risk management involves anticipating outcomes and planning a strategy in advance given the likelihood and consequences of events, not just reacting to those events after they occur. That is, the four main aspects of risk management involve (1) identifying potentially risky events, (2) anticipating the likelihood of possible outcomes and their consequences, (3) taking actions to obtain a preferred combination of risk and expected return, and (4) restoring (if necessary) the firm's capacity to implement future risk-planning strategies when distress conditions have passed (Hardaker, Huirne, and Anderson; Patrick; Barry).

Because farmers vary in their attitudes toward risk and their ability to address risky situations, risk management cannot be viewed within a "one size fits all" approach. That is, it is not wise to say that "All midwestern corn farmers should hedge 50 percent of their crop in futures," or that "No farmer should plan to obtain more than two-thirds of his or her income from a single commodity." Different farmers confront different situations and structural characteristics, and as explained in this report, their preferences toward risk and their risk-return tradeoffs have a major effect on decision-making in each given situation. A large, industrialized operation, for example, may hire marketing expertise to directly use hedging and options, while a small family farm may prefer to forward contract with other parties better able to hedge directly.

Understanding risk in farming is important for two reasons. First, most producers are averse to risk when faced with risky outcomes. Someone who is risk averse is willing to accept a lower average return for lower uncertainty, with the tradeoff depending on the person's level of risk aversion. This means that strategies cannot be evaluated solely in terms of average or expected return, but that risk must also be considered. Second, identifying sources of uncertainty helps farmers and others address the most important strategies for mitigating risk, and aids in circumventing extreme outcomes, such as bankruptcy.

Because farmers vary in their attitudes toward risk and their ability to address risky situations, risk management cannot be viewed within a "one size fits all" approach

Types of Risk Most Important to Producers

A 1996 USDA survey indicates that producers are most concerned about changes in government laws and regulations (institutional risk), decreases in crop yields or livestock output (production risk), and uncertainty in commodity prices (price risk). In general, producers of major field crops tend to be more concerned about price and yield risk, while livestock and specialty crop growers are relatively more concerned about changes in laws and regulations.

According to a 1996 USDA Survey, producers of major field crops are generally more concerned about price and yield variability than any other category of risk.

Several surveys have asked farmers about the most important types of risk that they confront in their farming operations. These types of questions are typically part of a larger survey that inquires about producers' risk management strategies, and offers respondents a list of concerns that they can score in terms of importance. Scores generally are not ranked relative to one another, meaning that producers independently analyze each concern on the list.

In 1996, USDA's Agricultural Resource Management Study[1] (ARMS), a nationwide survey of farm operators, questioned farmers as to their degree of concern about factors affecting the operation of their farms. The ARMS is probability-based, and results can be expanded to reflect the U.S. farm sector. The concerns cited in the survey varied from "uncertainty in commodity prices" to "ability to adopt new technology." Mean scores for each concern were estimated by assigning a value to each measure of importance, with "not concerned" receiving a value of 1.00 and "very concerned" receiving a value of 4.00.

Wheat, corn, soybean, tobacco, cotton, and certain other producers

[1]The ARMS survey was formerly known as the Farm Costs and Returns Survey (FCRS).

answering the survey were more concerned about yield and price variability than any of the other categories (table 1). This may be partly due to the 1996 Farm Act, which greatly reduced government intervention in markets for program crops (wheat, corn, cotton, and other selected field crops), and may have heightened producers' wariness concerning price risk. Producers of other field crops, nursery and greenhouse crops, beef cattle, and poultry were relatively more concerned about changes in laws and regulations, perhaps reflecting trepidation about changes in environmental and other policies. Across all farms, the ARMS results indicate that producers' degree of concern was greatest regarding changes in government laws and regulations (with a score of 3.02), decreases in crop yields or livestock production (with a score of 2.95), and uncertainty regarding commodity prices (with a score of 2.91).

Other surveys have also examined producers' risk perceptions, most often focusing on crop production in specific geographic areas. These other surveys, despite the limited location and time period of the analysis, generally support the ARMS findings that price and yield risk are the most important concerns facing producers of major field crops. One of the most comprehen-

Table 1—Farmers' degree of concern about factors affecting the continued operation of their farms

How concerned are you about each factor's effect on the continued operation of your farm?	Other cash grains	Wheat	Corn	Soybeans	Tobacco	Cotton	Other field crops	Fruit/nuts	Vegetables	Nursery/greenhouse	Beef	Hogs	Poultry	Dairy	Other livestock	All farms
										Mean scores [1]						
Decrease in crop yields or livestock production	3.35	3.51	3.2	2.98	3.16	3.68	2.53	3.05	2.85	2.78	3.09	3.53	3.20	3.4	2.41	2.95
Uncertainty in commodity prices	3.41	3.83	3.4	2.93	3.15	3.75	2.48	2.88	2.82	2.63	2.96	3.31	3.09	3.54	2.47	2.91
Ability to adopt new technology	2.52	2.38	2.39	2.33	2.21	2.77	1.92	2.34	2.09	2.24	2.25	2.63	2.60	2.45	2.12	2.23
Lawsuits	2.43	2.47	2.03	2.46	1.89	2.78	2.07	2.39	2.66	2.06	2.36	2.70	2.32	2.36	2.00	2.26
Changes in consumer preferences for agricultural products	2.65	2.55	2.39	2.40	2.40	2.86	2.13	2.44	2.59	2.69	2.58	3.01	2.79	2.76	2.30	2.47
Changes in Government laws and regulations	3.31	3.36	3.15	2.79	2.77	3.54	2.88	2.97	2.75	3.09	3.03	3.23	3.34	3.31	2.88	3.02

[1] 1 = Not concerned, 2 = Slightly concerned, 3 = Somewhat concerned, 4 = Very concerned.

Source: Perry, Janet, editor, "Adaptive Management Decisions--Responding to the Risks of Farming," unpublished working paper, U.S. Dept. Agr., Econ. Res. Serv., December 1997.

sive studies of producers' attitudes toward risk was conducted in 1983 at a land-grant university (Patrick and others, 1985). This survey, covering 12 States, was designed to elicit the most important types of variability faced by farmers and to determine the importance of different types of variability across different regions. Weather and output prices were cited as the most important sources of crop risk, regardless of location. Producers also marked inflation, input costs, diseases and pests, world events, and safety and health as other important sources of risk.

Interesting differences, however, appeared by farm-type grouping. For example, farmers in the Southeast, where mixed (crop and livestock) farming is important, and corn, soybean, and hog producers in the Midwest, gave less importance to variability from commodity programs than did cotton or small grain growers. Midwestern corn, soybean, and hog producers gave much greater importance to family plans as a source of variability than did the other farm-type groups.

Producers' circumstances also affected perceptions of risk in the

1983 Patrick survey. Using a slightly different sample than above, Patrick found that the greater the debt-to-asset ratio, the greater the importance given to risks associated with the cost of credit on crop farms. Risks associated with hired labor increased in importance as farm size increased. The producer's level of education appeared to be relatively unimportant in influencing the importance given to different sources of variability (Patrick).

More recently, participants in Purdue's 1991 and 1993 Top Farmer Crop Workshops were questioned about their attitudes toward farm risks. They rated crop price and crop yield variability as the top sources of risk in 1991, but ranked them second and third in 1993 (Patrick and Ullerich; Patrick and Musser). Concern about injury, illness, or death of the operator was the highest rated source of risk in 1993, significantly higher than in 1991 (table 2). The importance of changes in government environmental regulations, land rents, and technology also increased significantly between 1991 and 1993. Respondents did not give much importance to livestock price or pro-

> Farmers participating in a 1993 Purdue Workshop rated injury, illness, or death of the operator as the highest rated source of risk, followed by crop price and yield variability.

duction variability, likely reflecting the limited importance of this enterprise on their operations.

Other surveys of producers in the Midwest and Great Plains have found similar results. Farmers and ranchers in Nebraska indicated in the mid-1990's that output price risk and yield risk were the most important sources of risk (Jose and Valluru). On a 1-10 scale, the respondents rated output price fluctuations (6.07), input price fluctuations (5.98), and drought (5.73) as the most important sources of risk. Although hail damage was rated high in importance (6.58), the number of farmers who selected hail as the most important risk factor was low. Survey research focusing on Kansas lender-to-farming risks has provided similar findings (Mintert).

When California growers were questioned, important regional variations appeared. A 1992/93 survey of 569 California growers, which used a ranking scheme similar to the ones in the Patrick studies,

reveals that output risks are secondary to price risks among growers in that State (Blank, Carter, and McDonald). These growers ranked output price and input costs as first and second, respectively, among their risk concerns. These results largely reflect the low yield risk faced in California in most situations, due largely to the widespread use of irrigation.

Because of the apparent importance of yield and output price risk to many producers, particularly in the Midwest and Great Plains, these two risks are the focus of the following section, which examines the measurement of risk. Disaggregate (farm- and county-level) data are available to measure the price and yield risk confronted by producers across the country. Thus, the following section quantifies the price and yield risks for producers in different locations, using corn as an example crop.

> In California, where the use of irrigation is common, output risks are secondary to price risks among growers.

Table 2—Mean and standard deviation of importance ratings of sources of risk by Top Farmer Crop Workshop participants, 1991 and 1993[1]

Sources of risk	1991 (n = 80)		1993 (n = 61)	
	Mean	Standard deviation	Mean	Standard deviation
Changes in government commodity programs	3.83	1.08	3.66	1.03
Changes in environmental regulations	3.81	1.03	4.13**	.78
Crop yield variability	4.21	.91	4.13	.78
Crop price variability	4.31	.87	4.16	.86
Livestock production variability[2]	2.86	1.40	2.68	1.34
Livestock price variability[2]	3.17	1.54	2.75	1.37
Changes in costs of current inputs	3.70	.89	3.89	.84
Changes in land rents	3.18	1.16	3.56**	.96
Changes in costs of capital items	3.66	.94	3.77	.82
Changes in technology	3.54	1.03	3.84*	.97
Changes in interest rates	3.48	1.09	3.52	1.09
Changes in credit availability	3.05	1.29	3.21	1.23
Injury, illness, or death of operator	3.86	1.30	4.39**	.94
Family health concerns	--	--	4.05	.91
Changes in family relationships	3.36	1.42	3.73	1.29
Changes in family labor force	2.96	1.28	3.11	1.25

-- = Not applicable. n = Number. * The difference between years is statistically significant at the 10-percent confidence level. ** The difference between years is statistically significant at the 5-percent level.

[1] 1 = Not important; 5 = Very important. [2] In 1991, only 65 and 66 of 80 farmers responded to the livestock production and price variability questions. Had the nonrespondents been coded as a 1 (not important), the means would have been 2.50 and 2.79 for livestock production and price variability, respectively.

Source: Excerpted by ERS from Patrick, George F., and Wesley N. Musser, *Sources of and Responses to Risk: Factor Analyses of Large-Scale Cornbelt Farmers*. Staff Paper No. 95-17, West Lafayette, IN: Purdue University, Department of Agricultural Economics, December 1995.

Sources of Risk in Farming

Some risks are unique to agriculture, such as the risk of bad weather significantly reducing yields within a given year. Other risks, such as the price or institutional risks discussed below, while common to all businesses, reflect an added economic cost to the producer. If the farmer's benefit-cost tradeoff favors mitigation, then he or she will attempt to lower the possibility of adverse effects. These risks include the following (Hardaker, Huirne, and Anderson; Boehlje and Trede; Baquet, Hambleton, and Jose; Fleisher):

Production or yield risk occurs because agriculture is affected by many uncontrollable events that are often related to weather, including excessive or insufficient rainfall, extreme temperatures, hail, insects, and diseases. Technology plays a key role in production risk in farming. The rapid introduction of new crop varieties and production techniques often offers the potential for improved efficiency, but may at times yield poor results, particularly in the short term. In contrast, the threat of obsolescence exists with certain practices (for example, using machinery for which parts are no longer available), which creates another, and different, kind of risk.

Price or market risk reflects risks associated with changes in the price of output or of inputs that may occur after the commitment to production has begun. In agriculture, production generally is a lengthy process. Livestock production, for example, typically requires ongoing investments in feed and equipment that may not produce returns for several months or years. Because markets are generally complex and involve both domestic and international considerations, producer returns may be dramatically affected by events in far-removed regions of the world.

Institutional risk results from changes in policies and regulations that affect agriculture. This type of risk is generally manifested as unanticipated production constraints or price changes for inputs or for output. For example, changes in government rules regarding the use of pesticides (for crops) or drugs (for livestock) may alter the cost of production or a foreign country's decision to limit imports of a certain crop may reduce that crop's price. Other institutional risks may arise from changes in policies affecting the disposal of animal manure, restrictions in conservation practices or land use, or changes in income tax policy or credit policy.

Farmers are also subject to the ***human or personal risks*** that are common to all business operators. Disruptive changes may result from such events as death, divorce, injury, or the poor health of a principal in the firm. In addition, the changing objectives of individuals involved in the farming enterprise may have significant effects on the longrun performance of the operation. *Asset risk* is also common to all businesses and involves theft, fire, or other loss or damage to equipment, buildings, and livestock. A type of risk that appears to be of growing importance is *contracting risk*, which involves opportunistic behavior and the reliability of contracting partners.

Financial risk differs from the business risks previously described in that it results from the way the firm's capital is obtained and financed. A farmer may be subject to fluctuations in interest rates on borrowed capital, or face cash flow difficulties if there are insufficient funds to repay creditors. The use of borrowed funds means that a share of the returns from the business must be allocated to meeting debt payments. Even when a farm is 100-percent owner financed, the operator's capital is still exposed to the probability of losing equity or net worth.

The sources of risk in agriculture range from price and yield risk to financial and contracting risk.

Types of Risk Most Important to Producers

Measuring Price and Yield Risk

Price and yield risk, the most important types of risk faced by many producers, have interesting characteristics. Yield risk varies regionally and depends on soil type, climate, the use of irrigation, and other variables. In contrast, price risk for a given commodity depends on such factors as commodity stock levels and export demand. As illustrated below, crop prices tend to be more volatile than livestock prices, reflecting the yield risk inherent in crop production. For a more detailed understanding of risk measurement and how historical information can be used to estimate future risk, see appendix 1.

Yield variability is higher at the farm level than at the State or national level.

Yield Randomness Varies Regionally

Yield variability for a given crop differs geographically and depends on soil type and quality, climate, and the use of irrigation. Yield variability is often measured by an indicator known as the "coefficient of variation," which measures randomness relative to the mean (or average) value in the yield series. Using this measure, variability in corn yields, for example, ranges from about 0.2 to about 0.4 across U.S. farms (fig. 1). These estimates were obtained by combining 10 years of individual farm-level yield observations (obtained from USDA's Risk Management Agency (RMA) records) with longer series of county yield observations from USDA's National Agricultural Statistics Service (NASS).[2]

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[2]Yield variances were estimated by county for 1995 by regressing 1956-95 NASS yields on time using a generalized least squares estimator, which corrected for yield heteroscedasticity. Variances of differences between farm yields and NASS county yields were estimated for all farms in the RMA records using 1985-94 observations for the two data sets. Farm yield variances by county were estimated as the sum of the estimated county yield variance and the average variance of farm-county yield differences for farms in the county. Covariances between farm-county yield differences and county yields were assumed to be zero, which is true, on average, for all farms in a county.

As can be seen from the map, yield variability tends to be lowest in irrigated areas and in the central Corn Belt, where soils are deep and rainfall is dependable. Much corn production in Nebraska, for example, is irrigated, and yield variability is, as a result, quite low. Yield variability is also quite low in Iowa, Illinois, and other Corn Belt States, where the climate and soils provide a nearly ideal location for corn production. In areas where corn acreage tends to be fairly low and in areas far removed from the central Corn Belt, yield variability is generally higher.

Yield variability can be measured using farm-, State-, or national-level data. Estimates tend to be lower when variability is measured at the higher State or national levels of aggregation than at the farm level of aggregation, as shown in the map. This is because random deviations tend to offset each other when averages are taken across farms. Also, conditions across the region of aggregation may vary widely. Farmers' risks can be seriously underestimated by using yield variabilities measured at the county level or at higher levels of aggregation.

Figure 1
Estimated farm-level corn yield coefficient of variation by county, 1995

Coefficient of variation
- 0.20 to 0.24
- 0.25 to 0.29
- 0.30 to 0.40
- Greater than 0.40
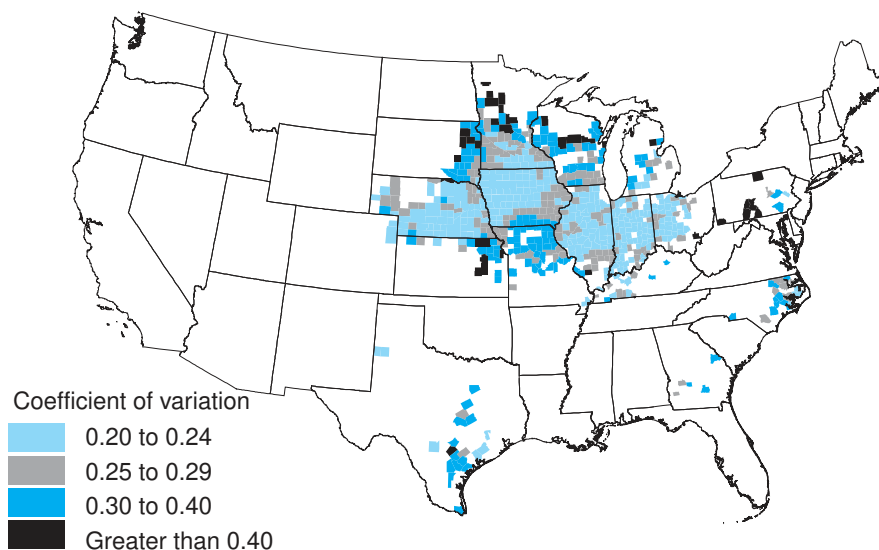
Notes: Shaded areas include counties with at least 500 acres planted to corn. Lower corn yield variability indicates that farm yields fall within a narrower range. Based on farm-level data, 1985-94, and long-term county-level trend.
Source: Constructed by ERS from USDA, NASS electronic county yield files, 1997, and USDA, RMA electronic experience and yield record database.

Price Randomness Differs Among Commodities and Changes Over Time

While yield expectations before planting generally follow trends, price expectations often fluctuate substantially from year to year depending on commodity stock levels, export demand, and other factors. Futures price quotes serve as useful proxies for price expectations for commodities traded on futures exchanges. For example, a September quote for the Kansas City wheat futures contract that matures the following July can be interpreted as the market's expectation in September of the value of hard red winter wheat in that next July.[3]

Price randomness can be estimated by measuring futures price quote changes from one trading date to another. Thus, one measure of price risk for winter wheat at planting time is the standard deviation (or coefficient of variation) of price changes from September to July in the July wheat futures price. That is, the difference between the September 1 quote and the next July 1 quote on the July futures contract can be obtained for several years, and the standard deviation (or coefficient of variation) calculated on that annual series of price difference observations.

Price variability or risk can be measured using ratios of successive prices, P_t / P_{t-1}, instead of differences, $P_t - P_{t-1}$, as used in the example above. Ratios offer several advantages. First, the use of ratios may eliminate the need to make adjustments for inflation, provided that inflation rates are approximately constant over the period analyzed. Second, ratios are unit free, which facilitates comparisons among commodities. Third, measuring price variability using ratios

The level of futures prices reflects traders' expectations of prices at delivery time.

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[3]A futures contract is an agreement entered into on an exchange (such as the Chicago Board of Trade or the Chicago Mercantile Exchange) between a seller who commits to deliver and a buyer who commits to pay for a commodity. Exchange trading and standardization foster competition, and futures contract quotes are among the best current estimates of prices expected at delivery time.

allows the comparison of volatilities estimated over time intervals of different lengths. For example, the price volatility estimated with daily data for a given month can be compared with the volatility estimated for a year using this procedure.

Futures quotes provide a vehicle for observing price volatility changes over the growing season. To illustrate, volatilities in December corn futures prices were estimated by month using a 10-year average of the annualized standard deviation of log (P_t / P_{t-1}) for "t" ranging over all trading days of the month.[4] In this example, volatility in December corn prices tends to be relatively low from the preceding December until just prior to planting time in April (fig. 2). Volatility increases at planting time and is quite high during the critical months of the growing season as information (particularly weather information) emerges and affects prices. Volatility is lower again in September and the follow-

ing months, when yields have been largely determined.

Price volatility differs among commodities. To estimate volatility for those commodities not traded on futures markets, price expectations must be approximated in other ways. The preceding year's price is one of the simplest proxies for the expected price in a given year. Figure 3 reports estimates of price volatilities, based on annual observations, for 20 commodities. The volatilities shown are the standard deviations of the logarithms of ratios of the current year's price to the preceding year's price for 1987-96. Price variability changes over time, of course, as market conditions and government programs change, but relative price variabilities for the different commodities tend to be similar between decades (Heifner and Kinoshita). In this example, crop prices were more volatile than livestock prices, largely reflecting the importance of yield risk in crop production. Those crops exhibiting the highest volatilities (exceeding 20 percent) include dry edible beans, pears, lettuce, apples, rice, grapefruit, and grain sorghum. Volatilities for turkeys, milk, and beef cattle were

> Futures prices tend to be most variable during months where weather has the greatest impact on yields.

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[4]For example, the January volatility estimate was constructed by averaging over the 10 years the annualized standard deviations of logarithms of daily December futures settlement price relatives, $\log(P_t / P_{t-1})$, over the trading days in each January.

Figure 2
Volatility of December corn futures by month, averages for 1987-96
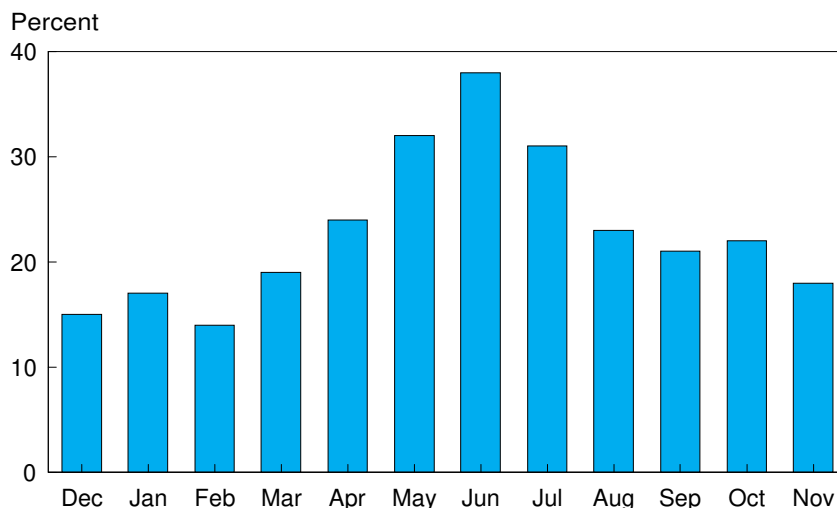
Source: Estimated by ERS from Chicago Board of Trade data.

Figure 3
Price volatility, selected commodities, 1987-96
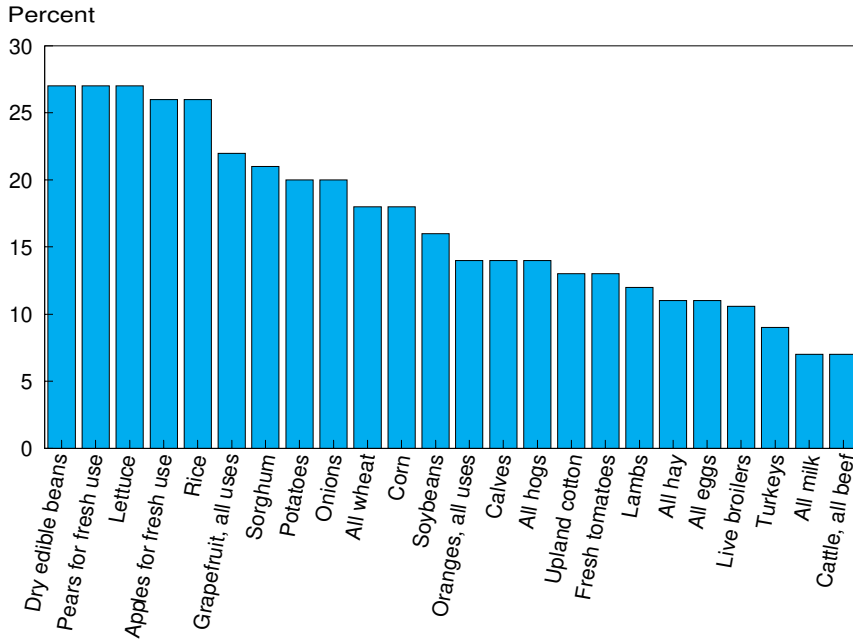
Percent

Source: Estimated by ERS from USDA, NASS, *Agricultural Prices,* various issues.

less than 10 percent, while volatilities for the other commodities fell in the 10- to 20-percent range.

Price variability changes not only within the year, but also between years due to year-to-year differences in crop prospects over the growing season, changes in government program provisions, and changes in global supply and demand conditions. Figure 4 shows estimates of corn price volatility by decade, based on annual observations and the log (P_t / P_{t-1}) procedure described earlier. Corn price variability was quite high during the 1920's and 1930's, largely due to the collapse of grain prices in the post-World War I period and very low yields in 1934 and 1936. Volatility was low during the 1950's and 1960's, a period characterized by high government support, fairly stable yields, and consistent demand. The 1970's realized sizable purchases by Russia early in the decade, and poor crops in 1983 and 1988 contributed to variability in the 1980's. Since 1990, variability has been near long-term average levels. The same pattern applies to the other grains as well.

Although price volatility (as well as price levels) can vary substantially over time, prices are highly correlated geographically. Price differences between locations are more or less held constant by the potential for transporting commodities from low-price areas to high-price areas, while price differences between grades and classes are similarly constrained by the possibility of substituting one grade or class for another. However, prices for grades or classes that normally sell at a premium on a more limited market, such as high protein spring wheat, may be more variable than prices for the bulk of the commodity.

Hauling commodities is profitable whenever the price differential between two points exceeds hauling costs. These spatial price relationships are re-established daily for those commodities traded on futures exchanges as local buyers adjust the prices they offer to farmers to maintain desired relationships with the futures price. For example, consider a central Illinois elevator operator in

Grain prices tend to be more volatile than livestock prices, with some fruits and vegetables also exhibiting quite high year-to-year volatilities

January, who sees the March futures price for corn decline. If the operator did not respond by reducing the price to producers, the elevator may end up paying more to producers than the corn could be sold for in March.

In contrast to prices, yields are much less highly correlated geographically. Yield differences between locations vary from year to year due to varying weather conditions in different locations. In 1988, for example, a major drought greatly reduced corn and soybean yields in the Midwest. As a result, the yield differential between the central Corn Belt (Iowa and Illinois) and the Southeast was much less than in years of widespread normal weather.

Yields and Prices Tend To Move in Opposite Directions

Prices for agricultural commodities at the national or world level tend to be high when yields are low, and vice versa, because total demand for food changes only moderately from year to year, while supply can fluctuate considerably due to weather in major producing countries. Consumers bid up the price for crops in short supply, while

crops in abundant supply clear the market only at low prices. When two variables, such as price and yield, tend to move in opposite directions, they are said to be negatively correlated.

The magnitude of price-yield correlation, which measures the strength of the relationship between price and yield, varies depending on the level of the comparison. Yield and price on a farm, for example, need not be related because the output of one farm does not noticeably affect market prices. However, yields among farms within a region tend to move together. As a result, individual farm yields in major production areas tend to be positively correlated with national yields and, therefore, negatively correlated with price. A negative yield-price correlation means that a farmer's revenue is less variable from year to year than it would be otherwise. The more negative the correlation, the greater the "offsetting" relationship (or "natural hedge") that works to stabilize revenues.

Estimates of the farm price-yield correlation for corn in selected counties in the United States indicate that the correlation tends to be more strongly negative in the

> In major producing areas, the tendency for price to be high when yields are low (and vice versa) provides farmers with a "natural hedge" that makes their incomes less variable than otherwise.

Figure 4
Volatility of corn prices by decade

Percent
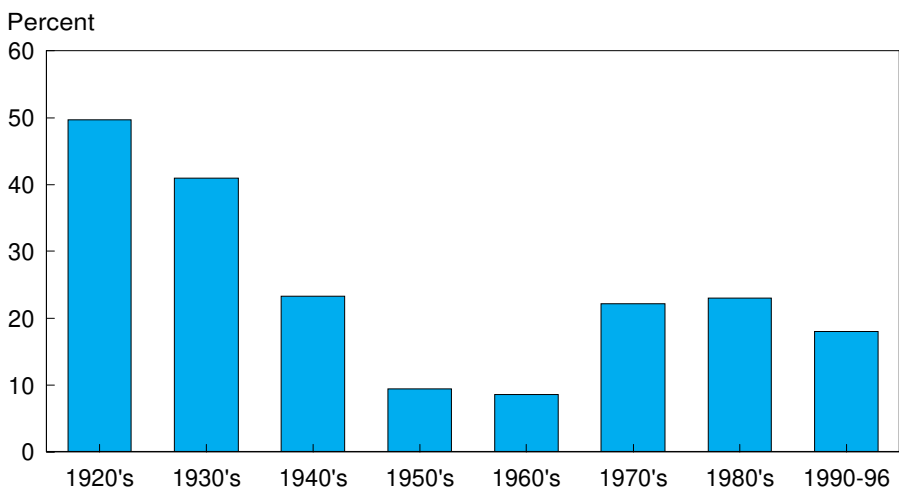
Source: Estimated by ERS from USDA, NASS, *Agricultural Prices*, various issues, and other historical price data published by USDA.

Corn Belt than in bordering areas of production (fig. 5). Thus, the natural hedge is more effective in the Corn Belt, and natural movements in price and yield work to inherently stabilize incomes to a greater extent in that area than elsewhere. In areas outside major producing locations (such as in the Southeast or along the east coast), the natural hedge is much weaker, meaning that low yields and low prices (or conversely, high yields and high prices) are more likely to occur simultaneously. Wheat generally exhibits lower yield-price correlations and weaker natural hedges than corn because production is less geographically concentrated.

The magnitude of the natural hedge has implications for the effectiveness of various risk-reducing tools. A weaker natural hedge (with a slightly negative correlation between price and yield), for example, implies that forward pricing by hedging in futures or by selling forward on the cash market is more effective in reducing income risk than when a strong natural hedge exists, other factors held constant. In such situations, fixing a sales price for the crop works to establish one component of revenue, reducing the likelihood of simultaneously low (or high) prices and yields. As a result, hedging corn can, at times, be more effective in reducing risk in those areas outside the major producing regions of the Corn Belt.

Because income risk depends on factors other than the price-yield correlation, however, the effectiveness of hedging in reducing risk is more complicated. In particular, yield variability is an important factor. Corn yields are typically more variable outside the Corn Belt, and hedging effectiveness declines as yield variability increases. Because yield variability tends to outweigh the impacts of the price-yield correlation, hedging effectiveness tends to be higher in the Corn Belt than in less robust producing areas. The interaction of yield variability, price variability, and the price-yield correlation in influencing the effectiveness of risk management tools are important factors affecting producers' choice of the risk management strategies discussed in the next section.

The tendency for corn yields and prices to be negatively related is stronger inside than outside the Corn Belt.

Figure 5

Farm-level corn yield-price correlation by county, 1974-94

Yield-price correlation
- Less than to -0.40
- -0.39 to -0.30
- -0.29 to -0.15
- Greater than -0.15
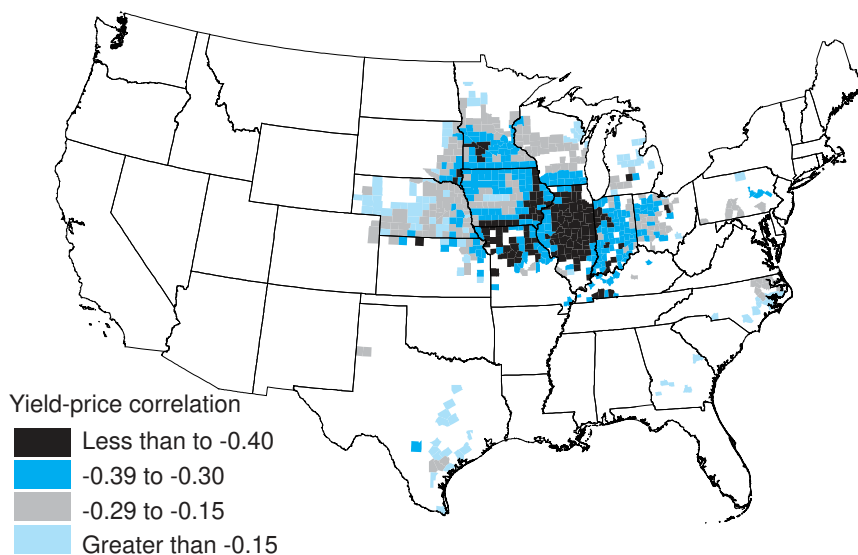
Note: Shaded areas include counties with at least 500 acres planted to corn.
Source: Constructed by ERS from USDA, NASS electronic county yield files, 1997, and USDA, RMA electronic experience and yield record database.

How Farmers Can Manage Risk[5]
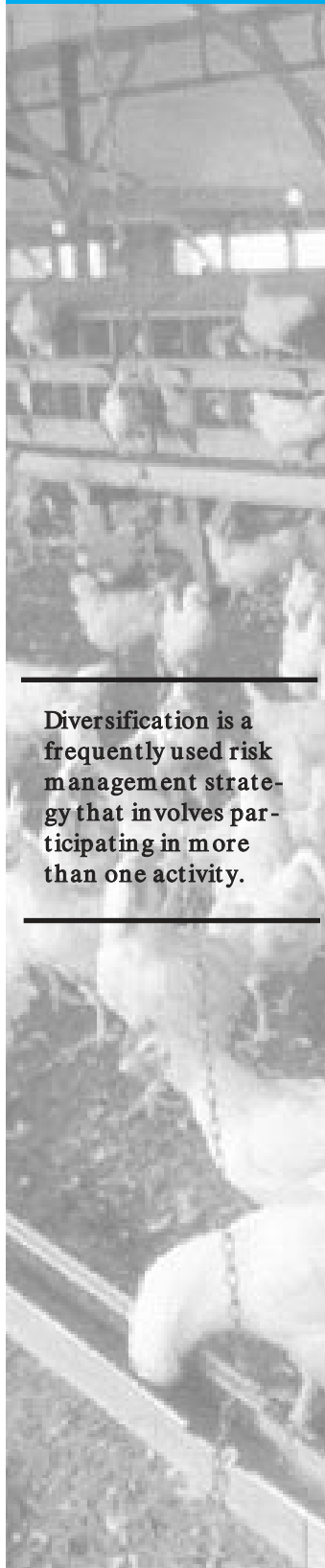
Diversification is a frequently used risk management strategy that involves participating in more than one activity.

Farmers have many options in managing agricultural risks. They can adjust the enterprise mix (diversify) or the financial structure of the farm (the mix of debt and equity capital). In addition, farmers have access to various tools—such as insurance and hedging—that can help reduce their farm-level risks. Indeed, most producers combine the use of many different strategies and tools. Producers must decide on the scale of the operation, the degree of control over resources (including how much to borrow and the number of hours, if any, worked off the farm), the allocation of resources among enterprises, and how much to insure and price forward.

The price and yield risks discussed earlier, along with a farmer's attitude toward risk, have a major impact on the choice of risk management strategies and tools. In analyzing the risk-return tradeoffs associated with different approaches, a producer must consider his or her expected return to different choices and the variance in returns. Economists have used several approaches to capture these tradeoffs, which vary in how they describe a farmer's "world view" and how flexible they are in specifying risk attitudes (see appendix 2 for details).

Enterprise Diversification

Diversification is a frequently used risk management strategy that involves participating in more than one activity. The motivation for diversifying is based on the idea that returns from various enterprises do not move up and down in lockstep, so that when one activity has low returns, other activities likely would have higher

returns. A crop farm, for example, may have several productive enterprises (several different crops or both crops and livestock), or may operate disjoint parcels so that localized weather disasters are less likely to reduce yields for all crops simultaneously.

Many crop farms in the Corn Belt, for example, produce both corn and soybeans. By producing both crops instead of only one, the farm is less at risk of having low revenues because revenues from the two crops are not perfectly positively correlated. In some years, low corn revenues may be counterbalanced by relatively high soybean revenues. Diversification in farming has many similarities to the management of financial instruments. Mutual fund managers, for example, tend to hold many stocks, thus diversifying and limiting the losses of a particular stock doing poorly.

The extent of farm diversification in U.S. agriculture is a difficult concept to measure. USDA analysis has measured diversification using an entropy index, which accounts for both the mix of commodities and the relative importance of each commodity (measured by its estimated value) to

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[5]The ordering of topics in this section does not reflect their relative importance. In addition, the length of discussion associated with a particular topic is not meant to indicate importance, but reflects the complexity of the topic and diversity of the literature.

farm businesses (Jinkins). The entropy index spans a continuous range from 0 to 100. The value of the index for a completely specialized farm producing one commodity is 0. A completely diversified farm with equal shares of each commodity has an entropy index of 100. These entropy indexes for individual producers can be aggregated to provide weighted average entropy indexes by farm type, farm size, and other classifications.

Based on the Agricultural Resource Management Study (ARMS), USDA's entropy index work indicates that cotton farms (with an average index of 50) are among the most diversified, producing substantial quantities of cotton, cash grains, fruits and vegetables, and in some cases, livestock (table 3). Poultry farms, where 96 percent of the value of production was from poultry in 1990, were the least diversified, likely in part due to the importance of production contracts. Such contracts can reduce producers' risk, reducing income variability and lessening producers' interest in diversification as a risk management tool (Dodson). In the Northern Plains and Corn Belt, farms tended to be less diversified than in other parts of the country, particularly when compared with farms in the Southeast (Jinkins).

In addition, data from the ARMS survey indicate that a large portion of commercial farming operations specialized in one or two enterprises during the period 1987-91.[6] On average, one-third of all commercial U.S. farms received nearly all production from just two enterprises during that period. Further, about one-third of aggregate farm production on commercial farms was from those engaged in only two enterprises (Dodson).

Many factors may contribute to a farmer's decision to diversify. The underlying theory suggests that farmers are more likely to diversify if they confront greater risks in farming, are relatively risk averse, and face small reductions in expected returns in response to diversification. Other factors may also be important. Continuing the corn and soybean example discussed earlier, planting corn after soybeans may reduce the need for fertilizer because of the nitrogen-fixing properties of soybean plants, and planting both corn and soybeans may spread out labor and machine use over critical times in the planting and harvesting seasons. In situations where livestock is part of the enterprise mix, the operator may be kept busy throughout the year, and crop and animal byproducts may be used more fully (Beneke).

Depending on the farm's situation, however, the costs of diversifying may outweigh the benefits, and specializing may be the preferred strategy. Diversifying often requires specialized equipment (for example, different harvesting attachments), and may be limited by managerial expertise and labor, the productive capacity of the land, and the market potential in the surrounding area (Dodson). Diversifying requires a broader range of management expertise than does producing only one commodity, and does not typically allow for intensive management. As technologies become more complicated, such intensive management and greater farm specialization may well be increasingly important (Beneke).

Based on USDA research, cotton farms are among the most diversified, while poultry farms are among the most specialized.

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[6]Commercial farms in this specific paper were defined as those that received at least $50,000 in annual sales, and where the operator supplied at least 2,000 hours of labor annually and designated farming as his or her primary occupation. This definition is more restrictive than is commonly assumed.

Table 3—Diversification measurement using entropy indexes, 1990

Commodity	Extent of measure of diversification	Value of production from major commodity	Average enterprises in the operation
	Entropy index	Percent	Number
Cotton	50	62	2.5
Tobacco	42	76	2.2
Cash grains	39	76	1.9
Vegetables, fruits, and nuts	39	80	1.9
Nursery, greenhouse	32	57	1.2
Beef, hogs, and sheep	25	85	1.8
Dairy	24	85	2.4
Poultry	9	96	1.5

Source: Excerpted by ERS from Jinkins, John, "Measuring Farm and Ranch Business Diversity," *Agricultural Income and Finance Situation and Outlook Report*, AFO-45, U.S. Dept. Agr., Econ. Res. Serv., May 1992, pp. 28-30.

> The benefits associated with diversifying arise through the potential offsetting revenue interactions among enterprises, and the complementarity of equipment and activities that are used within the farming operation.

As a result, farmers face tradeoffs when examining diversification as a strategy versus specialization. Specializing can refine the expertise needed for a particular productive activity, and may also lead to the economies of scale that lower per unit production costs, increasing the profitability of the operation. Indeed, a producer's decision to specialize (or diversify) may be motivated purely by expected profits, with no consideration given to reducing risk. Conversely, the benefits associated with diversifying arise through the potential offsetting revenue interactions among enterprises, and the complementarity of equipment and activities that are used within the farming operation (Scherer).

Empirical analyses of diversification in farming have usually focused on factors influencing enterprise choices. As an example, a study of over 1,000 crop farms in the San Joaquin Valley of California examined the relationship between diversification and such variables as farm size and wealth. The authors were interested in the tradeoffs between risk reduction and potential size economies in a given activity. They found that wealthier farmers are more specialized, perhaps because they are less risk averse than farmers having lower net worths (Pope and Prescott). Similarly, they found that corporate farms (with diversified ownership and limited liabilities) are more specialized, as are operators of smaller farms (as measured by cropped acreage) and younger (or less experienced) operators. Young farmers may start small and specialized operations, and perhaps become more diversified as they expand their operations. Farm size (measured by acres cropped) had a positive effect on diversification.

The effects of multiple enterprises on reducing risk have also been analyzed. Schoney, Taylor, and Hayward examined crop enterprise mixes for Saskatchewan farmers, and found that the gross incomes among crops were highly correlated. As a result, they concluded that little risk reduction was gained by diversifying beyond two or three crops. In addition, they found that, although several crops typically had a risk-reducing effect on the portfolio, these benefits were typically outweighed by the lower gross incomes associated with such levels of diversification.

Several diversification studies have also looked at combining livestock and crop enterprises on an operation, with the results depending on the time period of the analysis and other factors. Held and Zink, for example, found that adding livestock to a hypothetical

eastern Wyoming irrigated crop farm could increase gross margin by 7 percent and reduce the coefficient of variation from 0.63 to 0.42. Woolery and Adams indicated that diversified land use, combined with livestock, could increase net income and reduce relative income variability for South Dakota and Wyoming farms. Other studies have reached mixed results as to the risk-return tradeoff (see Persaud and Mapp; Sonka and Patrick). Despite any benefits that may accrue to enterprise diversification, the opportunities are often limited by resources, climatic conditions, market outlets, and other factors (Sonka and Patrick).

Geographical diversification (farming at several noncontiguous locations) may also mitigate risks in crop production by reducing the chances that local weather events (such as hail storms) will have a disastrous effect on income. Nartea and Barry examined this form of diversification using Illinois corn and soybean data, and found that risk was not reduced significantly until land parcels were separated by at least 30 miles. They accounted for the costs associated with farming across widely dispersed plots (for example, moving equipment and people and monitoring crop conditions), and concluded that widely dispersed tracts typically create unfavorable risk-return tradeoffs for producers. When widely dispersed parcels are observed, it is likely because of farmers' desire to expand their operations, and their difficulty in finding additional tracts of farmland that are close to their farming bases. Those most likely to gain from geographic dispersion of parcels are institutional investors with large acreages who do not have to transport equipment and who use tenants to farm their holdings.

Vertical Integration

Vertical integration is one of several strategies that fall within the umbrella of "vertical coordination." Vertical coordination includes all of the ways that output from one stage of production and distribution is transferred to another stage. Farming has traditionally operated in an open production system, where a commodity is purchased from a producer at a market price determined at the time of purchase. The use of open production has declined, however, and vertical coordination has increased as consumers have become increasingly sophisticated and improvements in technology have allowed greater product differentiation (Martinez and Reed; Allen). A vertically integrated firm, which retains ownership control of a commodity across two or more levels of activity, represents one type of vertical coordination (Mighell and Jones).[7]

There are many examples of vertical integration in farming. Farmers who raise corn and hay as feed for their dairy operations are vertically integrated across both crop and livestock production. Similarly, cattle producers who combine raising a cow-calf herd, backgrounding the animals to medium weights, and feeding cattle to slaughter weights

Opportunities for diversification can be limited by resources, climatic conditions, market outlets, and other factors.

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[7]Other types of vertical coordination reflect differing degrees to which a firm at one stage of production exerts control over the quality or quantity of output at other stages (Martinez and Reed). When production contracts are used, for example, the contractor (or integrator) typically retains control over the commodity and most inputs, and the farmer usually receives an incentive-based fee for production services. In this case, the producer retains little control over production decisions. When marketing contracts are used, in contrast, a firm commits to purchasing a commodity from a producer at a price formula established in advance of the purchase, and the producer retains a large degree of decision-making control. Both production and marketing contracts are discussed in subsequent sections in this report.

are vertically integrated. As these examples illustrate, vertical integration can encompass changing the form of the product (corn into livestock), or combining stages in the production process under ownership by one entity (as in the cattle example).

From the farmer's perspective, the decision to integrate vertically depends on many complex factors, including the change in profits associated with vertical integration, the risks associated with the quantity and quality of the supply of inputs (or outputs) before and after integration, and other factors. In particular, the relationship between vertical integration and risk involves an evaluation of the expected returns and the variance and covariance of the farmer's return on investment for the current activity and the integration alternative (Logan). If the correlation is positive and large across activities, the gains in risk efficiency from vertical integration may be relatively low. In contrast, a negative correlation across activities implies that integrating vertically may well reduce risk for the farmer by internalizing processes within the operation.

In practice, vertical integration in agriculture often involves owner-ship of both farm production and processing activities, particularly in certain parts of the livestock sector (table 4). Vertical integration is fairly common in the turkey industry, for example, where about 30 percent of production takes place on farms that perform multiple functions. On the largest operations, the enterprise mix may include a feed mill, a hatchery, a grow-out operation, a slaughter facility, and a packing plant. In such cases, integration moves both backward into inputs (feed manufacturing) and forward into the finished, consumer-ready product. Similarly, egg producers with large operations may own their own feed mill, hatchery, laying operation, and freezing/drying plant for the processing of egg products (Manchester).

Vertical integration is also common in certain specialty crops, particularly for fresh vegetable and potato operations (table 4). In these industries, vertical integration often encompasses not only production of the crop, but also sorting, assembling, and packaging products for retail sales. Large, vertically integrated vegetable growers, for example, often both pack and sell their own vegetables, displaying their private brand names on packages, and at times

> Vertical integration is much more common in certain livestock and specialty crop industries than in field crops.

Table 4—Extent of farm production coordinated by vertical integration

Commodity	1970	1990
	Percent	
Livestock:		
Broilers	7	8
Turkeys	12	28
Hogs	1	6
Sheep and lambs	12	28
Field crops:		
Food grains	1	1
Feed grains	1	1
Specialty crops:		
Processed vegetables	10	9
Fresh vegetables	30	40
Potatoes	25	40
Citrus	9	8
Other fruits and nuts	20	25
Total farm output	5	8

Source: Martinez, Steve W., and Al Reed, *From Farmers to Consumers*: *Vertical Coordination in the Food Industry,* AIB-720, U.S. Dept. Agr., Econ. Res. Serv., June 1996.

investing in research targeted at developing new varieties. Incentives prompting an operation to adopt this type of vertically integrated strategy include the need for extensive quality control (through control of cultural practices and planting dates) and the desire for brand-name identification of products, signaling known-quality produce to buyers (Powers).

While the above examples relate to individual operations, farmers may join together in a cooperative organization that is vertically integrated across functions.[8] Examples of farmer-owned, vertically integrated cooperatives include Ocean Spray, which is owned by about 950 cranberry and citrus growers in the United States and Canada and markets fresh products and bottled juices (Shee). Other vertically integrated cooperatives include Land O'Lakes (owned by dairy growers) and Sunkist (owned largely by California citrus growers).

There are also examples of grain farmers who have cooperatively integrated into processing and other functions. Wheat growers in the Fairmount, North Dakota, area jointly invested in the construction of Dakota Valley Mills in late 1997, a farmer-owned mill supplied with wheat from local producers (Sosland Publishing Company, Sept. 1997). Similarly, a Kansas-based farmer cooperative, Twenty-first Century Grain Processing, secured an option in early 1997 to buy a New Mexico flour mill. Producer members who participate in this venture deliver wheat under a marketing agreement to different points in Kansas and Oklahoma for transport to the New Mexico milling site (Sosland Publishing Company, Feb. 1997; Fee).

[8]For more information on cooperatives, see Frederick. Although the discussion here focuses on farmer cooperatives that also engage in processing, many other types of cooperatives exist.

The Dakota Growers Pasta Company, which is run by producers in a three-State area in the upper Midwest and includes a mill and pasta plant, is similar in concept to the Twenty-first Century venture just discussed. Each Dakota Growers farmer buys a share of the company and enters into a contract for delivery of a pre-determined quality and quantity of wheat by a certain date each year (Martinez and Reed). If the average open-market price for a given period exceeds the contract price, a farmer's payment is increased above the initial contract amount. Conversely, if the average market price is less than the contract price, the firm makes up the difference. Premiums are paid for wheat of exceptional quality, and growers can purchase wheat from company-held stocks in severe yield-loss years. By operating in such a manner, the Dakota Growers Pasta Company is not only vertically integrated into milling and pasta production, but also relies on marketing contracts (see later discussion) among its farmer-members.

As noted earlier, the incentives for vertical integration can arise either from producers or from buyers further down the marketing chain who realize an opportunity to enhance their potential profits or reduce their risk. A farmer (or group of farmers) may vertically integrate "downstream" (forward in the marketing channel), for example, to assure a market for their commodity and to capture a greater share of the value that is associated with the production process. By doing so, they may enhance their profits by lowering transactions costs and by using management and other resources more efficiently. Risk can also be reduced by guaranteeing a market outlet and by avoiding the uncertainties of selling and purchasing intermediate commodities in imperfect markets. Conversely, a

The incentives for vertical integration can arise either from producers or from buyers further down the marketing chain who realize an opportunity to enhance their potential profits or reduce their risk.

processor may vertically integrate "upstream" (backwards in the marketing channel) to exercise greater control over the quality and timing of deliveries and the quality of inputs used in the production process. Again, reduced risk and/or greater profits may result.

The risk-reducing benefits associated with vertical integration depend to a great extent on the nature of the industry. Typically, the benefits associated with integration increase as production and marketing interrelationships become more complex and when breakdowns in marketplace competition are most likely (such as opportunistic behavior by contracting parties). For perfectly competitive industries, all firms are subject to price fluctuations caused by supply and demand shifts—whether or not they are vertically integrated—and integration cannot provide protection from such risks. In such industries, the benefits to integration may be small. When imperfect markets exist, in contrast, firms can benefit by some combination of improved information access, internalized transactions costs, and efficiencies in market exchange (Perry, 1989). As a result, firms tend to integrate when the costs incurred in using the market price mechanism exceed the costs of organizing those activities within the management control of a single operation (Scherer).

While vertical integration can lead to reduced risks and/or enhanced profits for some firms or growers, others may find such a strategy unattractive. Depending on the size of the firm and the extent of the proposed integration, the benefits associated with specialization and scale economies can be greatly reduced or lost, particularly in perfectly competitive markets. For growers in such markets who choose to vertically integrate, the gain may be primarily through

enterprise (or business) diversification (Perry, 1989). In addition, the size and scope of the operation can have a major impact on integration choice.

Empirical applications have examined the linkage between vertical integration and farm-level risk. One such study, focusing on cattle production in the Texas rolling plains, illustrates the importance of size of firm and income growth on integration choice (Whitson, Barry, and Lacewell). This study, responding to concerns about price uncertainty and the changing structure of the livestock industry, evaluated the risk-return effects of selling fed calves or holding them through subsequent stages in the production process. It included a weaned calf stage, a stocker phase (grazing on wheat pasture), a custom feeding phase (bypassing the stocker phase and custom feeding), and other options.

The authors found that, at low-income levels, the preferred sequence involved production of weaned calves with subsequent placement in a feedlot, a result consistent with negative covariances. As growth in ranch income increased, however, a wheat pasture activity was included in the vertical sequence to increase income and meet increased cash flow requirements over a 5-year horizon. The manager's willingness to accept risk and constraints to his or her ability to borrow were critical in determining the final integration choice.

Production Contracts

Production contracts typically give the contractor (the buyer of the commodity) considerable control over the production process (Perry, 1997). These contracts usually specify in detail the production inputs supplied by the contractor, the quality and quantity of a particular commodity that is to be

The benefits associated with integration typically increase as production and marketing relationships become more complex and when breakdowns in marketplace competition are most likely.

delivered, and the compensation that is to be paid to the grower. As an example, a broiler integrator (contractor) usually retains control over the chicks as they are raised by the producer, as well as prescribes specific inputs and special management practices throughout the production cycle. In return for relinquishing control over decision-making, growers—particularly hog and broiler growers—are typically compensated with an incentive-based fee. According to USDA's Agricultural Resource Management Study, commodities valued at approximately $18 billion were produced under production contracts in 1997.

Firms commonly enter into production contracts with farmers to ensure timeliness and quality of commodity deliveries, and to gain control over the methods used in the production process. Production contracting is particularly favored when specialized inputs and complex production technologies are used, and the end product must meet rigid quality levels and possess uniform characteristics. Production contracting is also favored when oversupply and undersupply have been problems, the risk-return tradeoffs are advantageous to both the producer and the contracting firm, production technologies are specific, uniform, and knowledge-based, centralized management is feasible,

and the commodity is highly perishable (Kliebenstein and Lawrence; Barry, Sonka, and Lajili; Farrell; Harris). In addition, integrators may prefer to keep fixed capital assets (such as buildings) off of their balance sheets for liquidity purposes (Barry).

Because the broiler industry possesses many of these attributes, production contracting in this industry is particularly common. Indeed, about 99 percent of the value of broiler output was produced under production contracts in 1997 (table 5). Such contracting is also commonly used in the egg and hog industries. For hogs, the use of production contracts has increased rapidly in the past 5 years, as the number of large, specialized operations has accelerated and size economies and new health technologies have encouraged greater concentration of animals. These contracts ensure that packers receive a consistent supply of high-quality hogs, allow processing firms to operate at close to optimal capacity, and allow the marketing system to be more responsive than in the past to changes in consumer preferences (Martinez, Smith, and Zering).

Two basic types of production contracts are used, which differ in the amount of control, risk, and uncertainty the buyer and seller assume: production management

Production contracting is most commonly found in the broiler, egg, and hog industries.

Table 5—Value of selected commodities produced under production contracts, 1997

Commodity	Value of production under production contracts	
	Percent	Million dollars
Broilers	99	6,664
Cattle	14	4,280
Eggs	37	773
Hogs	33	3,097
Vegetables	8	1,145
Total value of production under production contracts, all commodities[1]	12	18,215

[1]Includes $1,627 million in the crop category and $16,588 million in the livestock category. The total value of agricultural production is $191,724 million.

Source: USDA, ERS, 1997 Agricultural Resource Management Study, special analysis.

contracts and resource-providing contracts. The production management contract is commonly used for processing vegetables (sweet corn, snap beans, and green peas). With these contracts, the buyer gains additional control over decisions that would be made solely by the grower in the absence of a contract, including planting schedules and seed varieties (Powers). By assuming this degree of control, the contractor increases the likelihood of receiving a commodity that has specifically desired characteristics, and nearly all price risk is shifted to the contractor through the establishment of an agreed-upon price upon entry into the contract. Some price risk remains with the farmer, however, due to quality considerations, which may result in either a discount or a premium relative to the established contract price (Lucier). When crops fail, growers receive no payment under these contracts and, hence, bear the production risk associated with crop shortfalls.

The second type of contract is the resource-providing contract, which usually offers contractors a greater degree of control than do production management contracts. These contracts are often used when specialized inputs and management are required to ensure final-product attributes, and are particularly common in the broiler industry. Under such an arrangement, the broiler producer generally provides land, housing facilities, utilities, and labor, and covers operating expenses (repairs, maintenance, and manure disposal). The contractor usually provides the chicks, feed, veterinary services, management, and transportation. Significant production decisions—such as the size and rotation of flocks, the flock's genetic characteristics, and the capacity of chicken houses—are made by the integrator (Perry, 1997). Thus, the grower is essentially a custodian of

> Two basic types of production contracts are used: production management contracts and resource-providing contracts.

the production operation for the integrator.

Much attention in recent years has been focused on contracting in the broiler industry and the implications for producers' risks and returns. In this industry, payments are based on a grower's performance efficiency relative to all growers in his or her group or "round," and involve two components. The first component is the "base payment," which is a fixed amount per pound of live meat produced. The second component is the "incentive payment," which depends on the grower's efficiency in feed conversion, the poultry mortality rate for that grower, and the weight of that grower's finished birds relative to all growers in the round. These factors are weighted in a calculation that determines the grower's "settlement cost." If the settlement cost for all contractor flocks harvested within a specified period in the round is greater than the individual grower's cost, he or she receives a bonus. In contrast, a penalty is incurred if the grower's settlement cost is high relative to all other farmers in the round.

Several important risk-related features are associated with these "relative performance" contracts. Because grower payments depend largely on production outcomes— and not feed or broiler prices— growers do not explicitly bear any price risk. Furthermore, the relative nature of the contracts means that, in the presence of favorable growing conditions (like ideal weather), the costs of all growers in the round are lower and, hence, no single grower receives a larger per pound payment. Although growers do not bear this type of "common" production risk faced by all growers in their round, they do bear the "idiosyncratic" risk specific to their operation. For example, an operation that experienced an unusual disease outbreak and a higher mortality rate would have a

higher settlement cost—and a penalizing incentive payment—relative to other growers in the round. Because of these factors, this type of production contract shifts price and common output risk from individual growers to integrators, with growers retaining the idiosyncratic risk specific to the efficiency of their own operation (Knoeber and Thurman).

The risk implications associated with production contracts are highly conditional on the specific contract terms. One recent study of the broiler industry examined the risk-shifting associated with the type of relative-performance contract (a "contract with rounds") discussed previously, comparing the results to a "contracts without rounds" situation and to an "independent grower" situation (Knoeber and Thurman). They defined the payment in the contract-without-rounds case as a fixed payment plus the amount by which the grower's feed conversion performance varies from a fixed standard that did not change over time. The "independent" case assumed that the grower purchased inputs and sold broilers at market prices, and had not contracted with an integrator.

In that analysis, 89 percent of the growers realized risk reduction that was significantly greater in the relative performance contract situation than in the contract-without-rounds case. This is because relative production contracts eliminate the risk common to all growers in the round as well as price risk, leaving only the idiosyncratic risk specific to production on a given operation. In contrast, the without-rounds contracts—where payments are made on a fixed standard representing the average settlement cost for all growers for the entire sample—eliminate only price risk. Knoeber and Thurman also concluded that relative and without-rounds con-

tracts reduced risk by 97 and 94 percent, respectively, compared with the independent grower case. In both situations, the reduction in price risk accounted for the major risk-shifting component.

More recently, Martin analyzed the risk reduction associated with production contracts in the North Carolina pork industry. Martin's research found that the risk-shifting capacity of relative production contracts was significantly greater for 36-70 percent of contract growers compared with without-rounds contract growers. This is weaker evidence than realized by Knoeber and Thurman, and may partly be explained by the greater homogeneity associated with broiler production. Broilers usually are both placed on farms and marketed at uniform weights, while hogs may be placed on farms at 30-60 pounds and marketed at weights varying from 220-280 pounds. Because there is less output variation common to all growers in the hog industry, relative contracts have less of an impact on grower risk when compared with without-rounds contracts. Martin also found that without-rounds contracts shifted 90 percent of the grower's income risk to the integrator when compared with the independent-grower situation, with 93.5 percent of income risk shifted in the case of relative production contracts.

In addition to risk-shifting capacity, production contracts have other advantages for growers, as well as for contractors. For contractors, the use of production contracts can result in sufficient input supply control (without the need for vertical integration), as well as improved response to consumer demand. Evidence suggests that farmers enter production contracts to guarantee market access, improve efficiency, and ensure access to capital (Perry, 1997). Most production contracts lower farmers'

One study of the broiler industry concluded that "relative-performance" production contracts reduced income risk by 97 percent, compared with the independent grower case.

> One distinguishing difference between marketing contracts and production contracts is that producers using marketing contracts take greater responsibility for management decisions.

price risks when compared with risks on the open market. The combination of lower market risks and less variable incomes was a major reason cited by farmers for using production contracting in at least one survey (Rhodes and Grimes). This suggests that farmers are well aware of the risk-shifting capacity just illustrated. In addition, depending on contract terms, farmers can benefit from technical advice, managerial expertise, and access to technical advances (such as high-quality breeding stock) that may not otherwise be readily available (Perry, 1997).

Despite such advantages, however, production contracting has been criticized. Some observers argue that production contracting can limit the entrepreneurial capacity of growers, and others cite the risks of contract termination on short notice (Hamilton; Charlier; Harris). Contractors may require upgrades to buildings and other infrastructure that are unexpected by the grower, resulting in an investment risk. In addition, some growers under a relative performance system believe that they are at an unfair disadvantage, arguing that companies may not have the incentives to maintain strict accuracy in the accounting and allocation of inputs among growers, and that absolute standards (as in the "contracts-without-rounds" case) may be most equitable and transparent (Jenner). Issues between growers and integrators have led to lawsuits on various occasions, and Iowa, Kansas, and Minnesota have adopted some form of legislation regulating production contracting in agriculture (Johnson and Foster; Plain; Hamilton and Andrews).

Marketing Contracts

Marketing contracts are either verbal or written agreements between a buyer and a producer that set a price and/or an outlet for a commodity before harvest or before the commodity is ready to be marketed (Perry, 1997). Since ownership of the commodity is generally retained by the grower while the commodity is produced, management decisions (such as varieties or breeds, or input use and timing) typically remain with the producer. This latter characteristic—responsibility for management decisions—is critical in distinguishing marketing contracts from production contracts (table 6).

Marketing contracts can take many forms. They are at times used by grain farmers to forward price a growing crop with a country elevator, where they are referred to as cash forward contracts. The contract terms vary across contracts, but typically establish a price (or contain provisions for setting a price at a later date) and provide for delivery of a given quality (or grade) within a specified time period. A "flat price" (or fixed price) forward contract may, for example, state that a farmer will deliver 10,000 bushels of No. 2 yellow corn to the local elevator at harvest for a price of $3.25 per bushel. Premiums and discounts may be established for grain that does not meet specified quality standards. Flat price contracts are one of the most common types of forward contracts. The price typically is the elevator's "bid price" for all farmer-delivered grain. This "bid price" is based on a current futures quote, less a "basis" adjustment that reflects marketing costs between the local elevator and the futures exchange location.[9]

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[9]Country elevators entering into such marketing contracts generally hedge their positions using futures markets. Hedging provides an offset to any price-level changes associated with the marketing contracts that elevators negotiate with producers, and transfers price-level risk to basis risk (uncertainty in the relationship between futures and cash prices). See later discussion of price-level and basis considerations in the "hedging" section.

Table 6—Comparison of marketing and production contract characteristics

Marketing contracts	Production contracts
Contractor:	***Contractor:***
Buys a known quantity and quality of the commodity for a negotiated price (or pricing arrangement)	Arranges to have a specific quality and quantity of commodity produced
Doesn't own the commodity until it's delivered	Usually owns the commodity being produced
Has little influence over production decisions	Makes most of the production decisions
Contractee (operator):	***Contractee (operator):***
Has a buyer and a price (or pricing arrangement for commodities before they are harvested)	Provides a service and other fixed inputs (land, buildings, etc.) for a fee
Supplies and finances all or most of the inputs needed to produce the commodity	Supplies a small part of the total production inputs needed
Owns the commodity while it's being produced	Usually does not own the commodity
Makes all or most production decisions	Makes few, if any, of the production decisions
Assumes all risks of production but reduced price risk	Bears few price or market uncertainties and limited production risks
Receives largest share of total value of production	Receives a fee for production that does not reflect the full market value of the commodity

Source: Excerpted by ERS from USDA, NASS, *Costs and Returns Report Interviewer's Manual*, December 1996.

The variety of marketing contracts available to grain farmers has increased over time, and nomenclature and contract terms vary by location. Basis contracts, for example, are another type of marketing contract, which provide for the price to be determined by applying a specified difference (basis) to a particular futures contract price to be observed later, usually when desired by the farmer. This assures the farmer an outlet, for later ownership transfer, while allowing gains or losses from changes in the futures price. Other contracts transfer ownership immediately while postponing payment, such as delayed payment and delayed price contracts. These contracts may offer farmers tax advantages, while allowing the elevator to ship the grain and open up storage space. Among these contracts, delayed (deferred) payment contracts specify the price to be paid, while delayed price contracts (sometimes called "deferred price"

or "price later" contracts) provide that price will equal the elevator's bid price, or the futures price adjusted for basis at a time selected by the farmer.

In contrast, minimum-price contracts guarantee the producer a minimum price for harvest delivery, based on futures price quotes at the time the contract is established, with the incorporation of a pricing formula that gives farmers the opportunity to sell at a higher price if futures prices increase before the contract expires (Catania). When hedge-to-arrive (HTA) contracts are used, the futures price is fixed in the contract, but the basis is left undetermined until a later time. HTA's have effects similar to futures hedges for the farmer, except that no commissions or margin deposits are required and the farmer deals with a local buyer instead of a broker. (For a comprehensive listing of the different

Marketing contracts can vary in their treatment of price level risk and basis risk.

types of contracts and areas of risk exposure, see Kemp; Wisner.)

Most types of contracts do not completely eliminate price risk (table 7). The exception is flat-price contracts, which establish an exact price to be paid to the grower upon delivery and thus completely eliminate price risk. In contrast, nearly all other forward marketing contracts fix either the basis (for example, 10 cents under the Chicago Board of Trade November soybean contract) or the level of the futures price at the time the contract is negotiated, but not both. For those contracts that establish the basis, the risk of price-level variation is retained by the producer until the time of crop delivery and final sale. Conversely, fixing only the futures price in the contract (as with HTA contracts) leaves the farmer with basis risk. When HTA's are rolled over to successive months, the producer also incurs the risk associated with spreads across different futures contract months.

Farmers who forward contract a growing crop bear yield risk in addition to price risk. As a result, farmers generally are advised to forward price substantially less than 100 percent of their expected crop until yields are well

> *Farmers generally are advised to forward price substantially less than 100 percent of their expected crop until yields are well assured.*

assured.[10] Difficulties associated with overcontracting arise if poor weather results in low yields, and producers contracting a large proportion of their crop need to buy "replacement" bushels at an uncertain cash price to meet the terms of delivery on their forward contract. If the farmer's shortfall is caused by a severe drought, cash prices at the time such replacement bushels must be purchased, either as part of contract renegotiation or to meet delivery terms, may be quite high. When the crop size is known, producers can safely forward contract up to 100 percent of their crop. Deferred (or delayed) price contracts usually are not negotiated until the grain is delivered to the country elevator (when yield risk no longer exists). When such contracts are used, however, both futures price and basis risks typically are faced by the producer (table 7).

To illustrate the risks associated with a simple forward contracting situation, consider a farmer with irrigated corn acreage who expects, with considerable certainty, a crop of 50,000 bushels. This

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[10]The minimum-risk amount to cash forward contract typically is slightly larger than the minimum-risk futures hedge because basis risk is avoided. See subsequent discussion of optimal hedging.

Table 7—Most marketing contracts do not completely eliminate market risk[1]

Type of marketing contact	Market risks remaining			Guaranteed minimum
	Futures	Basis	Spread	
Flat price[2]				✔
Basis	✔			
Deferred price	✔	✔[3]		
Minimum price	✔[4]	[4]		✔
HTA (basic)		✔		
HTA (multiple crop)		✔	✔	

HTA= Hedge-to-arrive contract.
[1]The extent to which yield risk is an issue depends on when the contract is entered. Deferred price contracts, for example, can be entered into before the crop is harvested (when yield risk is an issue) or after harvest (when crop size is known and yield risk is zero).
[2]For definitions of the different types of contracts, see the glossary.
[3]Some deferred price contracts specify the basis, which eliminates basis risk for farmers.
[4]Downside risk is eliminated.

Source: Adopted by ERS from Kemp, Todd E., editor, *Hybrid Cash Grain Contracts*: *Assessing, Managing, and Controlling Risk*, a White Paper by the Risk Evaluation Task Force on Hybrid Cash Contracts, National Grain and Feed Association, Washington, DC, 1996.

farmer is considering two options and plans to finalize his decision in a few days (the end of April), just before planting time. The options involve either (1) selling the crop in October, right after harvest, for the cash market price, or (2) entering a flat price contract with the local elevator for October delivery. The probability distribution of cash prices in October, based on the farmer's expectations, is shown in figure 6, and the elevator at the time of the decision is offering flat price contracts for harvest delivery. The fixed price offered under the contract is shown by the vertical line. The figure illustrates both the downside protection and the upside potential forgone if the farmer chooses the contracting approach. Because the farmer in this simple example has no yield uncertainty, 100 percent forward contracting completely eliminates revenue risk (since the price for the entire crop is fixed). If the producer forward contracts and cash prices turn out higher at harvest than the contract price, a profit opportunity has been lost, but income is no less than expected. (For other examples, see Jolly.)

Marketing contracts are used not only for pricing field crops, but also in the specialty crops sector (table 8). Among specialty crops, they appear most often in grower sales of fruits, fresh pre-cut vegetables, and processed vegetables (Powers). In the pre-cut vegetable industry, for example, prepackaged shredded lettuce and cabbage, diced celery, and sliced carrots are used in large quantities by food establishments, institutions, and retailers. Purchasing pre-cut fresh vegetables can reduce costs to these buyers if sufficiently less labor is required in food preparation. These buyers usually negotiate marketing contracts that specify a tentative free-on-board price, quality, and delivery schedule for a 6- to 12-month period. The tentative contract price is based on the expected price during the agreement's duration, and may be renegotiated if warranted by market conditions (Powers).

Although less common, marketing contracts are also used in the livestock sector. Fed cattle, for example, can be forward priced using a cash forward contract—an agreement, in this case, by a cattle feed-

Marketing contracts are used not only for pricing field crops, but also in the specialty crops and livestock sectors.

Figure 6
Flat price contracts provide downside protection, but forgo upside potential

Probability density
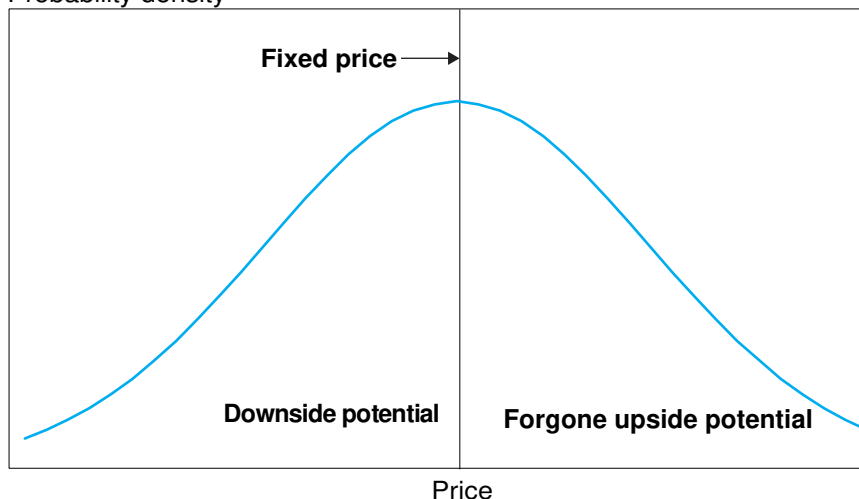
Source: Hypothetical example developed by ERS.

Table 8—Value of selected commodities produced under marketing contracts, 1997

Commodity	Value of production under marketing contracts	
	Percent	*Million dollars*
Barley	19	167
Canola	46	44
Cattle	9	2,735
Corn	8	1,720
Cotton	33	1,923
Dry edible beans	3	82
Eggs	6	131
Fruits	59	7,199
Oats	3	8
Peanuts	41	372
Peas	9	4
Potatoes	43	720
Rice	31	573
Sorghum for grain	6	86
Soybeans	9	1,672
Sugar beets	82	973
Sunflowers	8	51
Vegetables	24	3,374
Total value of production under marketing contracts, all commodities[1]	22	41,610

[1]Includes $21,323 million in the crop category and $20,287 million in the livestock category. The total value of agricultural production is $191,724 million.

Source: USDA, ERS, 1997 Agricultural Resource Management Study, special analysis.

One key issue for producers and contractors is that both understand the terms of the contract.

er to deliver a specified number of cattle, in a designated future month, to a packer. Two types of contracts are typically used. Similar to the situation for field crops, "flat price" contracts specify the price at the time the contract is negotiated between the two parties. In contrast, "basis" contracts specify the basis level (the cash price minus the futures price) at the time the contract is signed, allowing the cattle feeder to wait until a later time to fix the futures price, perhaps after the price level has increased. The final contract price is calculated by adding the basis specified in the contract to the futures price on the day the cattle are priced (Elam).

Although the price risks associated with the different types of marketing contracts vary, some types of risks are common to all contracts. All growers who enter into forward contracts face the risk of default by the merchandiser offering the contract, who may be unable to meet the financial obligation associated with the contract. In addition, producers and merchandisers may have different understandings of the contract terms and the potential financial impact (Kemp). As a result, legal risks may be confronted by farmers, as was the case for numerous individuals who had entered into HTA contracts in 1995.

Few empirical analyses have examined the reduction in price risk associated with the use of different marketing contracts, partly because time-series data capturing contract prices are generally not available to researchers. However, futures price data for field crops and livestock are readily available from exchanges. Because of the structure of most forward contracts for field crops and livestock, the use of futures prices in estimating optimal hedging amounts and risk reduction provides a close approximation to the analogous estimates that would exist in an analysis of many forward contracting situations.

Hedging in Futures

Futures contracts provide farmers (as well as processors, merchandisers, and others) with a method for reducing their risks. Futures contracts were almost exclusively traded on commodity prices in the past, although innovations in recent decades also have introduced contracts on interest rates, foreign exchange rates, price indexes, and crop yields. A primary use of futures involves shifting risk from a firm that desires less risk (the hedger) to a party who is willing to accept the risk in exchange for an expected profit (the speculator). Also, hedgers with opposite positions in the market trade with each other, and speculators with opposing views of the market may also trade.

A futures contract is an agreement priced and entered on an exchange to trade at a specified future time a commodity or other asset with specified attributes (or in the case of cash settlement, an equivalent amount of money). The U.S. exchanges that trade agricultural futures contracts are the Chicago Board of Trade; the Chicago Mercantile Exchange; the Kansas City Board of Trade; the Minneapolis Grain Exchange; the New York Coffee, Sugar, and Cocoa Exchange; and the New York Cotton Exchange. Trading is conducted either through "open outcry" on the floor of the exchange or electronically. The December corn contract traded on the Chicago Board of Trade, for example, specifies lots of 5,000 bushels for No. 2 yellow corn and a December delivery period. Contracts for major field crops (including corn, wheat, soybeans, cotton), four types of livestock and animal products (live cattle, feeder cattle, live hogs, and pork bellies), and sugar and frozen concentrated orange juice have been traded for years. More recently, futures contracts for rice, boneless beef, and dairy products have been intro-

duced. Because contracts are standardized, the only issue to be negotiated at trading time is price. Enforcing contract terms is a key function of the exchanges where trading occurs, and guaranteeing contracts is a key function of the exchange clearinghouse.

Most futures contracts are offset by opposite trades before delivery time, with each party to the transaction selling (or buying) a futures contract that was initially bought (or sold). For example, if a farmer (through his or her brokerage house and its trader on the Chicago Board of Trade) sells a corn contract in May for December delivery, his or her position may be offset by buying a December corn contract at any time before the end of the delivery period, which is about December 20. Such an offset usually occurs because the major motive in trading futures is to hold a temporary position, and then trade for money, and not to physically deliver or acquire a commodity (Hieronymus). Most hedgers offset because making or taking delivery on futures would be more costly than delivering through normal channels, while speculators generally do not want to own the actual commodity.

Because futures contracts are commitments to trade in the future, actual delivery and payment are not required until the contract matures. However, both buyers and sellers are required to make margin deposits with their brokers to guarantee their respective commitments. Because the margin deposit is small (typically 5-10 percent of the underlying value of the contract), speculators (who provide liquidity) are attracted to the market. The exchanges set minimum margins by contract, which can be raised by brokers to provide the protection they deem necessary. Using the December corn contract as an example, and assuming a $2.00 per bushel price quote, a cattle feeder who buys one contract

> Most futures contracts are offset by opposite trades before delivery time, with each party to the transaction selling (or buying) a futures contract that was initially bought (or sold).

(5,000 bushels) makes a $10,000 commitment. With a 10-percent margin, the feeder must post $1,000 with his or her broker. A "margin call" occurs when the price of the contract moves against the trader, say to $1.90 in this example. When a margin call occurs, the producer must post additional margin with his or her broker to cover the loss and restore the deposit. Similarly, when the price moves favorably for the trader by a specified amount, money can be withdrawn from the margin deposit.

Because futures prices reflect values of commodities at futures delivery points, the local cash prices confronted by farmers usually vary from futures contract quotes at a given point in time. The differences between futures and cash prices are termed "basis," and reflect differences in price across space (due to transportation costs), time (which are associated with storage costs), or quality (such as differences in protein premiums for wheat). The basis is calculated as the difference between the cash price (at a given location and at a given point in time) and the futures price (associated with a specified exchange and contract month).[11] The basis varies over time, and reflects only transportation costs and quality differences as the contract reaches maturity. As seen below, hedging largely eliminates price level uncertainty, but not basis uncertainty, which generally has a smaller variance.

Two categories of hedging exist: "long" hedging (where a futures contract is purchased) and "short" hedging (where a futures contract

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[11]Basis is sometimes calculated as cash price minus futures price and sometimes as futures price minus cash price, as mutually understood by the parties involved. Cash prices may be quoted relative to the futures, such as "10 cents over" or "20 cents under" the futures price. In this report, basis is calculated as cash minus futures, so that an "under" basis has a negative sign and an "over" basis has a positive sign.

is sold). Either type of hedge involves holding a futures position in anticipation of a later transaction in the cash market, and in both cases, the futures position is opposite to the cash position. Because futures and cash prices tend to move up and down together, losses and gains in the two markets tend to offset each other, leaving the hedger with a return near what was expected (the initial futures price plus the end-of-period basis—see later discussion). Thus, hedging helps protect the business from changes in price levels. Farmers may choose to hedge in many different situations, including the following:

- *Storage hedging*—Farmers or merchants who own a commodity can protect themselves from declines in the commodity's price by short hedging. This involves selling futures contracts as the commodity is harvested or acquired, holding the resulting short futures position during the storage period, and buying it out when the cash commodity is sold. Losses (gains) in the value of the cash commodity due to unexpected price changes will be largely offset by gains (losses) in the value of the futures position leaving the owner of the commodity with approximately the expected return from storage.

- *Production hedging*—Crop and livestock producers can protect themselves from declines in prices of expected outputs by short hedging. This generally involves selling futures contracts at the beginning of or during the growing or feeding period, holding the resulting short futures position until the product is ready to sell, and buying the futures as the output is sold. Losses (gains) in the value of the output due to unexpected price changes tend to be offset by gains (losses) in the value of

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Two categories of hedging exist:

- *"long" hedging*—where a futures contract is purchased.

- *"short" hedging*—where a futures contract is sold.

the futures position. However, yield variability reduces the risk-reducing effectiveness of hedging for crop growers and generally makes it inadvisable to sell futures equal to more than one-half to two-thirds of the expected crop.

- *Hedging expected purchases*— Livestock feeders anticipating the purchase of corn or feeder cattle can protect themselves from price increases by long hedging. This involves buying corn or feeder cattle futures contracts to match anticipated requirements and selling the resulting long futures positions as these inputs are purchased on the cash market. Increases (declines) in the cost of feeders or feed due to unexpected price changes will be partly offset by gains (losses) in the value of the futures position leaving the feeder with approximately the expected costs of inputs. Feeders' overall price risks may be further reduced by selling futures on prospective outputs, as discussed above.

To better understand the importance of basis risk in hedging, consider the example of a corn producer with irrigated acreage who is considering the pricing of his growing crop. Because the producer irrigates and faces few other natural perils, he knows the size of his crop with a great deal of certainty and is concerned only with price risk. If the farmer does not hedge, his risk is solely associated with the harvest cash price (P_2), which can also be calculated as the harvest futures price (F_2) plus the harvest basis (B_2). Thus, the farmer's net return in a cash-sale-at-harvest situation (R_u) can be calculated as the cash price ($F_2 + B_2$) at harvest multiplied by actual production (Y_2), minus production costs (C):

$$R_u = [(F_2 + B_2) * Y_2] - C.$$

Suppose now that the producer places a short hedge (for example, sells a futures contract) to reduce the risk of a price decline and a lower sales price for his growing crop. The expected final net return at harvest (R_h) is based on the cash price at harvest ($F_2 + B_2$), and the profit or loss associated with the farmer's futures market position ($F_1 - F_2$). The farmer's actual level of production is designated as Y_2 in the following equation, and the quantity hedged is $h * Y_1$, where h is the hedge ratio and Y_1 is expected production:

$$R_h = [(F_2 + B_2) * Y_2] + [(F_1 - F_2) * (h * Y_1)] - C.$$

Assuming that output is known with certainty at the time the hedge is placed, and that actual production equals the quantity hedged (for example, $Y_2 = h * Y_1$), gives the following:[12]

$$R_h = [(F_2 + B_2) * Y_2] + [(F_1 - F_2) * Y_2] - C,$$

or:

$$R_h = [Y_2 * (F_1 + B_2)] - C.$$

This last equation indicates that the price component of the farmer's net return depends on the futures price at the time the hedge is placed plus the harvest basis. Because the futures price is known with certainty at planting, and output is known with certainty in this example, the only risk faced by the farmer is the risk associated with the harvest basis. Thus, price level risk is eliminated by this anticipatory hedge, and the only risk faced by the grower is basis risk (the uncertain nature of B_2).

The existence of basis risk is a key factor distinguishing the risk associated with futures hedging and the use of many types of cash for-

When output is known with certainty, the hedger eliminates price level risk and only confronts basis risk.

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[12]This example also applies to a storage hedge, where output is known with certainty.

ward contracts (see previous section). When a producer enters into a "flat price" forward contract with his or her local elevator, for example, the basis risk he or she faces is zero. In addition, forward contracts are generally less standardized than futures contracts, and specific terms may vary across elevators. Physical delivery to the local elevator at harvest is generally required, and no margin calls exist when cash forward contracts are used (table 9).

Using a numerical example to illustrate hedging, suppose the corn producer discussed earlier wishes to reduce his income uncertainty by selling a futures contract at planting time. Because the farmer irrigates his corn crop, he is not concerned about yield risk, and the hedge quantity is assumed to equal actual output. The farmer in this example observes a $2.75 per bushel futures price at planting time. He expects a harvest basis of -$0.25, giving an expected cash price of $2.75 plus -$0.25, or

$2.50 per bushel (table 10). Two outcomes are shown in the table, a $0.25-price decrease between planting and harvest, and a $0.25-price rise. In both cases, the realized harvest basis is -$0.25, as expected.[13] With hedging, the return per bushel is $2.50 in both cases. This return can be calculated as (1) the futures price at planting time ($2.75) plus the harvest basis (-$0.25 in both scenarios), or (2) the cash price at harvest ($2.25 or $2.75, depending on the scenario) plus the gain or loss from the futures market position (+$0.25 or -$0.25).

Reality differs from the example illustrated above in that neither basis nor yields can be anticipated with certainty, even for an irrigated farm. Table 11 illustrates such yield and price risk for a 500-acre corn farm. The corn farmer's

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[13]The level of the basis varies with proximity to major markets, and in major corn growing areas, tends to be between $0.10 and $0.30 per bushel below the futures price at harvest.

> Forward contracts are generally less standardized than futures contracts, and specific terms may vary across elevators.

Table 9—A comparison of "flat price" cash forward contracts and futures hedging

Characteristic	"Flat price" cash forward contracts	Futures hedging
Competitiveness of price	Depends on margin taken by elevator	Yes
Basis risk	No	Yes
Default risk	Some	No
Ease of recontracting or offset	Depends	Yes
Physical delivery	Yes	Seldom
Margin calls	No	Yes

Source: For more information, see Heifner, Richard G., Bruce H. Wright, and Gerald E. Plato, *Using Cash, Futures, and Options Contracts in the Farm Business*, AIB-665. U.S. Dept. Agr., Econ. Res. Serv., April 1993.

Table 10—Effects of hedging on a hypothetical corn grower's return per bushel

Cash/futures price	Price decrease scenario	Price increase scenario
	Dollars per bushel	
Cash price expected at harvest	2.50	2.50
Cash price realized at harvest	2.25	2.75
Futures price at planting	2.75	2.75
Futures price at harvest	2.50	3.00
Futures return to the producer	+0.25	-0.25
Net price realized with hedging	2.50	2.50

Source: Hypothetical example developed by ERS.

Table 11—Returns to a cash sale at harvest and a futures hedge for a hypothetical corn producer

Scenario	Production	Harvest cash price	Spring futures	Harvest futures	Revenue from crop	Net return from cash sale at harvest	Net return with hedging	Difference in returns
	Bushels		Dollars per bushel			Dollars		
1	80,000	2.60	3.20	2.85	208,000	58,000	68,080	10,080
2	80,000	2.75	2.90	3.00	220,000	70,000	67,000	-3,000
3	50,000	3.15	2.70	3.40	157,500	7,500	-13,500	-21,000
4	50,000	2.80	3.15	3.05	140,000	-10,000	-7,000	3,000
5	30,000	3.15	3.65	3.40	94,500	-55,500	-48,000	7,500
6	30,000	3.30	3.65	3.55	99,000	-51,000	-48,000	3,000
Average net return	--	--	--	--	--	19,000	18,580	-420

-- = Not applicable.

Note: This illustration assumes that a producer has a 500-acre farm. The average yield for those acres varies across scenarios, from 160 bushels per acre in scenarios 1 and 2 to 100 bushels per acre in scenarios 3 and 4 to 60 bushels per acre in scenarios 5 and 6. The producer hedges six contracts at 5,000 bushels per contract. The commission on the purchase and sale of the contract is $35. For a total of six round-turn transactions, the cost is 6 * $70, or $420. The farmer's production costs total $150,000.

Source: Hypothetical example developed by ERS.

return from a cash sale at harvest (with no short hedge) ranges from -$55,500 to +$70,000 across the six scenarios. Now suppose that the farmer weighs his alternatives and decides to hedge in the spring. He anticipates that his output will not likely fall below 30,000 bushels in any given year, and thus considers his optimal hedge level to be six contracts (at 5,000 bushels per contract). At harvest time, he lifts his short hedge by buying back his futures contract, and sells his cash crop in the marketplace. He receives the proceeds from the cash sale of the crop (less production costs of $150,000) plus the gains or losses associated with the futures transaction (less commission charges of $420). Over the six scenarios, the producer's net return, including the return to the hedge, varies from -$48,000 to +$68,080. The variability in returns indicates that the return to hedging is less variable (as measured by either the range of outcomes or the standard deviation) than is associated with a cash-sale only strategy. The expected return over time, however, is approximately identical in both cases.

As can be seen by this example, the estimation of hedging amounts and risk reduction is much more complicated in the presence of yield risk. Generally, the effectiveness of hedging in reducing risk diminishes as yield variability increases and the correlation between prices and yields becomes more negative. Although hedging can reduce income uncertainty for many farmers, it never completely eliminates such uncertainty.

In addition to the considerations discussed previously in this section, hedging involves possible costs for interest forgone on margin deposits and for bias in futures prices. These costs generally are small relative to the value of the positions taken, but they partly offset the risk-reducing benefits from hedging (see box on "The Cost of Forward Pricing"). The possibilities that expected incomes can actually be increased by hedging are discussed in a later section of this report.

An extensive literature addresses farmer hedging. Much of this literature analyzes the risk reduction associated with hedging and the calculation of optimal (generally risk-minimizing) hedge ratios, which specify the proportion of the commodity that would be hedged to minimize risk. When output is certain, risk-minimizing hedge ratios are generally close to, but

The estimation of hedging amounts and risk reduction is much more complicated in the presence of yield risk.

slightly less than, 1.0 (100 percent of the commodity would be hedged).[14] In contrast, when output is uncertain (such as would be the case for a growing season hedge when a producer does not irrigate), the hedge quantity is usually substantially less than 100 percent of expected output. This situation exists due to the correlation between random production and random price. Because these variables are negatively correlated in most cases, a "natural hedge" stabilizing revenue is inherent in the system and the optimal strategy is to hedge a quantity lower than the producer's expected output (McKinnon).

Many optimal hedge models exist, and vary in their assumptions about futures and cash price determination, the unbiasedness of futures prices, risk aversion, and other factors (Berck; Miller and Kahl; Rolfo; Plato; Ward and Fletcher). In one study, Grant, for instance, examined the risk-minimizing optimal hedge for corn and soybean farmers in Iowa, Nebraska, and North Carolina in the presence of price and yield risk. His findings indicated that selling futures equal to 50-80 percent of expected production minimizes revenue risks for most corn and soybean producers in those States. These hedges would, on average, eliminate less than 50 percent of producers' revenue variance over the growing season due to basis and yield risk. Because selling futures involves costs for commissions and interest forgone on margin deposits and a 20-percentage-point reduction in the optimal hedge has a relatively small effect on risk reduction, Grant concluded that the best strategy may be for farmers to hedge between 30 and 50 percent of their expected crop.

> Futures and options contracts have been traded on crop yields as well as prices.

Recently, studies have explored other aspects of hedging. Lapan and Moschini examined the hedging problem, and assumed that price, output, and basis are random variables. Their findings indicate that, unlike earlier results using different approaches, the optimal hedge depends on the level of a producer's risk aversion. Further, they conclude that the effects of unhedgeable basis risk are exacerbated by yield risk. Other studies have, among other topics, examined the effectiveness of futures in providing revenue protection over a period of several years (Plato; Gardner, 1989).

Futures and options contracts have been traded on crop yields as well as prices. The Chicago Board of Trade introduced Iowa corn yield futures and options trading in 1995. Subsequently, trading in corn yields for four other Corn Belt States and the United States was added (Chicago Board of Trade, 1998; Grenchik and Campbell). Yield futures contracts remaining open at maturity are settled by cash payments based on USDA's National Agricultural Statistics Service (NASS) yield estimates. Although yield futures and options contracts provide potential hedging vehicles for crop insurers as well as farmers, trading volume has been low. Relatively low correlations between individual farm yields and State yields limit the effectiveness of such contracts in shifting farmers' yield risks. In addition, insurers appear to find the reinsurance provided by USDA through the Standard Reinsurance Agreement under the Federal crop insurance program satisfactory for shifting risk (Maurice; Lehman).

Recent research that examines hedging in both price and yield futures found that a risk-minimizing firm can reduce its income variance by simultaneously hedging in both price and yield futures (Vukina, Li, and Holthausen;

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[14]When output is known, basis risk generally causes the optimal hedge to be less than 1.0.

The Cost of Forward Pricing

When hedging with futures, farmers must pay commissions and forgo interest or higher earning potential on money placed in margin deposits. Those who use cash forward contracts may incur such costs indirectly, to the degree that local buyers lower prices paid to cover their hedging costs. Moreover, the prices obtained by hedgers may differ from the price expected at delivery by the amount that speculators require as compensation for standing by to take hedgers' trades and/or for bearing risks.

Commissions for futures trading vary by brokerage house and by size of trade, but typically the commission to both buy and sell is less than one-half percent of the value of the contract. Margin requirements also vary. For example, if the margin deposit averages 10 percent for 6 months, the interest forgone on the money at a 6 percent interest rate would be $0.1 \times 6/12 \times 0.06 = 0.3$ percent. Traders who meet margin requirements by depositing government securities with their brokers avoid such interest costs, although they may sacrifice some income by holding securities that yield lower returns than could be earned with other investments.

Farmers avoid directly paying commissions or making margin deposits by forward contracting with local buyers. However, elevators and other firms who buy from farmers generally incur hedging costs that must be covered. Such firms usually avoid interest costs on margin deposits by depositing government securities. Moreover, forward contracting assures them a flow of commodities through their facilities, which may increase their returns. Thus, they may or may not seek to recover their commission costs by paying slightly lower prices to farmers.

Futures markets facilitate forward pricing because short-term speculators ("scalpers") are present to take the opposite sides of sell or buy orders as they arrive from traders outside the exchange. Scalpers then quickly trade out of their positions with the expectation of a small profit, say one-quarter to one-half cent per bushel. This profit, which compensates scalpers for helping make the market liquid, constitutes a modest cost for hedgers.

Futures prices also may be less than expected cash prices because speculators require a risk premium for carrying hedgers' risks. Keynes suggested that such risk premiums could be expected in markets where short hedging exceeds long hedging. Dusak later pointed out that any such bias should be small because low transactions costs allow such risks to be spread very efficiently. Empirical studies indicate that futures price biases are small or nonexistent for most commodities, particularly for the grains, where active long hedging helps balance short hedging (Zulauf and Irwin; Bessembinder; Kolb). However, the issue is not fully resolved.

In summary, forward pricing involves costs that appear modest compared with the risk reduction obtained for most farmers, but that may make forward pricing more attractive to farmers who are very risk averse.

Hedging involves costs that appear modest compared with the risk reduction for most farmers.

McNew; Heifner and Coble, 1996). Vukina, Li, and Holthausen found that such hedging in both types of contracts can be more effective than using price futures alone, with the effectiveness of the two-instrument hedge depending on the volatility of the yield contract. As the variance of the underlying yield increases, the effectiveness of

hedging in both price and yield futures declines relative to hedging in price futures alone. They also concluded that hedging effectiveness depends critically on the price and yield bases.

Futures Options Contracts

A commodity option gives the holder the right, but not the obligation, to take a futures position at a specified price before a specified date. The value of an option reflects the expected return from exercising this right before it expires and disposing of the futures position obtained. If the futures price changes in favor of the option holder, a profit may be realized either by exercising the option or selling the option at a price higher than paid. If prices move so that exercising the option is unfavorable, then the option may be allowed to expire. Options provide protection against adverse price movements, while allowing the option holder to gain from favorable movements in the cash price. In this sense, options provide protection against unfavorable events similar to that provided by insurance policies. To gain this protection, a hedger in an

options contract must pay a premium, as one would pay for insurance.

Options markets are closely tied to underlying futures markets. Options that give the right to sell a futures contract are known as "put" options, while options that give the right to buy a futures contract are known as "call" options. The price at which the futures contract underlying the option may be bought (for a call option) or sold (for a put option) is called the "exercise" or "strike" price. As an example, suppose a wheat producer purchases a put option having a strike price of $3.00 per bushel. If futures prices move to $2.80, the option may be exercised for a net profit of $0.20 ($3.00-$2.80), minus the premium paid for the option. If the harvest cash price is $2.70 per bushel, the farmer's return is $2.90 per bushel ($2.70 plus $0.20), minus the premium.

The effects on realized returns from hedging with futures and put options are compared for a range of possible futures price outcomes in figure 7. In this example, corn is stored in November and sold in May, output risk is absent, and the

> Options provide protection against unfavorable events similar to that provided by insurance policies.

Figure 7
Effects of futures and options hedging on exposure to price variation at marketing time, a storage example

Realized return, $/bu.

Futures price at end of storage period, $/bu.
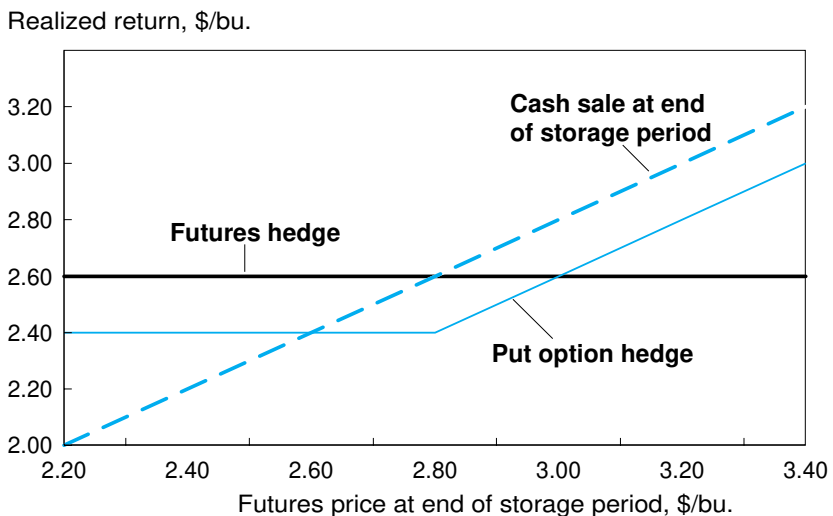
Source: Hypothetical example developed by ERS.

hedge ratio is 1.0. The May futures price is $2.80 per bushel at the beginning of the storage period and the expected May basis is -$0.20. By hedging with futures, the farmer obtains an expected return for the corn in storage of $2.80 - 0.20, or $2.60. Alternatively, the farmer can buy an at-the-money put option with a $2.80 strike price for a $0.20 premium. The put guarantees a price equal to the strike price, minus the premium, minus the basis, or $2.80 - 0.20 - 0.20 = $2.40, while allowing the farmer to gain if the futures price rises above $3.00 in May. By not hedging, the farmer gets the futures price minus the basis. The figure shows that the range of possible prices is greatest with the cash sale and least with the futures hedge. Unlike futures hedging, the put does not limit the potential profits associated with increasing prices, but the price must rise more than the premium cost before a profit is realized.

The premium paid for an option typically consists of "intrinsic" value and "time" value. The intrinsic value reflects the difference between the underlying futures price and the strike price. If the price of the underlying futures contract is $2.90 per bushel, for example, and the strike price is $2.70, then the holder of a call option could gain $0.20 by exercising the option immediately. Consequently, the premium in this case must be at least $0.20 per bushel, and the option is "in the money." If the strike price is above the futures price, the intrinsic value of the call option is zero and the put is said to be "out of the money." When the strike price equals the futures price, the option is "at the money."

The time value of an option, in contrast, depends on several factors, including the volatility of the underlying futures contract, the time until the option expires, the

interest rate, the strike price, and the underlying futures price. Time value refers to the money that buyers are willing to pay for the possibility that the intrinsic value of an option will increase over time. An option on a futures contract with very low volatility, for example, will have a small time value because traders do not expect the intrinsic value to change to a great extent over time. If the futures price is volatile, in contrast, the probability is high that the option's intrinsic value would increase and traders would be willing to pay more for the chance of such a gain (Sarris). In addition, intrinsic value depends on the time until the option's expiration. The greater the time horizon, the greater the intrinsic value because price uncertainty is greater. Observed options prices can be used to provide information about anticipated price variability (see box, p. 40).

Table 12 illustrates the situation for a central Illinois producer on March 15 who plans to produce 500 acres of corn and hedge with put options. The December futures price is $3.00 per bushel at planting time and the premium for at-the-money puts is $0.20 per bushel. His expected yield is 150 bushels per acre, and his production costs are estimated at $150,000. Because the farmer expects his production to fall no lower than 50,000 bushels, he buys 10 put contracts (5,000 bushels per contract * 10 contracts = 50,000 bushels), and selects a strike price of $3.00. The cost associated with this purchase is $10,000 in premiums (at an assumed cost of $0.20 per bushel), and $350 in commissions (10 contracts at $35 per contract).

As a simplifying assumption, suppose that the producer makes his decision on October 20 as to the sale of the option. If the futures price that day is $3.00 (equal to the strike price), the option has no

Unlike hedging in futures, put options (or call options) do not limit the poten-tial profits associat-ed with increasing (decreasing) prices.

Table 12—An illustration of net returns to a corn farmer who uses put options to protect against price risk

Item	Revenues, costs, and net returns	Dollars
1	Revenue from crop sale on October 20: (75,000 bushels * $2.50/bushel)	187,500
2	Total production costs	150,000
3	Net return from crop sale	37,500
4	Premium for put option paid on March 15: (10 put options * 5,000 bushels * $0.20 premium/bushel)	10,000
5	Return from put sale received on October 20: (10 put options * 5,000 bushels * $0.07/bushel)	3,500
6	Commissions on put purchase and sale: (2 * 10 put options * $35 commission)	700
7	Net return from put hedge (5 - 4 - 6)	-7,200
8	Net return from cash sale and put hedge (3 + 7)	30,300

Note: The put option has a $3.00 strike price and a $0.07 time value on October 20. Although net returns from the hedge in this example are negative, the example could as easily have been constructed to show a positive net return. (See discussions in the text regarding the expected return to forward pricing.)

Source: Hypothetical example developed by ERS.

> Many studies have found options to be a potentially useful method for stabilizing returns.

intrinsic value (since the option is at the money), and an assumed time value of $0.07 per bushel (reflecting the probability that the futures price will decline before the option expires, raising the option's intrinsic value). Using this estimate, the producer's return to the purchase of the option is the time value on October 20 at $3,500 ($0.07 * 50,000 bushels), less the premium cost of $10,000, and the commission cost of $700 (10 contracts * $35 per trade * 2 trades), or -$7,200. If the producer had sold his crop at the harvest cash price, his return would have been $37,500, instead of the $30,300 ($37,500 - $7,200) earned in this hypothetical put option situation.

The farmer's return to buying options depends largely on the futures price at harvest. With a high futures price in October (say, $3.75), the producer's loss associated with the option is even higher, while a low futures price (say, $2.50) would result in a higher gain than in the cash-sale-at-harvest-only case. In an efficient market, the producer's return from buying put options over a series of many years is expected to equal the return to either hedging with futures or simply selling the crop at harvest, except for commissions. Although returns are approximately the same in all three cases, hedging with either put options or futures reduces uncertainty about return.

Several studies have explored the risk-return properties of options as they affect the farm firm. Many of these studies have found options to be a potentially useful method for stabilizing returns (Heifner and Plato; Curtis, Kahl, and McKinnell). Various surveys have also found that options are used to at least the same extent as futures, including a study of the Iowa cattle sector (Sapp). In addition, large-scale Corn Belt producers participating in Top Farmer Crop Workshops in 1994 and 1995 indicated that they used options as frequently, or more frequently, than hedging and to price a significant portion of their crops (Patrick, Musser, and Eckman). In a 1988 survey of Iowa producers, about 11 percent of the grain producers responding indicated that they used hedging and about 11 percent indicated that they used options

(Edelman, Schmiesing, and Olsen). Hog and fed cattle producers, however, were more likely to hedge than to use options.

The conclusions of the literature, however, are not definitive as to the effectiveness of options contracts in reducing risk, based on different underlying assumptions. One study, for example, analyzes production, hedging, and speculative decisions in futures and options markets given the presence of basis risk (Lapan, Moschini, and Hanson). These researchers, assuming no production risk, found that options are a redundant hedging tool when futures and options markets are unbiased and when cash prices are a linear function of futures prices. They indicate that the optimal hedging strategy involves using only futures contracts (the returns of which are linear in futures prices) because they dominate options contracts (the returns of which are nonlinear in futures prices). If futures prices or options premiums are biased, however, the results indicate that options, used along with futures, provide the optimal strategy for insuring against price risk. They conclude that options are more appealing as a speculative tool to exploit private information about price distributions than as a hedging tool.

Intrigued by a comparison of survey findings with the Lapan, Moschini, and Hanson research, Sakong, Hayes, and Hallam questioned the conditions under which producers find options useful for hedging. Introducing both output and price uncertainty, these authors found that it is almost always optimal for farmers to buy put options and to underhedge on the futures market. Their results lend support to the practice of hedging the minimum expected yield on the futures market, while hedging the remainder of expected output against downside price risk

using put options. These researchers also found that their results are strengthened if the producer expects local production to influence national prices and if risk aversion is higher at low income levels.

Maintaining Financial Reserves and Leveraging

Leveraging refers to the producer's use of debt to finance the operation. Increasing the degree of leverage increases the likelihood that in a year of low farm returns the producer will be unable to meet his or her financial obligations, and heightens the potential for bankruptcy. Thus, in general, highly leveraged producers operate in an environment of greater financial risk than do producers who choose a less highly leveraged farm structure.[15]

A producer's choice of debt (relative to equity) depends on many factors, including the farmer's risk aversion, the size and type of operation, the farmer's market relationships with input suppliers and output purchasers, lenders' willingness to provide loans, and the availability of government programs for managing risk. Increasing the farm's leverage (that is, borrowing) increases the capital available for production, allowing expansion of the business, but also entails incurring a repayment obligation and creates the risk of loan default because of the risks inherent in the farming operation. Because of these many factors, a farmer's use of debt to finance the operation interacts with both the production and marketing risks faced by the producer (Barry and Baker; Gabriel and Baker).

Highly leveraged producers operate in an environment of greater financial risk than do producers who choose a less highly leveraged farm structure.

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[15]An increase in leveraging means that the farmer is at increased risk. In contrast, farmers who increase their use of most other risk management tools covered in the accompanying sections—such as hedging and insurance—reduce their risk.

Commodity Options Quotes Provide Estimates of Anticipated Price Randomness

Information about anticipated price variability within a given year can be obtained from commodity options quotes. The value of a commodity option depends on the volatility of the underlying futures price, the futures price level, the strike price, the interest rate, and the time to maturity (Black). Holding the last four variables constant, a higher volatility implies a higher price for both puts and calls. Volatility cannot be observed until after the fact. However, if an options price is observed along with the last four variables, an "implied volatility" can be calculated. Such implied volatilities embody the current judgments of traders—who have money on the line—as to the actual volatility likely to be realized.

To examine traders' ability to anticipate volatility in corn and soybean prices, the actual volatility was regressed on implicit volatility for the years 1987-95 using the December corn contract and the November soybean contract. The actual volatility (the dependent variable) was calculated using the log (P_t / P_{t-1}) procedure applied to futures prices from the end of each month to the last trading day preceding the futures delivery month. For the February estimate of corn price volatility, for example, actual volatility was captured by the standard deviation of the daily log of relative futures prices from March 1 to November 30. Implicit volatility (the independent variable) was calculated by applying the Black formula to at-the-money puts and averaging over the trading days in the month (for February, using the previous example). The R^2 from this equation is illustrated in the accompanying figure for each month prior to expiration of the December corn contract and the November soybean contract. The chart indicates that options traders can anticipate price volatility from May and June through the growing season, but not very well prior to planting time when such information would be most valuable.

Farmers and marketers can potentially use implied volatilities in making planting and storage decisions. Implied futures price volatilities, together with futures quotes, the producer's expected yields, and the producer's expectation of yield variability, may indicate that planting corn, for example, would result in higher and less volatile returns than planting soybeans (or vice versa). Farmers or marketers who are storing a crop may be able to make more use of implied price volatility information than those who are making planting decisions because output risk can be disregarded when storing.

> Options traders can anticipate price volatility throughout the growing season, but not very well prior to planting time.

Proportion of corn price volatility to harvest anticipated by options traders by month

R squared
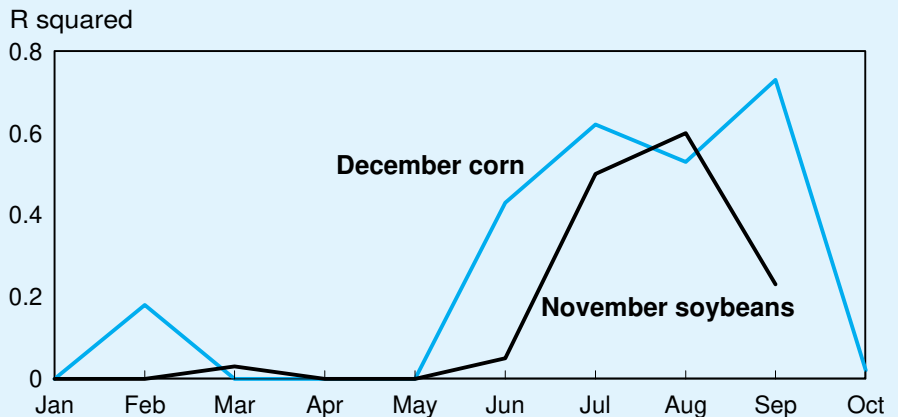
Source: Estimated by ERS from Chicago Board of Trade prices.

The risk management decision confronting a farmer who must choose the degree of leverage can be illustrated using the portfolio approach. Table 13 illustrates the effect of borrowing on the variability of returns to owned equity, where the expected rate of return to farming (R_a) is 12.5 percent and the interest rate for both borrowing and saving (i_d) is assumed to be 7.5 percent. The standard deviation of farming returns (σ_a) is 5 percent, and the standard deviation of the risk-free asset (σ_d) is zero. The higher rate of return to farming is consistent with the assumption that returns must be higher than the risk-free rate of return or risk-averse individuals would not invest in farming.

The first column of the table reports various levels of debt-to-equity ratios. A negative debt-to-equity ratio reflects a farm that has invested a portion of its equity in risk-free savings at a 7.5-percent return. In contrast, a positive debt-to-equity ratio indicates that the operator has borrowed to expand the operation. The expected return to equity capital (R_e) is:

$$R_e = (R_a * P_a) - (i_d * P_d)$$

In the equation, P_a and P_d are proportions of the two assets relative to equity, with the holdings of the risky asset (P_a) plus holdings of the risk-free asset (P_d) equaling 1.0 in the total portfolio. Leveraging implies negative holdings of the risk-free asset, resulting in a minus sign in the equation. This information is used in the second and third columns, which illustrate the tradeoff between expected returns and the variability of returns, with the standard deviation of the return to equity calculated as the weighted standard deviation of the risky asset:

$$\sigma_e = \sigma_a \, P_a$$

As an example, consider a debt-to-equity ratio of 0.25. In this case, holdings of the risky asset are 1.25 and holdings of the risk-free asset are -0.25. Thus, the expected return is calculated as (1.25 * 0.125) - (0.25 * 0.075), or 13.75 percent. The standard deviation of the return to equity is (0.05 * 1.25), or 6.25 percent.

As shown in the table, the -0.5 debt-to-equity ratio results in the lowest expected return and the lowest level of risk. In this situation, the producer holds the greatest proportion of his or her assets in the low-return risk-free investment, and the smallest proportion in the higher return risky asset. As more capital is invested in the higher risk, higher return farming operation, expected returns increase, as does the

In this example, the more highly leveraged the farm becomes, the greater the risk and the greater the expected return—which may not always be the case for a farmer in real life.

Table 13—An example of the effect of borrowing on the variability of returns to owned capital

Debt/equity ratio	Expected return to equity (R_e)	Standard deviation of expected return (σ_e)
	Percent	
-0.50	10.00	2.50
-0.25	11.25	3.75
0.00	12.50	5.00
0.25	13.75	6.25
0.50	15.00	7.50
0.75	16.25	8.75
1.00	17.50	10.00
1.25	18.75	11.25

Note: The expected return to farming equals 12.5 percent, with a standard deviation of 5 percent. The expected interest rate is 7.5 percent, with a standard deviation of zero.

Source: Adapted by ERS from Barry, Peter J., and C. B. Baker, "Financial Responses to Risk in Agriculture," *Risk Management in Agriculture*, ed. Peter J. Barry, Ames: Iowa State University Press, 1984, pp. 183-199.

standard deviation of returns to equity. Thus, the more aggressively the farmer borrows, the more highly leveraged the farm becomes and, in this example, the greater the risk and the greater the expected return.

Various research studies have examined producers' use of leveraging. For example, a recent study examined the sources of capital used by farm operators across the United States, averaging data from the 1991-93 Agricultural Resource Management Study (ARMS). Over the 3 years, lenders were found to supply 10 percent of the $638 million in total capital managed by commercial farms. Most commercial farm capital was held either as owned equity (55 percent) or was leased (35 percent), generally from landlords (table 14). As anticipated, reliance on debt and leased capital financing declined as wealth and age increased (Koenig and Dodson).

In another study, use of debt repayment capacity, measured as the ratio of actual debt relative to the maximum amount of debt supported by net cash income available for loan payments, was ana-

lyzed for various sales class sizes (Ryan). Use of debt repayment capacity was found to increase across all commercial farm size classes between 1991 and 1994, especially in the smallest category (defined as $40,000 to $99,999). In this category, use rose from less than 50 percent in 1991 to over 70 percent in 1994.

For those producers who are highly leveraged, understanding and managing price and yield risk can assume heightened importance. This is because highly leveraged farmers must be concerned about meeting their financial obligations, and high yield and price risk in such situations may increase the likelihood of insolvency and bankruptcy. Thus, farmers' decisions about leveraging (and hence, the financial risk they confront) must be considered in the context of the business risks they confront on their operations.

Several studies have examined this interaction between price and yield (business) risk and producer behavior with regard to financial risk. In particular, one line of research has addressed the topic of "risk balancing," and considered

> Research indicates that farm policies that create a lower risk business environment might induce financial choices that increase total farm risk

Table 14—Sources of capital for various groups of commercial farm operators, 1991-93 average

| Item | Young commercial[1] | | | Older commercial[2] | | | All commercial |
	Low-resource	Aspiring	Wealthy	Low-resource	Traditional	Wealthy	
	Percent						
Share of total managed capital that is:							
Leased capital	69	52	27	60	34	21	35
Debt capital	17	12	10	15	10	8	10
Owner capital	14	36	62	25	56	71	55
Total	100	100	100	100	100	100	100
Farms							
Number of farms	40,260	66,845	33,062	180,194	240,105	67,576	562,866
Dollars							
Average total managed capital per farm	543,361	805,375	1,937,478	587,534	952,741	2,827,468	1,133,906

[1]Young farmers are under 40 years of age. The category definitions are low resource (less than $150,000 net worth), aspiring ($150,000-$500,000 net worth), and wealthy (greater than $500,000 net worth).
[2]Older farmers are over 40 years of age. The category definitions are low resource (less than $250,000 net worth), traditional ($250,000-$1 million net worth), and wealthy (greater than $1 million net worth).

Source: Excerpted by ERS from Koenig, Steven R., and Charles B. Dodson, "Sources of Capital for Commercial Farm Operators," *Regulatory, Efficiency, and Management Issues Affecting Rural Financial Markets*, Proceedings of the NC-207 Regional Committee, Staff paper SP0196, ed. Bruce L. Ahrendsen, Fayetteville: University of Arkansas, Department of Agricultural Economics and Rural Sociology, January 1996, pp. 70-83.

the producer's financial leveraging strategy in the presence of government farm programs that help stabilize prices and/or yields. In this context, "risk-balancing" refers to adjustments in business and financial risk that result from an exogenous shock (such as a stabilizing policy) that affects the existing balance. The seminal work in this area was conducted by Gabriel and Baker, who developed a conceptual framework that linked production, investment, and financing decisions via a risk constraint. Their model indicated that, in the aggregate, farmers make financial adjustments leading to decreased (or increased) financial risk in response to a rise (or fall) in business risk. Thus, farm policies that create a lower risk business environment might induce financial choices that increase total farm risk.

In further investigating "risk balancing," other research has examined the impacts of income-supporting farm policies on leverage. Collins, for example, developed a structural model of a risk-averse producer's overall debt-equity decision, supporting Gabriel and Baker's conclusions that risk-reducing farm policies may well increase financial risk-taking behavior on the part of producers. Collins also concluded that, for risk-averse producers, greater risk-taking behavior also may be associated with policies intended to raise expected farm income. Other work has shown that risk-reducing and income-enhancing policies may, due to increased leveraging, increase the likelihood of farmers losing part of their equity or going bankrupt (Featherstone, Moss, Baker, and Preckel). Further, research that includes more complex specifications, such as tax laws, credit subsidies, and other factors, reach similar conclusions (Moss, Ford, and Boggess; Ahrendsen, Collender, and Dixon).

In addition to approaches that have examined the links between financial risk and business risk, other research has examined optimal farm decisionmaking, including links that span financial, marketing, and production considerations. The underlying tenet of this line of research is that certain marketing strategies often work to stabilize business risk, and also to reduce the risks associated with debt repayment by ensuring more predictable incomes. Thus, a farmer may choose either a forward contracting, hedging, or other business risk strategy accommodating lenders' preferences for greater liquidity (see next section) and loan repayment certainty (Barry and Baker). These models often are based on risk programming and stochastic simulations, and typically assume risk aversion on the part of the producer.

Several of these studies have focused on hedging (a financial strategy for which data are readily available) and its relationship to a producer's use of leverage. These studies generally conclude that hedging tends to increase as the farm's debt level rises. Using an optimal hedging model that explicitly accounts for the financial structure of the farm, one such theoretical article concludes that hedging is positively related to debt because hedging reduces business risk, offsetting to some extent the increased financial risk associated with leveraging (Turvey and Baker, 1989).

Empirical research tends to support these findings, including studies focusing on a hypothetical corn and soybean farm in Indiana (Turvey and Baker, 1990) and Florida orange growers (Moss and van Blokland; Moss, Ford, and Castejon). A survey of Indiana farmers also indicates that highly leveraged farmers are more likely to hedge than other producers because they perceive that hedging

Studies indicate that highly leveraged farmers are more likely to hedge than other producers.

could increase their net returns and/or reduce their risk (Shapiro and Brorsen). Farmer's use of leveraging (and the resulting debt payment obligations) is closely related to liquidity management, the topic of the next section.

Liquidity

Another aspect of financial risk management is liquidity, which involves the farmer's ability to generate cash quickly and efficiently in order to meet his or her financial obligations (Barry and Baker). The liquidity issue relates to cash flow and addresses the question: "When adverse events occur, does a farmer have assets (or other monetary sources) that can easily be converted to cash to meet his or her financial demands?"

Asset liquidity depends on the relationship between the firm's assets and the expected cash proceeds from the sale of each of those assets (Barry, Baker, and Sanint). An asset is perfectly liquid if its sale generates cash equal to, or greater than, the reduction in the value of the firm due to the sale. Illiquid assets, in contrast, cannot be quickly sold without a producer's accepting a discount, reducing the value accruing to the firm by more than the expected sale price. Examples of liquid assets include grain in storage, cash, and company stock holdings, while illiquid assets include land, machinery, and other fixed assets. Factors that influence liquidity include marketability of the asset, the length of time allowed for liquidation before the cash is needed, transactions costs, and the asset's income-generating role in the firm (Barry, Baker, and Sanint; Pierce).

Liquidity management is interrelated with risk responses in production and marketing, and also with the farm's degree of leverage. The more highly leveraged the farm, everything else being equal,

> The more highly leveraged the farm, the greater the need for careful liquidity management in order to make timely payments on loans and other obligations.

the greater the need for careful liquidity management in order to make timely payments on loans and other farm financial obligations. Some of the methods that farmers use to manage liquidity, and hence their financial risk, include the following:

- *Selling Assets*—A producer's willingness to sell assets is an important financial response to risk, particularly in crisis situations (Barry and Baker). If a farmer faces a low net income in a given year, selling liquid assets (such as stored grain or nonfarm assets, such as stocks) is a first step in meeting expenses for the year. Holding liquid assets, however, may be costly because they typically earn lower returns than when used in the production process (assuming the economic viability of the operation). If the use of liquid assets is not adequate to meet financial demands, additional steps—such as the sale of less liquid assets—may be necessary. Because many farmers are heavily invested in illiquid assets, such as land, livestock, and machinery, maintaining liquidity to meet shortfalls in returns may at times be difficult.

- *Managing the Pacing of Investments and Withdrawals*—Maintaining flexibility in the timing of farm investments and withdrawals is also a response to financial risk. In low income periods, for example, a producer may postpone the purchase of new machines and other equipment. This is an approach favored by many producers during times of adversity. It avoids large financial outlays during such periods, builds equity, reduces indebtedness, and allows the strengthening of profitability in a rapidly expanding farm operation (Barry and Baker).

- *Holding Liquid Credit Reserves*—Producers commonly maintain liquid credit reserves to manage their financial risk. Credit reserves reflect unused borrowing capacity, and generally reflect additional capital from lenders in the form of an open line of credit. Maintaining credit reserves avoids the costs associated with liquidating assets to meet cash demands, and the possible later reacquisition of those assets when the adversity has passed (Barry and Baker). In addition, drawing from credit reserves when needed does not disrupt the farm's asset structure, the transactions costs are typically low, and institutional sources of funds are generally available to producers in rural areas (Barry, Baker, and Sanint). Several implicit costs are, however, associated with such reserves. For example, they represent an opportunity cost from forgone leveraging. Further, interest must be paid on new loans, and noninterest charges (such as loan fees) are at times used by lenders to compensate for establishing lines of credit (Barry, Baker, and Sanint).

Farmers' reliance on the last strategy listed above—accessing credit reserves to obtain liquidity during times of adversity—introduces risk in terms of lenders' responses. Lenders' decisions regarding the availability of credit are directly affected by a farm's capital structure (the degree to which the farm is leveraged), conditions in the agricultural sector (such as the level of market prices), and financial market conditions (such as interest rates) (Barry, Baker, and Sanint).

Partly due to significant loan losses in the 1980's, agricultural lenders increasingly have emphasized credit quality and management of credit risk in their loan portfolios. Both price responses (risk-adjusted interest rates) and nonprice responses (differential loan limits, security requirements, or loan supervision requirements) may be employed to address credit risk (Miller, Ellinger, Barry, and Lajili). In a 1992 survey of more than 1,000 banks in Illinois, Indiana, and Iowa, respondents indicated that they were quite able to distinguish between high- and low-risk borrowers, and to monitor their performance. Of the respondents, 70 percent indicated that they differentially priced loans to finance farm production, and 59 percent differentially priced loans secured by farm real estate. A smaller percentage of respondents indicated the use of risk-adjusted interest rates on loans (table 15).[16]

> Agricultural lenders increasingly have emphasized credit quality and management of credit risk in their loan portfolios.

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[16]Commercial banks may use differential rates for other reasons than credit risk. Complexity of pricing, a bank's capital position, bank size, and risk-distinguishing ability generally are associated with the use of differential and risk-adjusted pricing (Miller, Ellinger, Barry, and Lajili).

Table 15—Selected price and nonprice responses of respondent banks in Illinois, Indiana, and Iowa, 1992

Price and nonprice response	Indication of use
	Percent
Differential loan pricing on loans to finance agricultural production	70
Differential loan pricing on loans secured by farm real estate	59
Risk-adjusted loan pricing on loans to finance agricultural production	57
Risk-adjusted loan pricing on loans secured by farm real estate	40
Charging of fees on agricultural loans	43

Source: Excerpted by ERS from Miller, Lynn H., Paul N. Ellinger, Peter J. Barry, and Kaouthar Lajili, "Price and Nonprice Management of Agricultural Credit Risk," *Agricultural Finance Review* 53 (1993): 28-41

In addition, lenders may require that producers use one or more risk management strategies to increase the likelihood of timely payments on financial obligations. Indeed, lenders' recommendations can have an important influence on producers' risk management decisions. A survey of Texas lenders and producers in the late 1980's, for example, indicated that the use of risk management practices—including hedging, forward contracting, crop insurance, farm program participation, and diversification—resulted in lenders viewing loan requests more favorably (Knight, Lovell, Rister, and Coble). Using a logit model, this research also found that lenders can greatly increase the probability of their borrowers adopting certain risk management practices if the use of those practices is recommended by the lender.

Regardless of lender recommendations, empirical research provides evidence of the effectiveness of such risk management strategies. As discussed earlier, studies show that the use of hedging or options reduces financial risk and improves cash flow, potentially lowering a farmer's credit risk (Turvey and Baker, 1989). Because of this risk reduction, high-debt producers with low credit reserves would be expected to hedge more than low-debt producers with large credit reserves (Turvey and Baker, 1990). Turvey and Baker's results support the notion that lenders will benefit from producers' hedging (and presumably, their use of other risk management strategies) because it decreases portfolio riskiness (Heifner, 1972a).

Leasing Inputs and Hiring Custom Work

Producers can also manage their farming risks by either leasing inputs (including land) or hiring workers during harvest or other

> Leasing has similarities to leveraging, in that both are methods used to expand control over resources.

peak months. Leasing refers to a capital transfer agreement that provides the renter (the actual operator) with control over assets owned by someone else for a given period, using a mutually agreed-upon rental arrangement (Perry, 1997). Farmers can lease land, machinery, equipment, or livestock.

Leasing has similarities with leveraging (a topic discussed previously in this section), in that both are methods used to expand control over resources. In addition, both commit the farmer to regular payments. Leasing appears, however, to have some advantages. One advantage is that control can be gained over long-life inputs (such as land and machinery), without making long-term payment commitments. In addition, leasing provides producers with flexibility in allocating their asset portfolios—a producer can be in either the farming business or the land ownership business, without being in both.

Leasing has potential advantages to those who are renting. Leasing improves the renter's flexibility to respond to changing market conditions. In addition, leasing reduces the long-term fixed payments on borrowed capital that may strain liquidity in years of reduced output, and can reduce both financial and production risk for the renter (Sommer and others, 1998). In essence, leasing limits fixed costs, providing greater flexibility for the renter to adapt. It also offers a way to enter farming or to manage the size of the operation without requiring large investments of capital. One disadvantage, however, is that renting may limit the short-term borrowing capacity of an operation because of the absence of collateral to back a loan (Sommer and others, 1998).

Advantages may further accrue from the perspective of the owner. Leasing allows the owner of the

asset to receive a return on his or her investment, and may reduce risk when a share rental arrangement is used if the owner is confident of the renter's management ability. In the case of a cash lease, the owner's income risk is reduced substantially.

Leasing of land is common in U.S. agriculture. According to USDA's ARMS data, about 9 percent of U.S. farm operators leased all of their land in 1995, 36 percent operated on at least some rental land, and 55 percent owned all of the land that they operated (Sommer and others, 1998). The ARMS results also indicated that full-owner farms (those that rented neither land nor other production assets) accounted for proportionally smaller shares of acreage, income, and sales than part-owner farms that rented land and other assets (fig. 8). Farms that rented land and other productive assets operated more than twice the U.S. average acreage, and had income and sales 3.5 to 4 times the national average. Although apparently increasing in recent years, leasing of nonreal estate assets is at a lower level than of farmland (Barry; also see Koenig and Dodson).

Land rental arrangements can fall either in the category of "share renting" or "cash renting." With share renting, the landlord and tenant share in the operation's returns and each provides a predetermined set of inputs. The two parties usually share input costs in the same proportions as outputs and share the risk of yield variability. They typically have equal say in management decisions, although the tenant usually carries out most of the production decisions. Often, the owner provides land, while the renter provides machinery and labor. In practice, the renter (as well as the owner) may have several such arrangements.

The risk benefit of this type of arrangement is derived from the financial sharing of potential losses between the partners. If net returns are negative in a particular year, for example, losses are spread across the participants in the share rental arrangement. In essence, share leasing is a highly risk efficient form of financing, in that the operator's rental obligation moves in a perfectly correlat-

Land rental arrangements can be classified as either "share renting" or "cash renting."

Figure 8
Distribution of farms, acres operated, gross cash income, and gross value of sales by tenure class, 1995
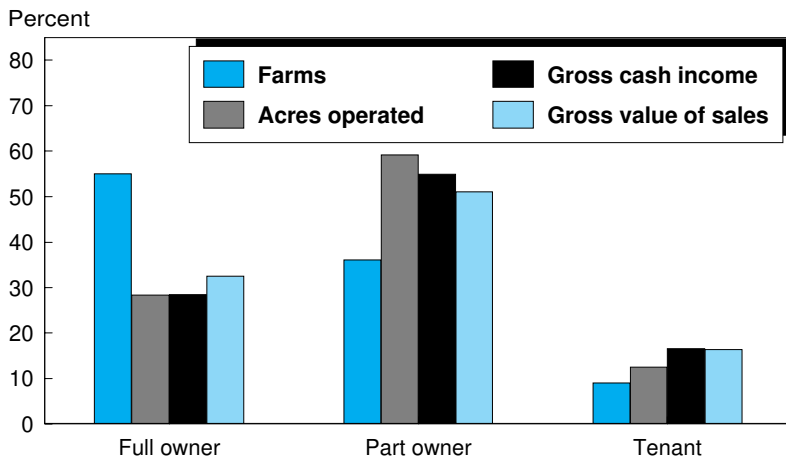
Source: Sommer, Judith E., Robert A. Hoppe, Robert C. Green, Penelope J. Korb, *Structural and Financial Characteristics of U.S. Farms, 1995: 20th Annual Family Farm Report to Congress*, AIB-746, U.S. Dept. Agr., Econ. Res. Serv., November 1998.

ed way with receipts from the operation, thus stabilizing the after-rent income position relative to a fixed-payment cash lease.

Share-rental arrangements can be difficult to manage, however, and the trend has been away from share leasing to cash leasing. Some of the impetus for this trend is on the part of landowners, particularly if the owner is absentee and questions arise regarding the renter's practices and skills. The owner may decide that his or her income risk is too great and that monitoring the management skills of the renter is too time consuming, and may instead opt for a cash rental arrangement. Some of the impetus for this trend is also from operators. It is easier to bid for additional tracts of land using cash bids than share bids, and cash leasing avoids the sharing of management responsibilities with several landlords.

With cash renting, the tenant rents the land for a pre-specified, fixed amount per acre. Cash renting affords the renter flexibility, as in a share-rent agreement. All of the yield and price risk are absorbed by the renter in a cash renting arrangement, and none remains with the owner, who receives only the agreed-upon cash rent payment (Perry, 1997). In addition, the renter typically provides inputs other than the land (including the machinery), reducing the fixed costs committed by the landowner. To better match rental arrangements with the needs of landlords and tenants, "hybrid" contracts are now being used. These "flexible" cash rents incorporate the risk-sharing advantages of share leases, without the sharing of responsibilities (Barry).

Research suggests that accounting rates of return may vary systematically with a farm's tenure position, but that these differences do not necessarily have implications

> Cash renting affords the renter flexibility, although the renter absorbs all of the yield and price risk.

for performance in terms of economic rates of return. Accounting rates of return for owned farmland have been low historically, with empirical research indicating that, as tenancy increases, accounting rates of return to assets and leverage positions tend to increase (Ellinger and Barry). Differences across tenure classes largely reflect the nondepreciability of farmland and its inherently low rate of return and low debt-carrying capacity because part of the returns to land ownership occur as capital gains rather than as current income (Barry and Robison). Low accounting rates of return may mask underlying economic rates of return, and provide producers with liquidity problems that worsen with the degree of financial leverage.

Owners who hire custom help (who provide skilled labor and their own equipment) can lower the costs associated with committing capital to fixed inputs. Producers may, at times, find that hiring workers full-time for the entire year may be costly when those workers are only essential during harvest or other peak months. With the use of custom workers (or hired or contract labor), the owner has a great deal of flexibility, potentially lowers his or her costs, and obtains specialized labor (Perry, 1997). The use of such arrangements, however, may increase the owner's risk because he or she would have less control over resources than if equipment were owned outright or workers hired full-time.

Insuring Crop Yields and Crop Revenues

Insurance is often used by crop producers to mitigate yield (and hence, revenue) risk, and is obviously prevalent outside of agriculture. Property, health, automobile, and liability insurance are all

forms of insurance regularly purchased by individuals to mitigate risk. For an individual, the use of insurance involves the exchange of a fixed, relatively small payment (the premium) for protection from uncertain, but potentially large, losses. When losses occur, virtually all types of insurance policies require a deductible, meaning that the individual must assume a portion of the value of the loss. Indemnities compensate individuals for losses up to the level of the insurance guarantee, which is based on the deductible chosen by the insured (within ranges set by policy terms).

A key characteristic of an insurance market involves the concept of risk pooling. Risk pooling involves combining the risks faced by a large number of individuals who contribute through premiums to a common fund, which is used to pay the losses due any individual in the pool (Ray). More specifically, when an insurance company sells policies to many different individuals who have less than perfectly correlated risks, the total portfolio will be less risky than the average of the individual policies. This is because, at any point in time, the odds of all insureds in the pool having a claim are extremely low. Thus, the insurer diversifies non-systemic (uncorrelated) risks across the insurance pool (Goodwin and Smith; Miranda).

In part because of several "market failure" arguments, the Government operates the multi-peril crop insurance (MPCI) program. One market failure argument is based on the idea that many of the natural disaster risks associated with crop production (such as drought, flooding, and disease) are correlated across widespread geographical areas. As a result, it has been argued that pooling risks on a scale that is feasible for most private insurers is difficult (Miranda and Glauber;

Ray).[17] Others argue that private multi-peril insurance fails because other types of producer responses to risk—such as diversification and smoothing of consumption over time through savings and borrowing—greatly reduce the additional effect of insurance in smoothing consumption, and make insurance unattractive to farmers when offered at competitive market prices (Wright and Hewitt).

In addition, research has shown that moral hazard and adverse selection are problems that significantly affect the viability of multiple peril crop insurance (Ahsan, Ali, and Kurian; Chambers; Goodwin and Smith). Moral hazard is present when an insured individual can increase his or her expected indemnity by actions taken after buying insurance. Adverse selection occurs when a farmer has more information about the risk of loss than the insurer does, and is better able to determine the fairness of premium rates. Both moral hazard and adverse selection affect the actuarial soundness of insurance, and pose a particularly difficult dilemma in multi-peril crop insurance. A lack of extensive producer-specific yield-risk information, which is needed to control adverse selection, has been a problem historically, and monitoring farmers' protection against losses, which is the basis for controlling moral hazard, is also difficult. Empirical research has used various data sets and approaches, and provides evidence of moral hazard in multi-peril crop insurance (Just and Calvin, 1993a; Coble, Knight, Pope, and Williams), as well as

In part because of several "market failure" arguments, the Government operates the multi-peril crop insurance program.

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[17]This argument has been countered by those who argue that a wide array of reinsurance options are available in international markets that allow systematic risks to be diversified. Goodwin and Smith, for example, state that, "Such markets are more than able to permit a sufficient degree of diversification to permit risks that appear to be systematic to individual markets to be spread across a wider range of activities and markets."

adverse selection (Just and Calvin, 1993b; Goodwin; Luo, Skees, and Marchant; Quiggin, Karagiannis, and Stanton).

In contrast to multi-peril crop insurance, certain other agricultural risks—such as the risks associated with hail damage or the death of livestock—are insured by private companies with no government subsidization or reinsurance (see box for information on livestock insurance, p. 53). Unlike multiple peril crop insurance, these markets are generally characterized by risks that are nonsystemic across producers, similar to the risks underlying liability, automobile, life, and other types of private-market insurance.

The Federal multi-peril crop insurance program has been the focus of interest in recent years, and the Federal Crop Insurance Reform Act of 1994 increased the level of the premium subsidy provided to producers, as well as grower participation. With passage of the 1994 Act, Congress introduced catastrophic (CAT) coverage, for which growers do not pay a premium. Rather, producers who choose to obtain CAT must pay an administrative fee.[18] CAT policies pay for losses below 50 percent of a producer's average yield (based on a 4- to 10-year "actual production history," or "APH," yield series for the grower). When losses qualify, indemnity payments are made at a rate of 55 percent of the maximum price set by USDA's Risk Management Agency (RMA).[19]

Growers can select among a wide variety of coverage levels under the program. More specifically, a grower can obtain multi-peril crop

> The Federal Crop Insurance Reform Act of 1994 increased the level of the premium subsidy provided to producers, as well as grower participation.

insurance at levels between 50 and 75 percent of his or her APH yield, using 5-percent increments.[20] Growers can also select a price coverage level of up to 100 percent of the established price set by RMA. Coverage above the CAT level, up to a maximum of 75/100 (the first number refers to the yield coverage and the second number to the price coverage level), is termed "buy-up" coverage. Producers receive indemnities under the program according to the following equation:

$$\text{Indemnity} = \text{Max } [(\text{Guaranteed Yield - Actual Yield}), 0] * \text{Price Guarantee}.$$

Within this equation, the guaranteed yield is calculated by multiplying the producer's APH yield by the coverage level that he or she selects. To illustrate, assume that a soybean producer has an APH yield of 40 bushels per acre, and selects a coverage of 75 percent. The guaranteed yield is then 30 bushels per acre (0.75 * 40). If the actual yield is 20 bushels in a given year, an indemnity would be paid on the 10 bushels (30 - 20) of shortfall from the yield guarantee. If the actual yield is above the guarantee, the farmer receives no indemnity. The price guarantee places a dollar value on the loss. If the farmer chooses a $5.50 price election, for example, his or her indemnity would total $5.50 * 10 bushels, or $55 per acre.

Except at the CAT level, producers must pay a premium for coverage under the multi-peril crop insurance program. The key to insurance rate setting is the accurate estimation of expected indemnities.

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[18]Before 1999, producers paid an administrative fee of $50 for CAT coverage. Beginning in 1999, the fee is $60.

[19]Starting in 1999, CAT coverage declined from 50-percent yield and 60-percent price coverage to 50-percent yield and 55-percent price coverage.

[20]Starting in 1999, APH coverage is available at the 85-percent yield coverage level in selected areas and for selected crops. Various revenue insurance products (see upcoming discussion, p. 52) will also allow 85-percent coverage in selected locations and for selected crops. Higher level coverage is also available under the Group Risk Plan (see upcoming discussion, p. 52).

In effect, insurers must set actuarially sound premium rates so that the premiums collected are in balance with total expected indemnities. Under an actuarially sound program with no subsidization, the average insured individual would, in the long run, expect to receive the same amount in indemnities as is paid in premiums.

While actuarially fair rates provide a starting point, insurance premiums generally must cover additional costs. Private insurance companies must price their products in order to recover overhead, operating costs, and a desired return on equity. When these costs are added into the premium, the cost of insurance over time exceeds indemnities that will be paid out. Individuals are willing to accept such contracts for automobile, medical, and other private insurance products (as well as hail and livestock insurance) due to risk aversion (see appendix 2). In short, private insurance is priced according to the following formula:

Premium = (Actuarially Fair Premium + Administrative Costs) > Expected Indemnity.

In contrast, Federal multi-peril crop insurance attempts to encourage participation by providing four primary types of subsidies. These categories include the following:[21]

- *Premium subsidy*—The premium paid by producers has been subsidized since 1980, with the subsidy depending on the level of coverage. Currently, the maximum subsidy for multi-peril crop insurance (other than for CAT, which is subsidized at 100 percent), is 41.7 percent of the total premium, and is offered at the 65/100 coverage level. The subsidy varies with other levels of coverage and by type of product.

- *Delivery expense reimbursement*—The private companies delivering policies to farmers are, as of 1998, reimbursed for their sales and service expenses at 11 percent of (implicit) total premium for CAT coverage and 24.5 percent of total premium at buy-up levels. In the absence of government involvement, private companies would include this expense in the premium paid by the producer.

- *Reinsurance*—The Government reinsures private companies that sell policies (that is, the Government shares in the risk of loss) to help reduce financial losses in years of widespread disasters. Companies can also earn underwriting gains when certain conditions are met, as determined in the Standard Reinsurance Agreement signed between USDA and the companies.

- *Excess losses*—Indemnities are paid to qualifying farmers regardless of the level of premium income. Such "excess losses" are paid by the Government in years when indemnity payments exceed total premiums. The Federal Crop Insurance Reform Act of 1994 legislates that operation of the program (including the setting of premiums) is to be conducted in a manner so that the loss ratio (total indemnities divided by total premium) is not to exceed an expected maximum of 1.075 over the long run.

Thus, premiums charged the farmer under multi-peril crop insurance are priced according to the following equation:

> Federal multi-peril crop insurance attempts to encourage participation by providing four primary types of subsidies.

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[21]In addition, the administrative costs associated with funding USDA's Risk Management Agency are appropriated annually by Congress. This funding supports RMA's development of rates and policy terms for the multi-peril crop insurance program, the research and development costs associated with new RMA product introductions, compliance functions associated with private companies delivering policies, and other activities.

$$\text{Premium} = (\text{Actuarially Fair Premium} - \text{Premium Subsidy}) < \text{Expected Indemnity}.$$

As a result, farmers have two incentives for obtaining multi-peril crop insurance. Because the program is subsidized, participants are expected to receive indemnities in excess of their premium cost, resulting in a positive net return. In addition, research has confirmed the risk-reducing effectiveness of crop insurance, particularly in situations of high yield variability.

Risk protection is greatest when crop-yield insurance (which provides yield risk protection) is combined with forward pricing or hedging (which provide price risk protection). Using an example, research indicates that a corn producer in North Carolina—a fairly high-risk corn-producing area—would expect that his or her revenue would fall below 70 percent of expected revenue about 23 percent of the time. With the purchase of 75/100 crop insurance, the percentage falls to 17 percent, and with the use of both crop insurance and an optimal hedge, the percentage falls to 7 percent. Generally, revenue insurance provides protection similar to the combination of crop insurance and an optimal hedge (Harwood, Heifner, Coble, and Perry).

Since 1990, Congress and the Administration have become increasingly interested in encouraging the development of new types of policies. Group Risk Plan (GRP) insurance, which is based on county (rather than individual) yields, was first introduced on a pilot basis in 1993, and has since been expanded to nearly all major field crops in the late 1990's (Skees, Black, and Barnett). Because it is based on area (not individual) yields, producers with significant yield losses may find themselves unprotected because the county yield does not warrant

an indemnity payment. Various studies have shown that GRP is most effective at protecting individual yield risk when a strong correlation exists between individual and county-level yields (Miranda; Skees; Glauber, Harwood, and Skees).

In addition, both producers and policymakers have expressed considerable interest since the early 1980's in the concept of revenue (and cost of production) insurance. In the 1981 Farm Act, for example, Congress mandated a study on the feasibility of revenue insurance. In the 1994 Federal Crop Insurance Reform Act, Congress mandated a cost of production insurance plan that was to compensate producers for reductions in yield and/or price resulting from an insured cause. And, in the 1996 Federal Agriculture Improvement and Reform (FAIR) Act, Congress clearly signaled the need for introducing pilot revenue insurance programs.

As of 1998, three revenue insurance products were available to producers of major field crops in selected areas: Crop Revenue Coverage, Income Protection, and Revenue Assurance (see appendix 3). These products complement many strategies, such as the use of diversification, and provide a more comprehensive alternative to the use of multi-peril crop insurance. In designing these alternatives, policymakers, program analysts, and insurance companies have benefited from witnessing Canada's experience with the Gross Revenue Insurance Program (GRIP) in the early 1990's. Canada's GRIP was expensive (in terms of both government and farmer costs) and interfered with market signals and planting decisions, largely because it used long-term average prices in establishing the guarantee (Sands; Turvey and Chen). Based on this experience, U.S. revenue insurance products use an intrayear futures

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Generally, revenue insurance provides protection similar to the combination of crop insurance and an optimal hedge.

Several Types of Livestock Insurance Are Available Through the Private Sector

Several types of insurance covering livestock are widely available in the United States through the private sector. Like private hail insurance, these products are not subsidized by the Federal Government. Livestock and hail insurance are quite different from multi-peril crop-yield and crop-revenue insurance in that coverage is typically limited to those losses that are independent geographically, such as hail (in the case of hail insurance) or fire, lightning, hail, collision, and other such perils (in the case of livestock).

One of the most popular private products used by livestock producers is a blanket farm personal property policy. Under this type of policy, livestock coverage is included as part of the farm's business property, and is subject to the same terms, conditions, and limitations faced by other property associated with the farm business. The insured selects an amount of protection and pays premium on that amount, with each policy limiting the actual cash value or market value per animal. Typical per animal values are $2,000 per head of cattle and $500 per head of swine (Anderson). At least one insurer offers an endorsement to their blanket policy, for an added premium, that includes coverage for freezing or smothering in blizzards or snowstorms (Skees and Pyles).

An alternative to a blanket policy is a "stated value" policy. Under this type of policy, the insured provides the insuring company with a list of the value of individual animals to be insured. Coverage is for animal death caused by named perils for animals on the farm or in transport to another location. Perils typically covered by such policies include fire, lightning, aircraft or falling objects, collision with a vehicle, smoke, vandalism, and theft (Anderson).

A third type of insurance is livestock mortality coverage, which is all-risk term life insurance. This coverage is typically used to insure high-value show or performance animals and covers loss due to death or theft. Livestock insured under such policies must pass a veterinarian's inspection and their values must be substantiated at the time of policy issuance (Anderson).

Hail insurance and several types of livestock insurance are available through the private sector.

price guarantee, rather than a guarantee based on long-term average prices.

Revenue insurance was first introduced in the United States in 1996. The Income Protection product was developed by USDA's Risk Management Agency in 1996. Crop Revenue Coverage, which was designed by American Agrisurance, Inc., a private company, was also introduced in 1996. These programs were expanded from limited coverage in 1996 to new geographic areas in 1997 and 1998. A more recent product, Revenue Assurance, was offered in 1997 for corn and soybeans in Iowa, and was developed by the Iowa Farm

Bureau. Research has indicated that the effectiveness of revenue insurance in reducing farm-level income risk can be substantial, and is similar to the effectiveness of combining the purchase of crop insurance with hedging (Harwood, Heifner, Coble, and Perry).

As implemented for 1998 crops, these three plans have many similar features, but also differ in many ways. Each of the products combines price and yield risk protection in one program. Indemnities under each plan equal the amount, if any, by which guaranteed revenue exceeds the revenue realized at harvest. All calculate guaranteed and realized revenues from

farm yields and from futures prices at signup and at harvest time. They all use policy terms associated with basic coverage under the multi-peril crop insurance program. In addition, each product requires that producers pay a premium for coverage, which is subsidized by the Federal Government in a manner similar to multi-peril crop insurance. The Federal Government also reinsures private companies against a portion of the losses associated with each of the products, and provides reimbursement for delivery expenses. The uniqueness of each product, in terms of the specification of the guarantee and other variables establishing the producer's coverage, is explained in the appendix. In addition, each product is unique in its rating methodology and the producer's ability to subdivide acreage into individual parcels for loss adjustment purposes.

Among the revenue insurance products currently available, Crop Revenue Coverage (CRC), which is available over the widest geo-

graphic areas and has been the most widely publicized, has the highest enrollment. Despite CRC's higher premium rates, sales were strong relative to multi-peril (APH) crop insurance in 1996 and 1997 in many areas (see figs. 9 and 10 for 1997 data). Indeed, little correlation appears to exist between premium rates (relative to APH) and the proportion of acreage covered by CRC.

CRC sales were particularly strong for corn and soybeans in Iowa and Nebraska in 1997. Two factors likely explain this result. First, Iowa and Nebraska were the only States having prior experience with CRC in 1996, and producers were likely more familiar with the program than in locations in which 1997 was the first year of CRC coverage availability. Second, Nebraska has a large American Agrisurance, Inc. (the CRC-developing company) sales force, and agent enthusiasm—a key to the successful marketing of insurance policies—was likely strong. Third, American Agrisurance, Inc., invested consid-

> Among the revenue insurance products available, Crop Revenue Coverage has the highest enrollment.

Figure 9

Proportion of corn Crop Revenue Coverage (CRC) acres to all buy-up insured corn acres, 1997

Percent
- Less than 30
- 31 to 50
- 51 to 75
- Greater than 75
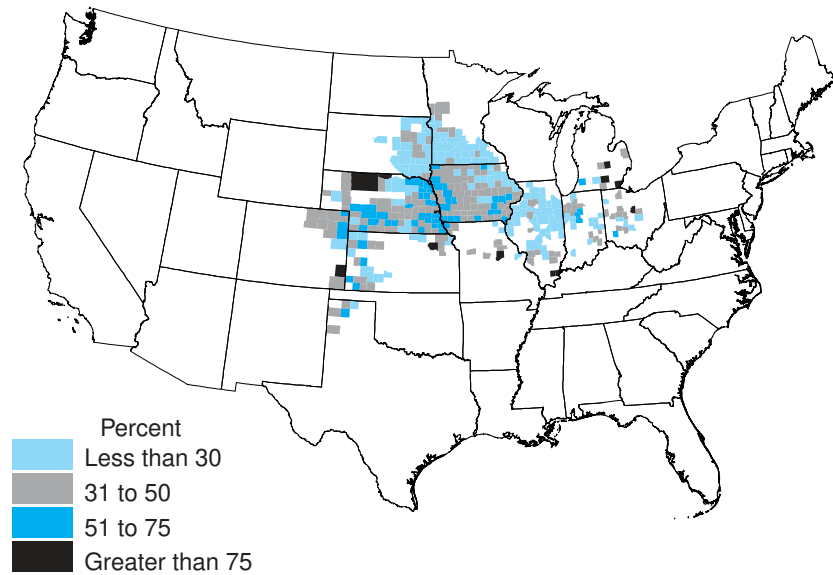
Note: Shaded areas include counties with at least 500 acres planted to corn.
Source: Estimated by ERS from USDA, Risk Management Agency, electronic experience and yield record database, 1996 and 1997.

Figure 10
**Proportion of soybean Crop Revenue Coverage (CRC) acres to all
buy-up insured soybean acres, 1997**

Percent
- Less than 30
- 31-50
- 51-75
- Greater than 75
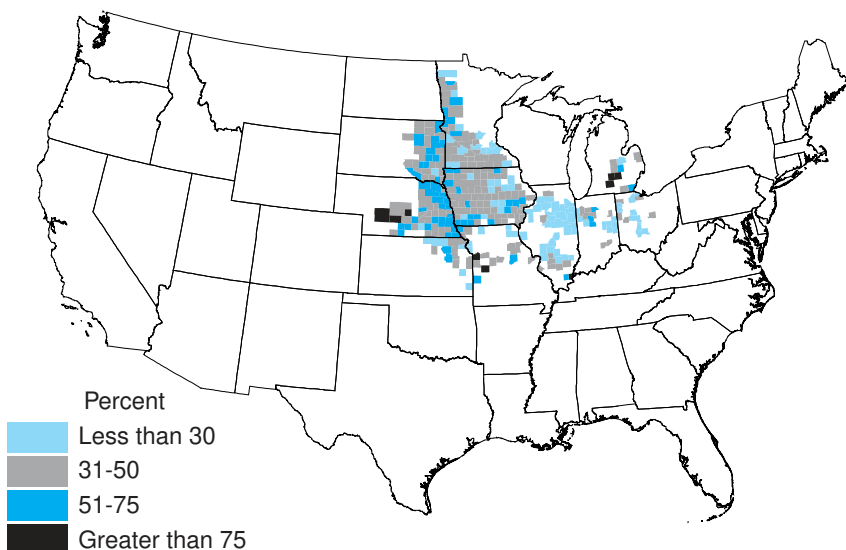
Note: Shaded areas include counties with at least 500 acres planted to soybeans.
Source: Estimated by ERS from USDA, Risk Management Agency, electronic experience and yield
record database, 1996 and 1997.

erable time and effort in promotional activities (such as agent and commodity group meetings) in Iowa and Nebraska (Cleaveland).

Off-Farm Employment and Other Types of Off-Farm Income

Earning off-farm income is another strategy that farmers may use to mitigate the effects of agricultural risk on farm family household income. Not only can off-farm income supplement household income, it may also provide a more reliable stream of income than farm returns. In essence, off-farm income can offer a form of diversification. The incentives for diversifying income sources depend on the level and variability of returns when considering a risk-averse producer. If farm households are risk averse, then they will be willing to supply relatively more labor to stable off-farm occupations than they would otherwise (Mishra and Goodwin, 1997). Or, they may seek out other types of off-farm income (such as interest and dividends) to counter negative fluctuations in farm income.

According to USDA's ARMS data, a large percentage of farm families earn off-farm income, and the levels of off-farm income relative to farm income can be significant. ARMS data for 1996, for example, indicate that 82 percent of all farm households had off-farm income that exceeded their farm income (Hoppe). For each farm type category (including very large farms), at least 28 percent of the households within the category had off-farm income exceeding farm income.

Farm household income can be categorized as earned off-farm income (wages and salaries), unearned off-farm income (social security, pensions, and investments), and farm net cash income (fig. 11). As illustrated in the figure, reliance on off-farm income is related to farm size. About 10 percent of farm households were classified as primarily engaged in farming and having sales between $100,000 and $249,999 in 1996. These farms relied on off-farm sources for about 57 percent of their total household income. In contrast, households operating very large farms (those

Off-farm income
can offer a form
of diversification.

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Economic Research Service, USDA · *Managing Risk in Farming: Concepts, Research, and Analysis*

with sales of $500,000 or more) accounted for 3 percent of all farms and relied on off-farm sources for a relatively small percentage of their average income (Hoppe).[22]

Several studies have modeled factors, such as off-farm work, that affect inequality in the distribution of income among farmers. Gardner (1969) found that off-farm work reduced both shortrun and longrun income inequality, and postulated that off-farm work may enable poor farmers to add to their own capital stock. A study focusing on New York farmers reached similar conclusions, finding that if incomes are improved by increasing income from nonfarm sources, inequality among farm families would likely be reduced (Boisvert and Ranney). Using 1991 ARMS data, another study found that the distribution of income in the North Central region was most equal among U.S. regions, and most unequal in the West (El-Osta, Bernat, and Ahearn). In addition,

> Evidence suggests that the riskiness of farm income is positively related to working off the farm.

results indicated that farm operator households that did not participate in off-farm employment experienced higher income inequality as a group than did their participating counterparts.

Research has also addressed the decision to engage in off-farm work and the hours of off-farm work supplied by farmers. One study, focusing on off-farm labor supply in Illinois, found that off-farm work was quite sensitive to economic incentives, and that a 10-percent increase in the off-farm wage entailed an 11-percent increase in hours of off-farm work, holding other factors constant (Sumner). A study focusing on Massachusetts farmers in 1986/87 concluded that the hours of work supplied by the farm operator depended on the participation decision of the spouse. In addition, family and farm characteristics were important to both the participation decision and hours worked by the farm operator (Lass, Findeis, and Hallberg).

Various empirical studies have examined the relationship between

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[22]For more information on historical off-farm earnings, see Hoppe and others; Hamrick; Kassel and Gibbs.

Figure 11
Farm household income by sales class, 1996[1]
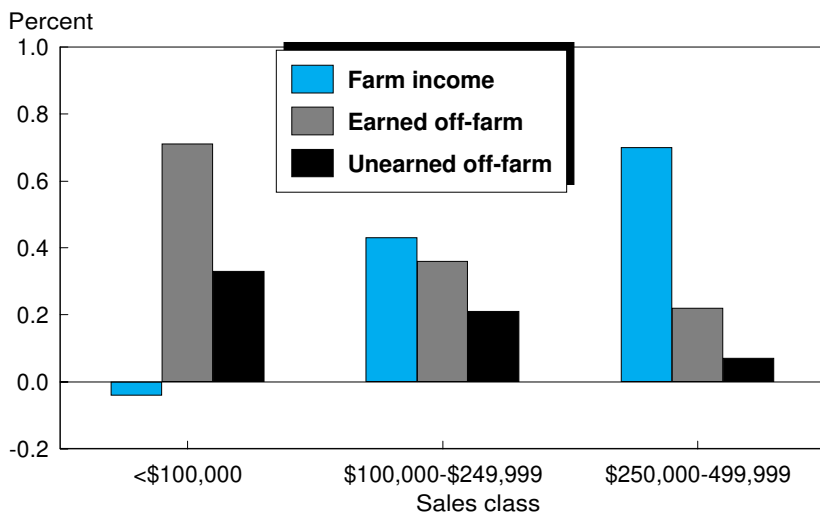
Note: For sales classes less than $250,000, the operator's principal occupation is farming.
[1]Farm operator households are associated with farms organized as individual operations, partnerships, or family corporations, and are generally closely held by the operator household. Household income includes income from farming activities and earnings from nonfarm sources by all household members in the reporting year.

Source: USDA, ERS, 1996 Agricultural Resource Management Study, special analysis.

off-farm employment and farm income variability. In one study, a times series analysis of aggregate data indicated that the fraction of total farm family income earned from off-farm sources was higher in the 1980's than in the early 1970's, and suggested that the riskiness of farm income is positively related to working off the farm (Kyle). A study focusing on producer responses to a survey in Dodge County, Georgia, in the 1980's indicated that risk and low incomes were major disadvantages associated with full-time farming (Bartlett). In another study, farm household total income was found to be significantly less variable if producers and their spouses worked off the farm (Sander).

More recent research has more explicitly linked the decision to work off the farm with farm income variability and other factors (Mishra and Goodwin, 1997). Mishra and Goodwin's analysis, using a simultaneous-equation Tobit model, confirmed that the off-farm labor supply of farmers is positively correlated with the riskiness of farm income among Kansas farmers. Their results also indicated that off-farm work (for both the farmer and spouse) is positively correlated with off-farm experience and with the degree of leverage associated with the farm. Further, operators of larger farms and those receiving government supports were less likely to work off the farm. In a followup study, Mishra and Goodwin (1998) also found a positive and significant correlation between farm income variability and the decision by farm operators in North Carolina to work off the farm.

Although the focus of this section has been on off-farm employment, off-farm income may be derived from other sources as well (such as interest and dividends). Indeed, several studies have concluded that the low correlation between

financial assets (stocks, bonds, certificates of deposit) and farm assets suggests that diversifying into financial assets may yield important gains in risk efficiency for farm households. A quadratic programming analysis of a representative Illinois grain farm, for example, indicated that various levels of diversification could reduce the relative variability of the farm's rates of return on assets by 15-25 percent compared with holding farm assets alone (Young and Barry). Conversely, other research has focused on nonfarm equity investment in agriculture, generally concluding that investors can gain from inclusion of farm assets in their investment portfolios (Crisostomo and Featherstone; Moss, Featherstone, and Baker).

Other Ways of Managing Risk

The strategies and tools just discussed in detail are by no means all inclusive. Many other diverse strategies for farm risk management are commonly used by producers on their operations. Some of these additional strategies include the following:

- *Adjusting inputs and outputs*— Producers can respond to risk by altering output levels, input use, or some combination of the two. Research indicates that greater output price risk results in lower levels of both input use and final output. Given that preferences toward risk and circumstances can vary greatly across producers, the final input and output levels chosen by producers can, accordingly, vary considerably for individuals in similar situations. (See Sandmo; Hawawini; Ishii; Robison and Barry; and Just and Pope for more detail.)

- *Cultural practices*—Cultural practices can be used to reduce yield and, hence, income risk. One such practice involves planting short-season varieties

Farm household total income has been found to be significantly less variable if producers and their spouses work off the farm.

that mature earlier in the season, protecting against the risk of early frost and yield loss. Supplemental irrigation due to abnormal weather is another means to protect against yield loss.

- *Excess machine capacity*—A farmer may have enough machine capacity so that planting and harvesting crops can occur more rapidly than needed under normal weather conditions. By having such resources, the farmer can avoid delays at either planting or harvest that may reduce yield losses.

Other methods of risk management in farming are also important, and focus on other types of issues than those specific to production, marketing, and finance. Legal risks and issues associated with farm liability, for example, have become increasingly important. In addition, tax concerns are a key issue in managing the income risks associated with year-to-year income flows, as well as estate transfers from generation to generation (Keller; Keller and Rigby-Adcock; Baquet, Hambleton, and Jose). Government payments—such as contract payments under the 1996 Farm Act—can also be used to provide liquidity, for example, or to pay the premium for an options contract or a "buy up" crop insurance policy.

Farmers' Reported Use of Risk Management Strategies

Several surveys of farmers' use of risk management strategies have been conducted over the past 10-15 years. The results vary. Results of the 1996 Agricultural Resource Management Study (ARMS), for example, conducted shortly after passage of the 1996 Farm Act, indicate that operators in the largest gross income categories (more than $250,000 annually) are most likely to use virtually all risk management strategies. In contrast, operators with less than $50,000 in sales were less likely to use forward contracting or hedging. Keeping cash on hand for emergencies and good buys was the number one strategy for every size farm, for every commodity specialty, and in every region.
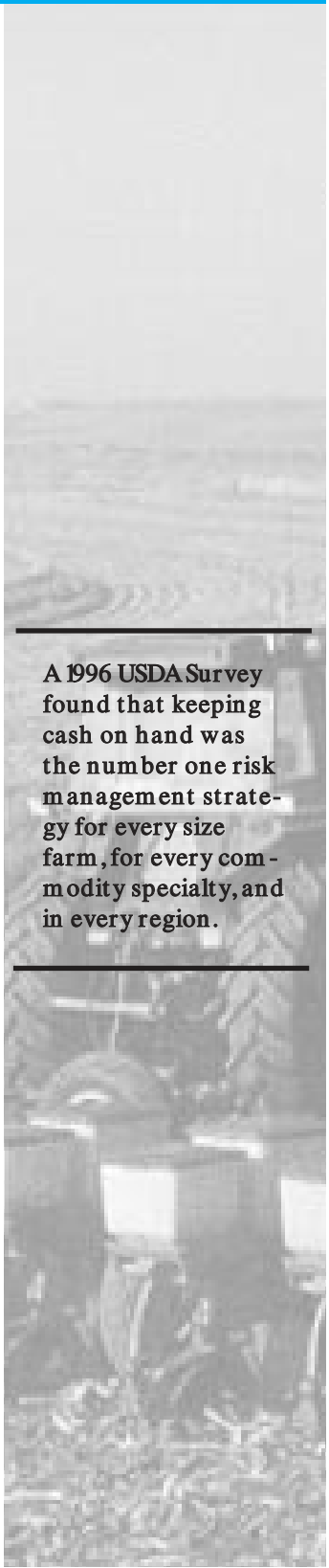
Previous sections in this report have focused on addressing the myriad strategies that producers can use to manage their farm-level risks and their effectiveness. This section, in contrast, addresses the questions: "How have producers used these tools and strategies on their farming operations?" "What factors are associated with farmers' use of different strategies?" Several surveys of farmers' use of various risk management strategies have been conducted over the past 10-15 years. These surveys typically focus on asking producers whether or not they use hedging, crop insurance, and forward contracts, as well as whether they manage risk through diversification, keeping cash on hand, and other strategies.

Two difficulties are present in assessing and interpreting the results of these surveys, which must be kept in mind while reading the results presented in the next paragraphs. First, many of the surveys are focused on specific States or areas. Because different questions are asked of different groups of farmers at different times, it is difficult to compare responses on a "one-for-one" basis across studies or across time.

Second, farmers are typically questioned as to their use of a strategy to manage risk. Some producers may indicate that they use a given strategy (such as diversification or hedging), even though profit maximization (and not risk reduction) may be their primary motivation.

The most comprehensive survey of farmers' use of selected risk management strategies is USDA's Agricultural Resource Management Study (ARMS). Results of the 1996 ARMS survey, conducted shortly after passage of the 1996 Farm Act, indicate that operators in the largest gross income categories (more than $250,000 annually) are most likely to use hedging, forward contracting, and virtually all other risk management strategies. In contrast, operators with less than $50,000 in sales were less likely to use forward contracting or hedging, and significantly fewer reported diversification as a method for reducing risk (fig. 12). Keeping cash on hand for emergencies and good buys was the number one strategy for every size farm, for every commodity specialty, and in every region.

The 1996 ARMS survey also asked producers about the impact of the

> A 1996 USDA Survey found that keeping cash on hand was the number one risk management strategy for every size farm, for every commodity specialty, and in every region.

Figure 12

Farmers' use of alternative risk management strategies by sales class and all United States, 1996
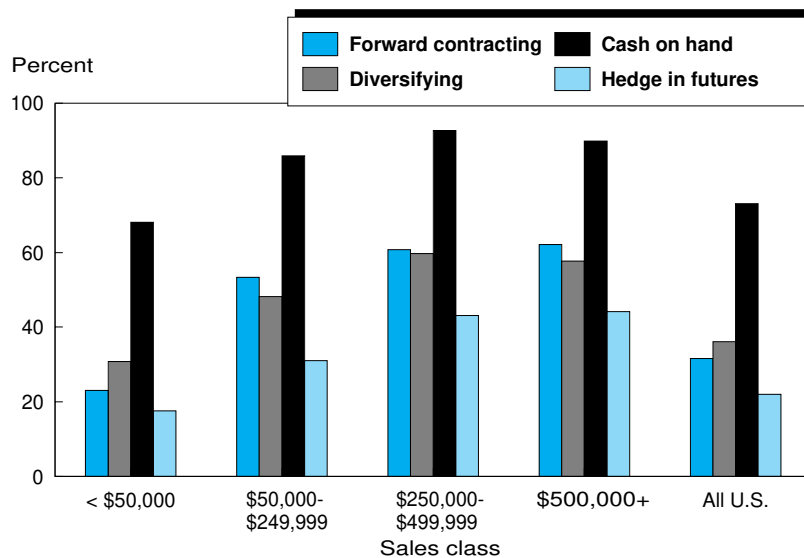
Note: For all sales classes, the principal occupation of the operator may or may not be farming.
Source: USDA, ERS, 1996 Agricultural Resource Management Study, special analysis.

Of producers receiving government payments, 5-8 percent indicated that they increased their use of at least one risk management tool or strategy in 1996 in response to the 1996 Farm Act.

1996 Farm Act in influencing whether or not they were considering the use of new strategies. At the U.S. level, about one-third of the producers responding to the survey reported receiving direct government commodity payments. Of those receiving government payments, between 5 and 8 percent indicated that they increased their use of at least one risk management strategy or tool (forward contracting, futures hedging, use of options, use of insurance, or other strategy) in 1996 in response to the 1996 Farm Act.[23] Responses were fairly consistent across all U.S. regions. With less government intervention in farming and greater trade liberalization, farmers appear to be increasingly relying on forward contracting and other risk management tools to reduce their farm-level risks.

A recent *Farm Futures* survey also questioned its readers nationally as to their use of various risk management strategies. The 690 respondents reflect a nonrandom pool of

the magazine's readers. These readers are generally in the top 10 percent of all U.S. farmers, with about 75 percent located in the Corn Belt and almost all have sales exceeding $100,000 annually. Commonly used strategies reported by a high proportion of these respondents included using government farm programs, diversifying into both crops and livestock, planting varieties with different maturity dates, contracting inputs to lock in a favorable price, buying crop insurance, and using crop-share rental arrangements (table 16).

Several surveys of producers' use of risk management strategies have been conducted by university extension specialists. In a survey conducted in the mid-1990's, Nebraska producers were questioned about their use of alternative marketing tools, including cash forward contracts, hedging with futures, hedging with options, hedge-to-arrive contracts, basis contracts, and minimum price contracts. They were also asked the percentage of their crops for which these tools, if any, were used, with use of a tool considered to be

_____
[23]This is approximately 1-3 percent of all U.S. farmers.

important if it was used to market more than 50 percent of the producer's crop (Jose and Valluru). The results indicate that cash forward and basis contracts were the most commonly used marketing tools for any percentage of the Nebraska producers' crops. Of those using cash forward contracts, about 47 percent indicated the use of this tool to price 75-100 percent of their crop. Similarly, of those using basis contracts, 49 percent indicated use of this tool to price 75-100 percent of their crop.

Among the responding producers participating in Top Farmer Crop Workshops held at Purdue University in 1993, 1994, and 1995, about two-thirds indicated that they used cash forward contracts. Producers participating in the workshops indicated that these contracts were, on average, used to price 20-30 percent of their corn and soybean crops. Hedging was used by approximately 10-20 percent of the participants, depending on the specific crop and year (Patrick, Musser, and Eckman; Musser, Patrick, and Eckman).

Evidence also exists from the Great Plains. A 1992 survey of Kansas producers indicated that over 30 percent of the respondents used forward contracting to price a portion of their wheat, corn, and soybean crops during the 1990-92 period. Corn was hedged in futures most frequently (reported by 11 percent of the respondents), followed by cattle (8 percent of the respondents). Nearly 15 percent of the wheat producers and about 10 percent of the cattle and corn producers had used options compared with less than 5 percent of soybean, grain sorghum, and hog producers (Goodwin and Schroeder).

Several surveys provide information historically on the use of forward contracting and futures hedging, and suggest that the use of these strategies may have increased over time. In a 1986 Wisconsin study, for example, about 20 percent of the respondents had used cash forward contracts at least once in the most recent 5 years, and 8 percent had used futures within that period (Campbell and Shiha). The survey also indicated that large-scale producers were more frequent users of

Regional surveys often point to the common use of cash forward contracts by producers.

Table 16—Results of a *Farm Futures* magazine questionnaire on farmers' use of various risk management strategies, 1997

Tool or strategy	Percentage of respondents indicating use of tool or strategy
	Percent
Used government farm program	69
Diversified operation by raising crops and livestock	39
Planted seed varieties with different maturity dates	39
Contracted inputs to lock in a good price	35
Bought crop insurance	30
Used crop-share land rents	25
Kept a credit line open to take advantage of attractive input prices	20
Used multiyear leases	16
Irrigated	13
Shared expenses with landlord	10
Refinanced loans to take advantage of lower interest rates	8
Hired custom operator to reduce machinery expenses	6
Hired custom operator to improve timeliness of crop operations	6
Diversified by growing crops not normally grown in the area	3
Leased equipment rather than bought	3
Rented equipment rather than bought	2

Source: Excerpted by ERS from Knorr, Bryce A., editor of *Farm Futures* magazine, Testimony before the Subcommittee on Risk Management and Specialty Crops, U.S. House of Representatives, April 10, 1997.

both forward contracting and futures than were small-scale producers.[24] In another study, only 7 percent of Kansas grain producers reported hedging in 1983, and 18 percent had forward contracted at any time in prior years (Tierney; Mintert). Based on a different sample, the Kansas Crop and Livestock Reporting Service reported that less than 5 percent of farmers hedged any of their grain in each of the years 1980-85.

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[24]ARMS survey results from 1983 provide information on the value of sales marketed by various methods regionally, and implicitly support the idea that large-scale producers are more likely to use forward contracts. The ARMS data indicate that between 50 and 60 percent of corn sales delivered at harvest in 1983 in Illinois, Iowa, Minnesota, and Ohio were priced by forward contract, while less than 30 percent of corn sales in Kansas, Michigan, and Missouri were priced using this method (Harwood, Hoffman, and Leath). Similarly, more than 50 percent of soybean sales delivered off-farm at harvest were forward contracted in Illinois and Minnesota in 1982 and 1983 compared with fewer than 25 percent of sales in Kansas and many Southeastern States (Leath). In contrast, less than 15 percent of wheat sales at harvest were forward contracted in 1983 in most major wheat-producing States, including Kansas and North Dakota (Hoffman, Harwood, and Leath).

Data from the 1996 ARMS survey indicate that more farmers in many areas may be using various risk managements strategies—such as forward contracting, diversifying, hedging, or keeping cash on hand—than reported in regional and State-level studies in the early- and mid-1980's (fig. 13). For example, about 40 percent of producers in the Corn Belt and Northern Plains regions used forward contracting and approximately 25 percent used futures in 1996. Producers in the Southern Plains were somewhat less likely to use many of the risk management strategies listed than those in the Corn Belt or Northern Plains, as were producers in the Northeast and Appalachia.

Empirical studies have at times extended survey data and examined the relationship between the use of various strategies and producer characteristics. A study of 41 selected farmers in Indiana in 1985, for example, found that the use of hedging was positively related to the farmer's perception of the income-stabilizing potential

> Data from the 1996 ARMS survey indicate that more farmers in many areas may be using various risk management strategies than in the 1980's.

Figure 13

Farmers' use of alternative risk management strategies by selected regions and United States, 1996
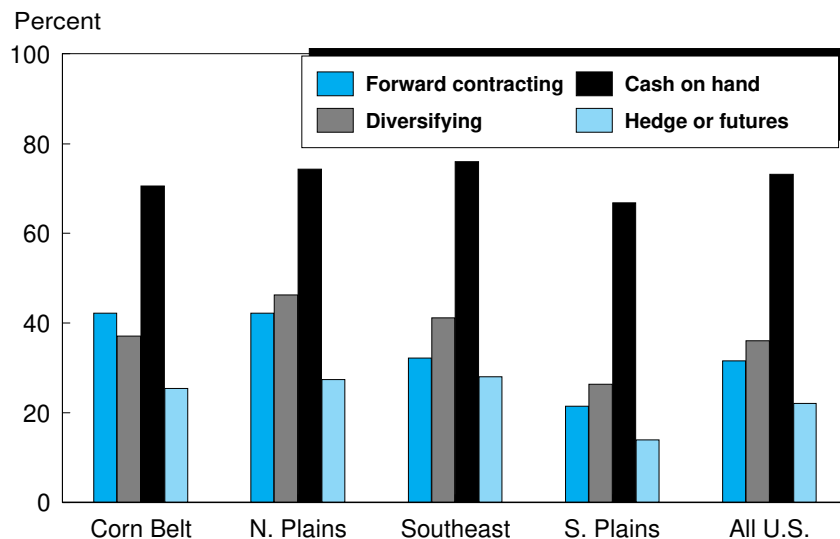
Note: For all regions, the principal occupation of the operator may or may not be farming.
Source: USDA, ERS, 1996 Agricultural Resource Management Study, special analysis.

Risk Management Education Can
Use Many Avenues

Risk management education has been an important initiative, as witnessed by a fiscal year 1998 effort jointly sponsored by USDA's Risk Management Agency, USDA's Cooperative State Research, Education, and Extension Service, and the Commodity Futures Trading Commission. These efforts have focused on the use of a wide variety of workshops, education programs, information events, and research to better help educate producers and understand the needs of farmers in the learning process. These efforts complement longstanding work undertaken in the cooperative extension community (Anderson and Mapp; Schroeder, Parcell, Kastens, and Dhuyvetter).

In theory, a producer's decision to obtain the human capital necessary to adopt a new technology—whether involving a new conservation technique or a new forward pricing strategy—is based on factors related to the expected returns and costs associated with adoption and the producer's risk attitude. Producers evaluate the discounted value of their expected returns from education (net of investment costs) to evaluate whether or not they should participate. If discounted expected net returns are positive, a producer would tend to participate (Ben-Porath). Using an example, discounted expected returns to investment in education fall as the time horizon decreases. Thus, the expected returns to education are expected to decline with the age of the producer, meaning that older farmers are less likely to participate in educational programs than younger farmers.

This theoretical basis was used to evaluate Kansas producers' participation in risk management and marketing education programs in 1992 (Goodwin and Schroeder). This research found, as expected, that more experienced (older) farmers are less likely to participate in educational programs. The percentage of crop acres on the farm, total farm acres, the degree of farm leverage, the educational level of the operator, and a preference for risk were all positively related to participation. Similarly, preference for farm-related education, measured by hours per week spent reading farm publications, also had a significant positive effect on seminar attendance. Importantly, the authors found that participation in marketing and risk management education seminars and programs significantly increased farmers' adoption of forward pricing techniques.

Farmers use many educational sources other than seminar attendance. Ford and Babb, for example, found that farm magazines, other farmers, and family and friends were among the most important information sources for a sample of producers in Indiana, Illinois, Iowa, and Georgia in the 1980's. In another study conducted in the 1980's, researchers conducting a random survey of Ohio cash grain producers found that older farmers and operators of small farms often cited radio and television broadcasts as the most useful source of marketing information, while operators of larger farms and those with at least some college education tended to cite marketing professionals as most useful (Batte, Schnitkey, and Jones).

Further, a nonrandom sample of large, commercial farm operations in the Corn Belt in 1991 found that producers spent an average of $2,578 per year on information sources, and that consultants accounted for 60 percent of total expenditures (Ortmann, Patrick, Musser, and Doster). Despite the importance of consultants, the use of "own farm records/budgets" were the highest-rated information source for production, marketing, and financial decisions for these producers. These results support recommendations by the extension service and others encouraging producers to keep and use farm records and to prepare farm budgets for planning purposes.

A series of questions included on USDA's 1996 Agricultural Resource Management Study provides information on priority educational needs. In this section of the survey, producers were questioned as to changes that they would make in their farming operation under adverse circumstances ("what would you do differently if faced with financial difficulty?"). The respondents were provided a listing of production, marketing, and financial activities from which to choose. Producers in the $50,000 and higher sales classes indicated consistently that they would adjust their costs, improve their marketing skills, restructure their debt, and spend more time on management (see table). These responses indicate the wide-ranging—yet interrelated—risk management education needs of producers, and can be effectively provided by both private and public sector interests.

Changes that producers would make in their operations if faced with financial difficulty, 1996

| Item | Sales Class | | | | |
	Less than $50,000	$50,000-$249,999	$250,000-$499,999	$500,000+	All
	Percent				
Restructure debt	24.3	47.7	45.8	48.7	30.3
Sell assets	31.1	27.8	31.2	28.5	30.4
Use more custom services	7.4	17.5	17.4	19.9	10.1
Scale back	25.6	23.1	20.0	23.7	24.8
Diversify	11.8	22.9	20.9	20.6	14.5
Spend more time on management	18.7	37.7	47.3	44.4	24.3
Use advisory services	18.8	22.1	28.0	26.3	20.1
Adjust costs	33.9	54.0	58.8	57.2	39.5
Improve marketing skills	29.5	47.2	53.1	53.4	34.6

Source: USDA, ERS, 1996 Agricultural Resource Management Study, special analysis.

Farmers' Reported Use of Risk Management Strategies

of hedging, debt position, and farm size (Shapiro and Brorsen). Contrary to expectations, education was found to be inversely related to hedging, a result that may be peculiar to the sample of producers analyzed in the study. In addition, risk attitudes were not significantly related to the use of forward pricing methods.

Other studies of this type have been based on larger participant samples. A survey of 677 Iowa grain, swine, and fed cattle producers in 1988, for example, indicated that use of hedging for grains was positively and significantly related to gross farm sales and the use of other forward pricing tools over the prior 2 years (Edelman, Schmiesing, and Olsen). These same variables also had the greatest significance in explaining use of futures to hedge swine and fed cattle.

In a study of 595 producers participating in USDA's Futures and Options Marketing Program between 1986 and 1988, model results indicate that prior use of forward contracts, possession of a bachelor's degree or above, membership in a marketing club, and gross sales had the greatest positive impact on the probability of

using futures and options (Makus, Lin, Carlson, and Krebill-Prather). A survey of 1,963 Kansas farms in 1992 found that the use of forward pricing techniques is positively and significantly related to years of formal education, cropland acreage, total farm acres, leverage, risk preference, input intensity, marketing seminar participation, and the use of crop insurance (Goodwin and Schroeder).

These studies, by providing information on producer characteristics and the use of forward pricing techniques, suggest strategies for producer education (see box). Operators of larger farms, those that are most highly leveraged, and those with prior experience using forward contracts would be most likely to be interested in using futures or options. In contrast, education on cash forward contracts would likely be more effective for the general farm population than education on futures and options. At least one study has found that the use of marketing clubs (which often emphasize a learning-by-doing approach) appears to be quite effective in introducing producers to futures and options (Makus, Lin, Carlson, and Krebill-Prather).

> Many different characteristics are associated with farmers' use of hedging, including farm size and prior use of forward contracts.

How Farmers Can Reduce Risk: Examples Using Hedging, Forward Contracting, Crop Insurance, and Revenue Insurance

To what extent can hedging, forward contracting, and crop and revenue insurance reduce uncertainty within the year (intrayear) and over longer periods (multiyear), and change farmers' average returns? All of these tools tend to reduce intrayear income uncertainty, but have only small or negligible effects on multiyear uncertainties. Some strategies—such as the combined use of insurance and forward pricing—tend to complement each other in reducing risks. Their risk-reducing effectiveness varies by crop and location, depending on yield variability and the degree to which farm yields and prices move together. In addition, crop and revenue insurance likely increase average returns slightly for most farmers because they are subsidized, but forward contracting and hedging, lacking subsidies, have little direct impact on average or expected returns.
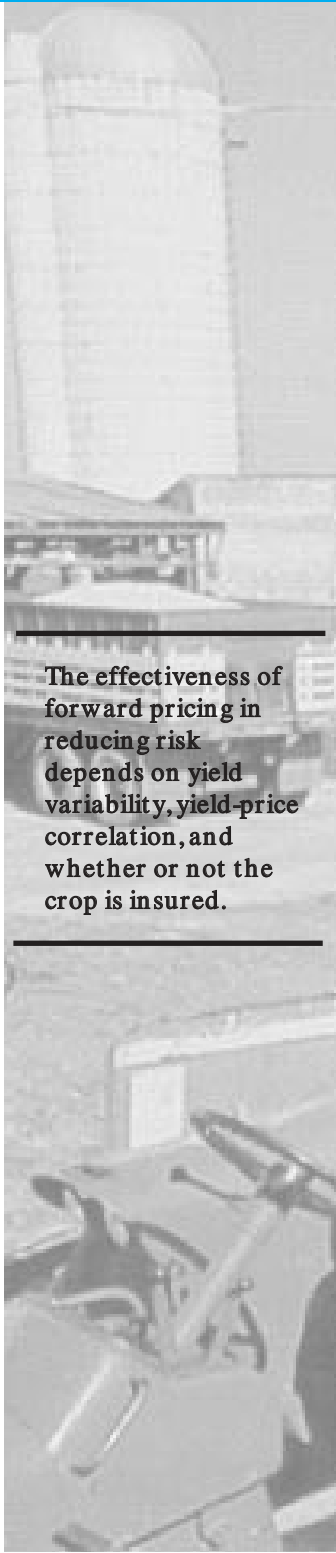
We have seen in the "How Farmers Can Manage Risk" section of this report that risk management strategies can reduce farmers' risk of income loss, at times substantially. This section provides a detailed analysis of the effectiveness of several risk management tools on income uncertainty within the year (intrayear income risk), income uncertainty between years (multiyear income risk), and farmers' average returns.

The analysis focuses on selected tools including futures hedges, cash forward contracts, crop insurance, and revenue insurance, rather than the many tools discussed earlier. There are several reasons. First, forward pricing and insurance are widely available to farmers and among the more effective risk-reducing tools. They are fairly easy to use and involve no commitment beyond the current crop year. Second, their optimal use is somewhat independent of

differences between farms in wealth, debt, rental arrangements, off-farm earning opportunities, and the use of other risk management tools. Third, focusing on this limited set of tools allows results for a few representative farms to have wide applicability.

Effects on Income Uncertainty Within the Year

The many different options available for managing income risk lead to questions about their effectiveness across different producing regions and about how they can best be combined to reduce producers' risks. A producer's choice among strategies is particularly complicated when both price and yield (output) risk is present—the case for a farmer with a growing crop in the field. In this situation, the degree to which strategies, such as forward contracting or hedging, reduce income risk depends on yield variability, the correlation between price and

> The effectiveness of forward pricing in reducing risk depends on yield variability, yield-price correlation, and whether or not the crop is insured.

yield, and whether or not the crop is insured.[25]

Recent research at the Economic Research Service (ERS) examined the effectiveness of several strategies—use of hedging,[26] crop insurance, and revenue insurance—in reducing farmers' income risks over the growing season in various corn-growing locations. These strategies were compared with the use of a "no risk-reducing strategy," which assumes that producers sell their crops at harvest for the local cash market price and do not insure. Four counties with differing yield variabilities and yield-price correlations were selected for the analysis, including the following:

- *Iroquois County*—Located in east central Illinois, this county has relatively low yield variability and a strongly negative yield-price correlation.

- *Anderson County*—In east central Kansas, this county represents an area with relatively high yield variability and a high yield-price correlation.

- *Lincoln County*—In west central Nebraska, Lincoln County represents an irrigated area where both yield variability and yield-price correlation are low.

- *Pitt County*—In east central North Carolina, this county represents an area of relatively high yield variability and low yield-price correlation.

> Revenue risk in corn growing tends to be higher outside than inside the Corn Belt.

_____

[25]As discussed earlier, the absence of yield risk greatly simplifies decisionmaking. In the extreme case, the absence of both yield risk and basis risk means that either forward contracting or hedging can eliminate revenue uncertainty completely. For example, the owner of a harvested crop can lock in a return to storage by contracting for a fixed price at the end of the storage period. When output is known for certain, but basis risk is present, hedging can reduce (but not completely eliminate) income risk.

[26]Although hedging is used in this example, the results associated with forward contracting are similar.

For each county, a "hypothetical" corn farm was specified, and risk reduction was estimated. The risk measure used is the probability of revenues falling below 70 percent of their average or expectation. This measure is unit free (as it is expressed in percentage terms), and facilitates comparisons across farms having different average yields.

The results indicate that a representative corn farm in Anderson County, Kansas, or Pitt County, North Carolina, has a much higher likelihood of very low revenues when no strategy is used (a cash sale at harvest and no crop insurance) than a corn farm in Iroquois County, Illinois, or Lincoln County, Nebraska (fig. 14). The probabilities are 21 percent in Anderson County, 25 percent in Pitt County, 9 percent in Iroquois County, and 8 percent in Lincoln County. The risk of catastrophically low returns is considerably higher in the Kansas and North Carolina counties because yields vary more in those counties than in counties where crops are irrigated (as in Nebraska) or where weather risk is inherently low (as in central Illinois).

In addition, the "natural hedge" (the price-yield correlation) is a factor in explaining risk outcomes. In major producing areas in the Corn Belt, such as in Iroquois County, widespread low yields can significantly increase prices. Conversely, low prices are often associated with bumper-crop years. This negative relationship between prices and yields tends to stabilize farmer revenues in these areas, and contributes to the low risk of loss in Iroquois County. Pitt County, in contrast, is more likely to have low corn prices and low yields (or high prices and high yields) at the same time, making corn revenues inherently more variable. This is because such areas have less impact than the central Corn Belt on national output and prices.

Figure 14
Effect of forward pricing (hedging) and insurance on probability of revenue less than 70 percent of expectation

Probability of revenue less than 70 percent of expectation
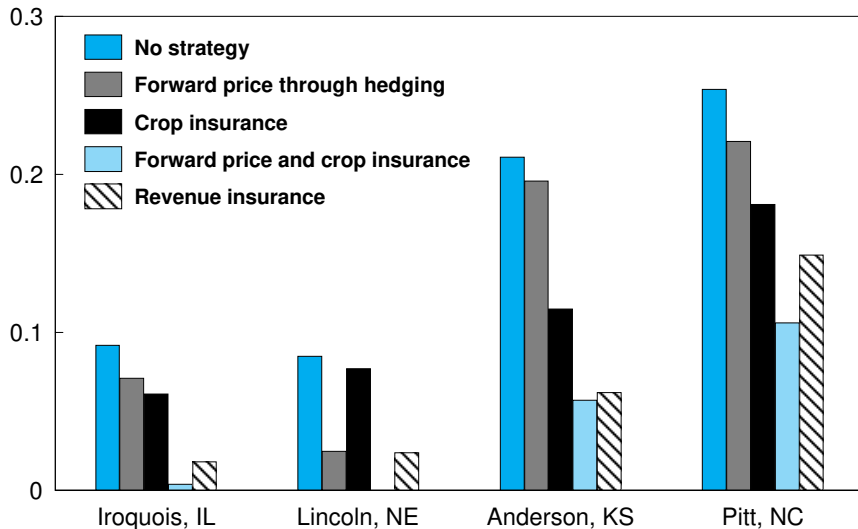
Source: Estimated by ERS.

Hedging an optimal level of expected output (shown by the second set of bars) modestly reduces revenue risk compared with the no-strategy case, although the impact varies greatly across locations.[27] The greatest impact is in Lincoln County, Nebraska, where the probability of income below 70 percent of expected income is reduced from 8 to 2 percent. The impact is most pronounced in this county because it has low yield variability due to irrigation and a weak price-yield correlation. In such locations, establishing an expected price (less harvest basis) greatly reduces revenue risk. Strong yield-price correlations or yield variabilities that exceed price variabilities prevent hedging from greatly reducing risk.

Crop insurance is generally more effective than hedging in reducing the risks of very low revenues across the four counties. When crop insurance alone is used by a producer (the third bar associated with each county),[28] the probability of very low revenues is reduced greatly in all counties except Lincoln County, Nebraska. In this county, irrigation is widely used, which protects against yield short-falls and essentially substitutes for insurance. In the other locations, crop insurance has an advantage over forward pricing because farm-level yields generally are relatively more variable than prices.

The fourth set of bars for each county represents risk reduction when 75-percent crop insurance coverage is combined with optimal hedging. As shown in the figure, risk is reduced substantially in each of the locations, and the use of crop insurance and hedging in concert is much more effective at reducing risk than either tool used alone. By protecting both

Crop insurance reduces risk more than forward pricing in most areas, but the greatest risk reductions are obtained by combining insurance and forward pricing.

[27]Optimal hedging, as defined for the calculations, involves selling December futures in March, with the hedge magnitude set at the level resulting in the greatest risk reduction. More specifically, the optimal hedge ratio–defined as the proportion of expected output that is hedged to minimize risk–ranges from 40 percent in Anderson County, Kansas, to 60 percent in Lincoln County, Nebraska, and Pitt County, North Carolina.

[28]We assumed 75-percent yield coverage.

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yield and price, the combined use of both tools is very effective, particularly in areas with a weak price-yield correlation and high yield variability.

The combined effects of crop insurance and hedging on risk reduction are similar to the situation where producers use revenue insurance (see the last set of bars associated with each county). (The revenue insurance plan assumed here is an intraseasonal guarantee based on individual farm yields and a futures price projection, and does not include a replacement coverage component—only a basic revenue guarantee. Thus, it is more similar to the Income Protection product than to Crop Revenue Coverage.) Such coverage reduces the probability of revenues less than 70 percent of expectations to near zero, except for the risks associated with differences between local prices and futures prices at harvest (e.g., basis risk).

Effects on Income Uncertainty Between Years

Farmers, like everyone else, face uncertainty about future incomes as well as current income. In particular, the payments required on the substantial debt needed to finance investments in land, machines, and equipment make a regular cash flow particularly important in farming. The importance of future income compared with current income partly depends on the farmer's ability to borrow or draw from savings to cover temporary income shortfalls. Producers who have low savings and little borrowing capacity must focus on covering their current expenses and loan obligations. In contrast, those with liquid savings or short-term borrowing capacity sufficient to cover temporary income shortfalls may be more concerned with protecting future income flows or wealth. The question posed in this

section is "Can the use of hedging and crop insurance help protect against income variability beyond the current year?"

The risks in farming would be substantially less if outputs could be insured and priced forward over periods more nearly matching the expected life of the specialized machines and equipment required for production. However, active trading in contracts that mature more than 18 months in the future has not evolved for agricultural commodities, and crop insurance is offered only on the current year's yields. Thus, hedging (or forward contracting) and crop insurance cannot directly assure farmers' incomes beyond 9 to 18 months.

At the same time, the use of crop insurance may *indirectly* help farmers stabilize their incomes around longer term trends. For example, a producer can anticipate expected yields in future years because insured yields change only gradually as each new yield is added to the farm's yield history. Thus, knowing that insurance will be available in future years can reduce uncertainty about those future years' incomes, even though the farmer cannot yet obtain such insurance.

The multiyear variability issues surrounding hedging (or forward contracting) are more complex. Unlike crop insurance, where yield guarantees change only gradually over time, the preplanting futures price quotes at which hedges can be made often vary markedly across years, depending on old crop stocks and anticipated demand. Tomek and Gray concluded that forward prices before planting are more stable from year to year than harvest prices for commodities that cannot be stored between crop years, such as potatoes. They also concluded that little stability was to be gained by forward pricing storable crops, such as grains.

> Combinations of crop insurance and forward pricing are close substitutes for revenue insurance in reducing risk.

Figures 15 and 16 illustrate how futures prices for harvest delivery varied over the season for corn and soybeans for the years 1977-96. The charts suggest that the prices at which those crops can be hedged vary almost as much from year to year as harvest prices.

There is, however, a weak tendency for harvest futures prices for corn and soybeans to be less variable in January than at contract maturity (tables 17 and 18), although this does not seem to be the case for July wheat in the preceding August (table 19).

Figure 15
First of month price for December corn futures, 1977-96 contracts

Cents per bushel

Source: Constructed by ERS from Chicago Board of Trade prices.

Figure 16
First of month price for November soybean futures, 1977-96 contracts

Cents per bushel

Source: Constructed by ERS from Chicago Board of Trade prices.

Forward selling has little effect on the year-to-year variability in prices received by corn and soybean producers.

Table 17—Mean and standard deviation of first-of-month December corn futures prices, 1977-96

Statistic	January	July	December
	Dollars per bushel		
Mean	2.62	2.73	2.54
Standard deviation	0.41	0.52	0.52

Source: Calculated by ERS from Chicago Board of Trade data.

Table 18—Mean and standard deviation of first-of-month November soybean futures prices, 1977-96

Statistic	January	July	November
	Dollars per bushel		
Mean	6.37	6.56	6.29
Standard deviation	0.78	1.07	1.08

Source: Calculated by ERS from Chicago Board of Trade data.

Table 19—Mean and standard deviation of first-of-month July wheat futures prices, 1978-97

Statistic	August	January	July
	Dollars per bushel		
Mean	3.45	3.49	3.50
Standard deviation	0.69	0.65	0.65

Source: Calculated by ERS from Chicago Board of Trade data.

Farmers' costs for hedging or forward pricing are small

Lack of futures contracts with more distant maturities has led to the consideration of using futures contracts that mature in the current year to hedge subsequent year's production. This could be accomplished by selling futures contracts to cover more than 1 year's crop production, and then sequentially rolling over the futures positions to later years as the later maturing contracts became available for trading. Gardner concluded in 1989 that such rollover hedging would not be very effective in reducing risk.

Indeed, the difficulties arising when this year's futures contracts are used to hedge next year's crops was demonstrated in 1996. Some corn and soybean producers who had entered hedge-to-arrive contracts on their 1995 crops, and lost out on the subsequent price rise, hoped to roll over the contracts to allow delivery of 1996 crops. How-ever, the low prices of futures on 1996 crops compared with 1995 crops made such rollovers unprofitable. Moreover, the elevators involved were anxious to settle the contracts, close out their futures hedges, and recover the large margin deposits that had been required.

Effects of Hedging, Forward Pricing, and Insurance on Average Returns

While many risk management tools involve trading off considerable expected return to reduce risk, forward pricing and insurance often can reduce risk with little or no sacrifice in average returns. Indeed, the use of crop insurance may increase average returns over time for many farmers due to the Government's subsidization of many crop and revenue insurance products. The costs of forward pricing, while not zero, generally are small. Thus, the farmer's optimal forward pricing and insurance strategy often can be closely approximated by minimizing risk.

The subsidization of crop and revenue insurance policies creates an interesting situation regarding the expected returns to producers. Crop (and revenue) insurance premiums are set so that expected

indemnities are approximately in balance with total premium. Total premium is shared between the farmer and the Government, with the Government paying 41.7 percent of the total premium cost at the 65/100 coverage level. In addition, the Government pays for any excess of indemnities over total premium (excess losses) in the event of disasters. Thus, subsidization of these programs causes indemnities to exceed producer-paid premiums, resulting in increased average returns to farmers as a group over the long run.

Based on these concepts, an indicator of a farmer's expected return to obtaining crop-yield insurance or crop-revenue insurance is the amount of indemnity per dollar of producer-paid premium. For crop years 1994-97, this return measure (in aggregate, across all crops and regions) ranged from $0.87 to $2.14 per dollar of farmer-paid premium (table 20). Over time, rates charged for insurance have been increased to bring expected indemnities closer in line with total premiums, reducing over the long run the likelihood of substantial excess losses to the Government. When total indemnities are divided by total premiums (including the subsidy), the resulting data in recent years are well below 1.0.

As can be seen from the subsidy structure, those producers who confront the highest total premium receive the largest premium subsidy because the dollar value of the premium subsidy is calculated as a percentage of total premium. Total per acre premium may be high due to the yield risk associated with production of that crop in the area, the value of the crop, and other factors. Figure 17 maps the per acre premium subsidy for wheat, in dollar value terms, across major growing areas in the United States. As examples, farmers in Montana received a premium subsidy of $2.85 per acre for 65/100 coverage, while wheat growers in North Dakota received an average subsidy at the 65/100 level of about $2.66 per acre.

In contrast to crop and revenue insurance, where government subsidies result in increased incomes on average for most participants, hedging and forward contracting may lower average incomes due to commissions or other costs, or from slightly lower prices received (see earlier box, "The Cost of Forward Pricing," p. 35). On the other hand, forward pricing may raise farmers' income if any of the following hold: (1) the farmer can time sales to hit higher than average prices; (2) reduced risks obtained through forward pricing allow the farmer to borrow at lower interest rates and/or expand operations; or (3) price information provided by futures quotes enables the farmer to make better decisions about production or storage.

Because of subsidization, crop-yield insurance and crop-revenue insurance result in increased average returns to farmers as a group over the long run.

Table 20—Indemnities, premiums, and loss ratios, 1994-97[1]

Item	1994	1995	1996	1997
	Million dollars			
Indemnities:				
Total	601	1,400	1,342	947
Premiums:				
Total	949	1,087	1,409	1,425
Producer-paid	694	654	856	872
	Ratio			
Loss ratios (no units):				
Based on total premiums	0.63	1.29	0.95	0.66
Based on producer-paid premiums	0.87	2.14	1.57	1.09

[1]Data for 1995-97 are based on buyup policies only.

Source: Calculated by ERS from USDA, Risk Management Agency, Crop Insurance Actuarial Information Public Access Server, FTP download page, http://www.act.fcic.usda.gov/actuarial/ftpdwnld.html

Figure 17

Illustration of the per acre premium subsidy, for wheat implicit in 65/100 crop insurance coverage, selected counties and States, 1996

Subsidy per acre

Less than $1.00
$1.01 to $2.00
$2.01 to $3.00
Greater than $3.00
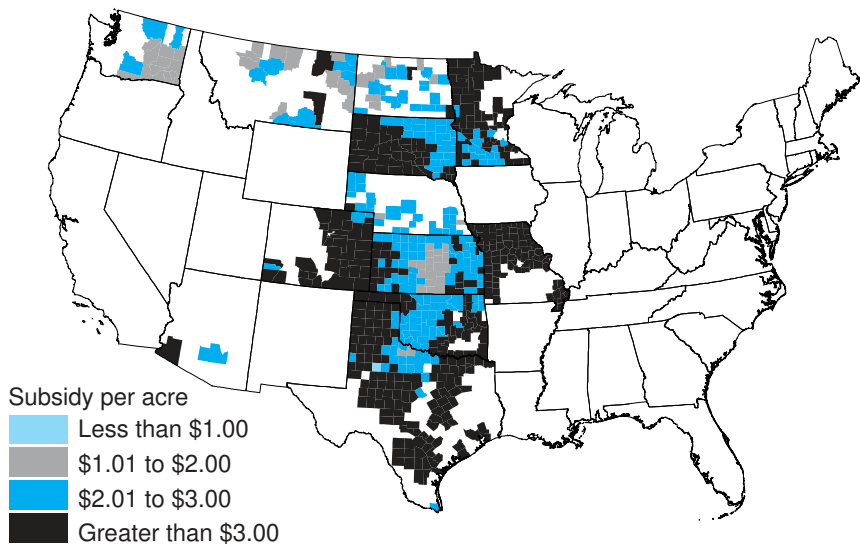
Note: Shaded areas include counties with at least 500 acres planted to wheat.
Source: Estimated by ERS from USDA, Risk Management Agency, electronic experience and yield database, 1997.

Farmers and other hedgers may profit by adjusting positions to take advantage of anticipated price changes—but only if they have superior price forecasting ability.

If the farmer can forecast futures price changes, hedges can be timed and adjusted to take advantage of the forecast. For example, if the futures price is expected to rise, a smaller short hedge or no hedge may be indicated. Alternatively, if the futures price is expected to fall, a larger short hedge may be indicated. The possibilities for timing trades are unlimited, ranging from hedging as soon as the futures or options contract is opened for trading on the exchange to simply selling at delivery. Futures contracts for corn, soybeans, and wheat are now listed for trading up to 3 years before delivery, although trading volume generally is light for contracts maturing more than 18 months in the future. Moreover, a farmer might change his/her futures position several times during the year, particularly if he/she were very confident in predicting prices.

To profitably time hedges requires the same price forecasting skills as pure speculation. Forecasts can be derived in many ways, ranging from simply looking for repeating

patterns in price behavior (technical analysis) to analyzing supply/demand conditions (fundamental analysis). Grossman and Stiglitz noted that when information is costly, markets cannot reflect all possible information, which leaves room for speculative profits for those with superior access to information or analytical ability. Indications are that some speculators do profit, but the majority apparently lose (Zulauf and Irwin).

The difficulties in forecasting futures price changes can be visualized by examining historical futures price behavior, which reflects traders' expectations for the market price at contract maturity. As new information becomes available in the market, expectations change. Seasonal movements in the December corn and November soybean futures contracts for 20 years are shown in figures 15 and 16, with each line in the figures connecting successive beginning-of-month futures prices for one contract over the 12 months preceding the contract's maturity date. Gaps in the lines

reflect the transition to each successive year's harvest contracts.

The figures show that futures price movements over the season differ markedly from year to year. In 13 of the 20 years, for example, prices fell from January (the first month of trading) to December for the corn contract, and from January to November for the soybean contract. The average declines were $0.08 for corn and $0.08 for soybeans (see tables 17 and 18). In comparison, the July wheat futures prices increased from the preceding August to July in 11 of 20 years by an average of $0.05 (table 19).

The figures suggest that corn and soybean futures prices tend to peak in midsummer. For example, the average price of the December corn future on July 1 during the 1977-96 period was $2.73 per bushel, while the average price on December 1 was $2.54. Producers who routinely sold forward in early July thus averaged a $0.19 larger return per bushel than those who routinely sold immediately after harvest in December. November soybean prices exhibited a similar pattern during 1987-96, but not during the 1977-86 period.

If such seasonal patterns continued, pure speculators as well as producers could profit easily by routinely selling in July and buying in November or December. As more traders followed this practice, however, July prices would be driven down and harvest prices would be driven up, diminishing the potential for trading profits. Indeed, such profit potentials can be expected to virtually disappear under the intense competition of futures trading. The result would be an "efficient market," where the current price captures all available information about the price to be expected at contract maturity.

There is much difference of opinion among those who advise farmers about timing sales in forward markets. Numerous studies have found possibilities for profits from particular strategies. Other studies show that futures markets appear to be quite efficient, leaving little room for profiting from timing trades. In reviewing the various studies, Zulauf and Irwin conclude that, for most producers, such strategies have limited ability to enhance income.

Can farmers convert lower risks obtained through hedging into higher average incomes? This depends on how much risks are lowered, on the farmer's financial situation, and on whether his or her lender is willing to increase loans when the farmer hedges or prices forward.

Do futures quotes provide information that farmers can use to improve production and storage decisions? For example, can farmers gain by storing if and only if the difference between the price for the future that matures at the end of the storage period exceeds the current futures price by more than the marginal cost of storage? Heifner (1966) found some evidence that this would work for storage, as did Tomek. However, others have found little evidence to support this possibility for producers (Irwin, Zulauf, and Jackson).

Forward pricing does not directly raise average prices received for most farmers, but the resulting lower risks may allow returns to be raised indirectly.

Some Practical Aspects of Farm Risk Management

To get desirable combinations of risk and return, farmers must selectively and carefully use the various risk management tools available to them. Only tools that have good prospects for reducing income uncertainty or increasing expected income are candidates. This section considers certain practical aspects of risk management, which are easily overlooked or contrary to intuition.

Farmers often must choose between higher average returns and lower risks.

Risk management implies different things for different people, depending on their attitudes toward risk, their financial situations, and the opportunities available to them. In some cases, managing risk involves minimizing risk for a given level of expected output or revenue. In other cases, it involves keeping risk within bounds while seeking higher expected returns. More generally, the goal of risk management is to obtain the best available combination of expected income and income certainty, given the individual's resources and risk preferences.

Farmers Often Are Willing To Accept Higher Risks To Obtain Higher Incomes

Farming, like any business enterprise, involves taking risks to obtain a higher income or higher satisfaction than might be obtained otherwise. Some farmers appear to virtually disregard risk. But for most, the amount of risk that can be accepted is limited. Thus, risk management is not a matter of minimizing risk, but of determining how much risk to take, given the farmer's alternatives and preference tradeoffs between risk and expected return.

To use an example, consider a producer who has just harvested 10,000 bushels of corn and is exam-ining three alternatives: (1) selling the crop and placing the income in a certificate of deposit (CD); (2) storing the corn until March, or (3) selling the crop and using the returns to custom feed cattle. Figure 18 shows expected outcomes for the three strategies in terms of expected profit on the horizontal axis and the probability of return less than $25,000 on the vertical axis. The CD provides zero probability of loss and the lowest expected profit, the cattle feeding alternative offers the highest risk and highest expected return, and the storage alternative is in the middle.

For farmers having similar wealth and farming situations, the most risk averse would likely choose the certificate of deposit. Those who are less risk averse would be more likely to choose storage. The least risk-averse farmers would tend to choose feeding cattle, the riskiest choice among the alternatives, but also the strategy with the highest expected return. In short, optimal choices under risk for producers in similar situations can differ widely among individuals.

Crop Insurance and Forward Pricing Generally Can Reduce Income Uncertainty at Very Low Cost

Reducing risk generally involves some cost or reduction in expected

Figure 18
Risk and return for alternative uses of a 10,000-bushel corn crop

Probability of return < $25,000
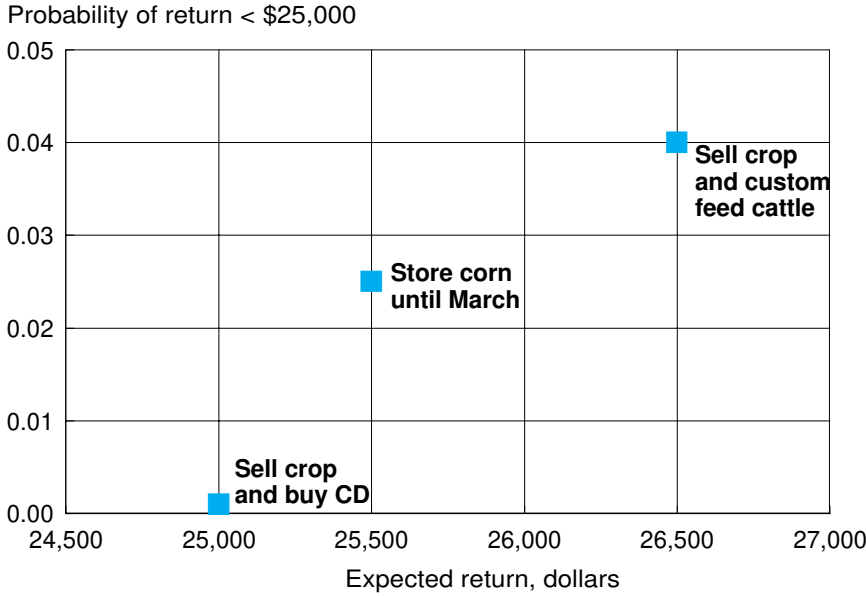
Source: Hypothetical example developed by ERS.

income. Consider Farmer Smith, for example, who is contemplating diversification, but knows that his expected net returns are maximized by planting continuous cotton. By diversifying into other crops, all of which have fairly stable (but relatively low) yields, Farmer Smith estimates that he reduces his average net return by about 15 percent. He calculates that the standard deviation in his income, however, is likely to be about 20 percent lower because the net returns to the various different crops he is considering are less than perfectly correlated. In this example, undertaking a risk-reducing strategy results in substantially lower net returns to Farmer Smith, which he must weigh relative to the benefits of lower income risk.

In contrast, strategies, such as hedging in futures, buying options, or forward contracting with a local elevator, tend to lower risk with little change in expected net returns. The low cost of forward pricing occurs because futures prices exhibit little bias, meaning that the price for each trade close-

ly approximates the price then expected to prevail when the contract matures. Most studies have found little or no bias in futures prices for commodities, such as grains, with active trading and substantial long as well as short hedging, but not all analysts agree (see Zulauf and Irwin).

Farmers who hedge directly in futures incur costs for commissions and interest forgone on margin deposits, but these generally sum to less than 2 percent of the value of the product. When options are used, a premium must be paid but, on average, the option holder gets the premium back as gains from exercising or selling the options. Farmers' costs also typically are low when crops are forward priced through contracts with local buyers. No commissions or margins are required from the farmer, although the buyer typically incurs such costs to hedge his or her position. Many country elevators appear willing to bear these costs in order to assure a timely flow of commodities into their facilities. Some may pass along part of their hedging costs to farm-

Crop insurance and forward pricing are ways to lower risk with little sacrifice in expected returns.

ers through a wider basis and thus a slightly lower price for forward contracts than expected to prevail at harvest time.

Unlike most risk management tools, crop-yield insurance and the new crop-revenue insurance products—which are subsidized by the Government—provide a special case where income risk is reduced *and* expected returns are enhanced. Because the private companies delivering policies to farmers are reimbursed directly for their selling expenses (which include agent sales commissions and data processing costs), such expenses are not incorporated in the total premium. Moreover, the total premium is also subsidized by the Government, meaning that total indemnities exceed farmer-paid premiums over time. As a result, buying crop-yield or crop-revenue insurance raises average returns as well as reduces risk for most participating farmers. In short, the relationship between risk and returns depends on the given tool or strategy, and the unique situations confronted by individual producers.

> Crop insurance and hedging typically can reduce probabilities of revenues less than 75 percent of average by about half, depending on yield variability and price-yield correlation.

Risk Reduction From Forward Pricing Can Be Quite Small for Farms With High Yield Variability or Strongly Negative Yield-Price Correlations

Farmers can reduce their price uncertainty through several mechanisms, including hedging in futures or options or entering into cash forward contracts. The effectiveness of these forward pricing tools, however, can vary greatly, depending on the yield risks faced by the given farmer, the interactions between price and yield, and the other risk management tools that are used on the operation. Table 21 illustrates the effectiveness of hedging and crop insurance on farms that have different price-yield correlations and yield variabilities. Although futures hedging is used as a proxy in the table for all types of forward pricing strategies, results for hedging with commodity options, or forward contracting, would be similar.

More specifically, the table illustrates how crop insurance and futures hedging work together to reduce risks for farmers in differ-

Table 21—Effect of futures hedges and crop insurance on the probability of returns less than 75 percent of expectations

Price-yield correlation	Risk strategy	Yield coefficient of variation (standard deviation/mean)				
		0.1	0.2	0.3	0.4	0.5
0	None	0.14	0.19	0.21	0.24	0.25
	MPCI	.12	.15	.18	.18	.20
	MPCI+hedge	.06	.08	.12	.14	.18
-0.1	None	.14	.17	.20	.22	.25
	MPCI	.12	.14	.15	.17	.18
	MPCI+hedge	.06	.06	.11	.15	.17
-0.2	None	.13	.17	.20	.21	.24
	MPCI	.11	.13	.14	.16	.17
	MPCI+hedge	.06	.06	.10	.14	.16
-0.3	None	.13	.15	.19	.20	.23
	MPC	.11	.12	.13	.14	.16
	MPCI+hedge	.06	.06	.10	.13	.14
-0.4	None	.12	.15	.18	.19	.22
	MPCI	.10	.11	.10	.13	.14
	MPCI+hedge	.06	.07	.10	.11	.13
-0.5	None	.11	.14	.17	.19	.20
	MPCI	.10	.10	.09	.12	.13
	MPCI+hedge	.06	.07	.08	.10	.11

Source: Estimated by ERS.

ent risk situations. Yield risk increases from left to right across the table, while negative yield-price correlations increase down the left column. The entries in the cells reflect the probabilities of revenues falling below 75 percent of expectations. Price volatility is assumed to be 20 percent, regardless of yield variability or the price-yield correlation.

Because the table is constructed using a wide range of parameters, it applies to many different farming situations. Corn producers in the Corn Belt, who confront fairly low yield variability and a strongly negative price-yield correlation, tend to lie near the lower left corner of the table. Dryland wheat growers and corn growers in areas distant from the Corn Belt tend to lie near the upper right corner. Producers who irrigate tend to lie near the upper left corner, as they experience low yield variability and tend to be outside major producing areas. The lower right corner, in contrast, is of minor interest because yield-price correlations are generally not strong where yield variability is highest.

Three risk management strategies are shown: no insurance or hedging (denoted by "none" in the table), crop insurance at the 75-percent yield coverage level ("MPCI"), and crop insurance combined with a minimum-risk futures hedge ("MPCI + hedge"). Risk-reducing effectiveness can be gauged by comparing the probabilities of low revenues across the different strategies. As expected, the risk-reducing effectiveness of crop insurance increases as yields become more variable. In contrast, the added risk reduction obtained by hedging an insured crop diminishes as the yield coefficient of variation increases. Thus, the effects of changes in yield variability or price-yield correlation on the total risk reduction obtained from insurance and hedging can differ

substantially for farmers in different situations.

Elimination of Deficiency Payments Increases Risks for Many, But Not Necessarily All, Producers of Program Crops

Replacing commodity programs (deficiency payments and supply management programs) with fixed Agricultural Market Transition Act (AMTA or contract) payments and planting flexibility in the 1996 Farm Act dramatically altered decades of significant government intervention in the markets for program crops.[29] Deficiency payments were in effect between 1973 and 1995, and provided compensation in years of low prices by paying farmers the difference, if positive, between a pre-established target price, and the higher of the average market price for the crop over a specified period or the loan rate. These payments averaged over $5 billion annually between 1990 and 1995, and accounted for more than one-half of total farm program outlays over that period (USDA, 1998). Their elimination has raised concerns about greater risk in farming, with some observers arguing that the elimination of deficiency payments— and their replacement with "contract payments"—removes the safety net in low-price years (Conrad).

One recent study, however, indicates that the effectiveness of deficiency payments in stabilizing income risk varied, depending on the correlation between individual and aggregate yields and the relationship between aggregate yields and prices (Glauber and Miranda). The study suggests that deficiency payments were least effective in stabilizing farmers' incomes in

Negative price-yield correlations reduce the effectiveness of deficiency payments in stabilizing farmers' incomes.

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[29]Program crops eligible for deficiency payments between 1973 (the start of the program) and 1995 included corn, sorghum, barley, oats, wheat, cotton, and rice.

areas where farm-level yields and prices are strongly negatively correlated. In the study, about 29 percent of corn acreage and 26 percent of wheat acreage was found to be located in counties where revenues were destabilized by deficiency payments. In several situations—such as that for Illinois corn and North Dakota wheat—the proportion of output in counties where income was destabilized was greater than 50 percent (table 22).

The relationship between local yields and prices is significantly related to the effectiveness of deficiency payments. In major producing areas, high prices tend to offset low yields (which can be strongly correlated with national yields), and vice versa. In the absence of deficiency payments, this relationship tends to stabilize revenues and is termed the "natural hedge." In major producing areas where the natural hedge is strong, deficiency payments may actually increase income variability by providing producers higher-than-average incomes in high-yield (low-price) years, while having only a small effect in low-yield (high-price) years. Outside major growing areas, the natural hedge is weaker, and deficiency payments tend to stabilize incomes compared with situations where producers depend only on the market. Thus, in markets where incomes are inherently most variable, deficiency payments, by stabilizing price, work to reduce revenue risk.

Demand considerations are also important in judging the risk-reducing effectiveness of deficiency payments. Such payments may provide even producers in major growing areas some protection against prolonged slumps in demand, such as might accompany a worldwide downturn in economic conditions. Thus, deficiency payments would likely be relatively more effective in protecting producer incomes in years like 1998, when large worldwide supplies and low prices resulted in weak demand for several U.S. crops.

> Research has found that deficiency payments reduced farm revenue variability on less than one-third of U.S. corn and wheat farms.

Table 22—Effects of deficiency payments on farm revenue variability

Crop	State	Average percentage of production destabilized
		Percent
Corn	Iowa	33.1
	Illinois	50.7
	Nebraska	25.1
	Minnesota	35.9
	Indiana	23.1
	Ohio	4.0
	South Dakota	52.3
	Wisconsin	19.4
	Missouri	53.8
	Michigan	0.0
	United States	28.9
Wheat	Kansas	37.4
	North Dakota	74.6
	Montana	1.4
	Oklahoma	3.6
	South Dakota	46.9
	Texas	15.7
	Colorado	6.5
	Minnesota	74.9
	Washington	0.0
	Nebraska	9.4
	United States	25.5

Source: Excerpted by ERS from Glauber, Joseph W., and Mario J. Miranda, "Price Stabilization, Revenue Stabilization, and the Natural Hedge," Working Paper, U.S. Dept. Agr., Office of the Chief Economist, and Ohio State University, October 30, 1996.

Spreading Sales Before Harvest Tends To Reduce Risk, While Spreading Sales After Harvest Tends To Increase Risk

Spreading sales over time appears, on the surface, to be a form of diversification, which is a sound means for reducing risk. Indeed, spreading pre-harvest sales of a crop over time to increase the amount forward priced as yield or output becomes more certain can reduce risk for producers in many cases. The risk-reducing effectiveness of such forward pricing actions depends on the degree of price-yield correlation and the yield variability confronted by the farmer. For most farmers, the minimum-risk forward sale at the time of planting is no more than 70 percent of the expected crop, and it may approach zero for farmers with a strong "natural hedge" or very high yield variability (Grant; Miller and Kahl; Lapan and Moschini; Coble and Heifner). It is higher for farmers with low yield variability or who carry crop insurance.

In contrast, once production is known with certainty, risk is minimized by fixing the price regardless of the time of delivery, if a competitive forward market is available. This is because forward prices tend to follow "random walks," meaning that successive changes are determined by chance and independent of one another. When producers postpone establishing the price for such activities as grain storage or livestock feeding, where output is known, risk actually is increased because the final price realized equals the current price, plus a series of unknown random price changes. Postponing the pricing of all or part of an assured output makes sense only for producers who confidently expect that prices will rise in the future. In such cases, the farmer takes greater risk in the hope of obtaining a higher expected return.

Forward Pricing May Help Reduce Price Uncertainty Not Only in the Current Year, but Also in Future Years

Forward pricing with futures, options, or cash forward contracts reduces or eliminates price uncertainty between the time the forward sale is made and delivery time. It serves farmers mainly as a tool for reducing uncertainty about prices for commodities to be sold, or bought, within the year. However, forward pricing offers some opportunities to reduce price uncertainty over a longer horizon. Futures for corn and soybeans are now traded up to 2 or more years ahead of maturity, allowing farmers to forward price more than 1 year's crop. However, low trading volume in the later maturing contracts means that hedgers must be more concerned about liquidity and possible price bias.

Another possibility is to hedge future years' anticipated production in contracts that mature this year or next, and then roll over the positions to contracts that mature in successive years as they become available for trading. For example, a farmer might sell contracts in this year's harvest time futures to cover parts of several future years' expected crops, and then successively roll over the contracts to later maturing contracts that would be bought back as each future year's crop is marketed. Although superficially appealing, this strategy holds little promise either for increasing average returns or decreasing risk. It is ineffective in projecting a high price for the current year's crop into future years because rolling over the contract generally would involve buying the old crop future at a high price and selling the new crop future at a lower price. Moreover, such interyear rollover strategies hold little promise for reducing risk due to the variability

> 'Rolling over" futures positions to cover parts of several futures years' expected crops holds little promise either for increasing average returns or reducing risk.

of interyear spreads (price differences between contracts maturing in different years) (see Gardner, 1989). In addition, trading costs would be substantial.

Simply forward pricing each year's expected output before planting reduces uncertainty about returns in future years, to the extent that planting time forward prices diverge less from longrun equilibrium prices than do harvest time prices. Tomek and Gray showed that such forward selling was more effective in stabilizing returns for nonstorable commodities, such as potatoes, than for storable commodities, such as grains and oilseeds. For storables, a large or small crop tends to affect prices for more than 1 year because stocks are carried from one year to the next. The current year's price is affected to the greatest extent by a very large or very small crop, but the impacts can resonate over a period of years. Table 23 shows that corn and soybean futures prices for harvest delivery have been slightly less variable from year to year in March than at harvest.

The effectiveness of forward pricing in reducing uncertainty about returns in future years depends on yield variability and the yield-price correlation, as previously shown for current-year risks. Finally, forward pricing cannot protect against longer term variations in demand, such as might arise from business cycles.

> Forward pricing is more effective in stabilizing returns from nonstorable than from storable crops.

Futures Prices Provide Information Useful in Making Production and Storage Decisions

Futures prices, which represent the best estimates of well-informed traders at a given point in time, reflect the foreseeable effects of potential production adjustments. Thus, no forward pricing rule based on price levels, or price levels relative to costs, is likely to be consistently profitable for either hedgers or speculators (see Zulauf and Irwin). In other words, the farmer who bases forward pricing decisions on future price levels generally takes on more price uncertainty than necessary with little assurance of a higher average return.

Although the level of futures prices relative to costs provides little guidance about whether to price forward, it does provide information useful in deciding whether to produce or store. The appropriate rule is "produce (or store) when variable costs can be covered," not "price forward only when costs can be covered." Variable production costs are those costs, such as for seed, fertilizer, custom work, and rent for land or storage space, that vary with the level of output. This contrasts with fixed costs, such as interest and depreciation on buildings and equipment, which must be met regardless of the level of output. If the price covers both fixed and variable costs, production likely will be profitable. If it covers variable costs, but not fixed costs, loss is minimized by producing. If it

Table 23—Standard deviations of first-of-month prices for harvest-time futures in March and at harvest-time, 1977-96[1]

Month	December corn contract	November soybean contract
	Dollars per bushel	
March	0.41	0.77
Last full month of trading	.51	1.11

[1]Calculations are based on annual observations.

Source: Calculated by ERS from Chicago Board of Trade data.

does not cover variable cost, loss is minimized by not producing.

Forward markets allow price setting and delivery at different times. Being able to price forward gives farmers opportunities to lock in returns when storage is profitable. Indeed, farmers can use market signals, *together with forward pricing*, to both increase their profits and reduce the risks associated with crop storage. For example, farmers can profitably store crops after harvest if their own storage costs are lower than the "market price of storage." The price of storage offered by the market is indicated by spreads between futures prices for successive months.

To illustrate, suppose that it is November and a farmer with new crop corn in a local elevator is deciding whether to store the corn until March. The local price for corn is $2.40 a bushel, the March futures contract is trading for $2.75, and the expected basis in March is $0.20 under. The elevator storage charge is $0.025 per bushel per month, all of which is variable cost since it can be avoided by not storing. Should the farmer store or sell the corn? The expected return from storage is $2.75 - $0.20 - $2.40, or $0.15 per bushel. The cost of bin space for 4 months is 4 * $0.025, or $0.10 per bushel. In addition, the farmer must cover the cost of interest on the grain. If the farmer's interest rate is 6 percent, the interest cost per bushel is 0.06 * 1/3 year * $2.40 = $0.05 per bushel. Thus, storage is a break-even operation at current prices. This is because the cost of bin space plus interest ($0.10 + $0.05 = $0.15) equals the expected return from storage. If the local cash price should fall relative to the March future, then storage would be profitable; otherwise, it is not profitable. The producer can minimize the risk of storage by entering a fixed price

forward sale for delivery in March, or by selling March futures contracts in an amount equal to the quantity in storage.

The importance of variable costs can also be illustrated by considering a second producer, who is holding corn in his own bins, which otherwise would be empty. The costs for the bin, including interest, depreciation, and insurance, are fixed and cannot be avoided by not storing. This farmer's variable (or added) cost for storing an additional 4 months is $0.02 per bushel for insurance on the grain and insect control plus $0.05 per bushel for interest, equaling $0.07 per bushel. The expected return above variable cost for storage is $0.15 - $0.07, or $0.08 per bushel. If the $0.08 more than covers the total cost of the bin, the farmer would make a profit. If the total cost associated with the bin exceeds $0.08 per bushel, the producer would be sustaining a loss over the long run. The farmer is, however, still better off to store than to leave the bin empty because he can cover his variable costs, plus a portion of his fixed costs that would be incurred anyway.

The return per month from corn storage declines after harvest as month-to-month storage charges accumulate (see table 24 for an example). In the example, a producer with storage costs of 2-1/2 cents per bushel per month, for example, might expect to store his crop until May. At this point in time, the per month expected return to storage is $0.05 3/4 divided by 2 months, or $0.0288, while the variable cost of storage is nearly equal, at $0.025. A prudent policy for this farmer involves selling the May or July futures contract when the corn was put in storage in October, and holding it until the expected return from storage no longer covers storage costs. At that time, the producer would sell the corn crop in the cash market and buy back the

Production or storage is advisable only when the forward price covers variable costs.

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Table 24—Expected return from storing corn between futures delivery months, 1997 crop[1]

Futures contract month	Futures price, 10/31/97	Difference from previous delivery month	Storage interval	Expected return to storage
	$ per bushel		Months	$ per bushel per month
December 1997	2.79 ¾	--	--	--
March 1998	2.89 ¼	0.09 ½	3	0.0317
May 1998	2.95	0.05 ¾	2	0.0288
July 1998	2.99 ¼	0.04 ¼	2	0.0212
September 1998	2.91	-0.08 ¼	2	-0.0412

-- = Not applicable.
[1]Estimates based on October 31, 1997, futures prices.
Source: Calculated by ERS from Chicago Board of Trade data.

futures contract. On average, those farmers with the lowest costs of storage would want to store for a longer period of time. Unlike decisions about crop production or livestock feeding, decisions regarding storage can be reversed at any time when the forward price no longer covers costs.

Revenue Insurance Generally Does Not Fully Substitute for Forward Pricing

By protecting against both price declines and low yields, revenue insurance partially substitutes for both forward pricing and crop insurance. It does not in all cases, however, completely replace hedging or forward contracting in protecting against price declines. This is because revenue insurance guar-

antees no more than 75 percent of expected revenue (85 percent for some commodities and locations), whereas forward pricing can guarantee as much as 100 percent of the expected market price. Thus, for example, a farmer with irrigated land and low yield risk (or a farmer with crop insurance) might reduce risk to a greater degree by guaranteeing 100 percent of the expected price with an at-the-money put option (or a short futures hedge) than with the purchase of 75-percent revenue insurance.

Recent research shows how revenue insurance as well as crop insurance affects risk-minimizing hedge ratios for corn producers (Coble and Heifner). The effect of different levels of yield and revenue insurance on optimal hedge

> Yield insurance tends to raise, and revenue insurance tends to lower, optimal hedge ratios, but these effects are small at insurance levels up to 75 percent.

ratios for Iroquois County, Illinois, is illustrated in figure 19, where the minimum-risk hedge without insurance is estimated to be 25 percent (see Heifner and Coble, 1998). The figure shows that with 50-percent yield or revenue insurance, the optimal hedge is essentially the same as with no insurance. With 75-percent yield insurance, the optimal hedge ratio rises to 40 percent, while it remains at near 25 percent with 75-percent revenue insurance. In other words, 75-percent revenue insurance has little impact on the optimal amount to hedge. The figure shows that higher levels of revenue insurance, if available, would reduce optimal hedge ratios.

Figure 19
Effect of insurance level on optimal hedge ratio, Iroquois County, Illinois

Optimal hedge ratio
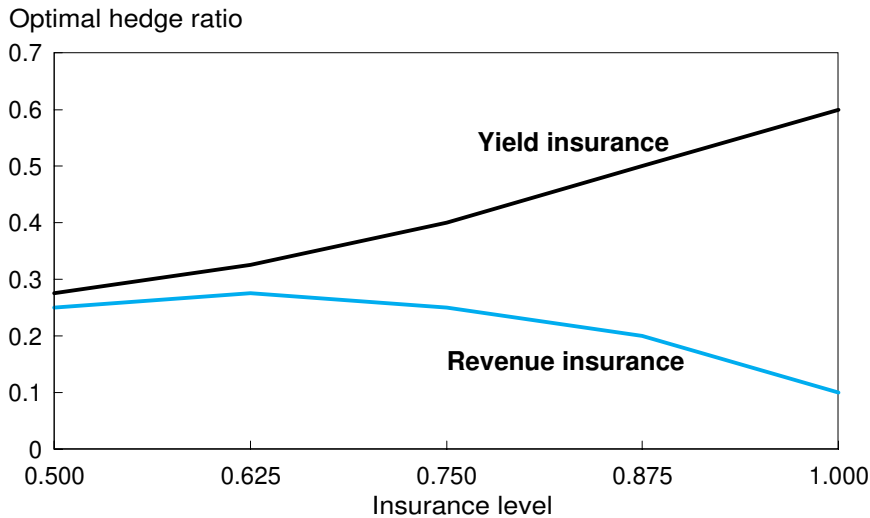
Note: Assumes expected utility maximization for a farmer with 500 acres of corn, a $300,000 net worth, and average risk aversion.
Source: Estimated by ERS.

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Glossary[30]

"Actual Production History" (APH) yield—The basis for determining the producer's guarantee under either the multi-peril crop insurance program or most federally subsidized revenue insurance policies. The producer's APH yield is calculated as a 4- to 10-year simple average of the producer's actual yield on the insured parcel of land. If a producer does not have actual yields, the series (up to 4 years) is filled in with a "transition yield," based on either county or program yields.

Actuarial soundness—An insurance term describing the situation where indemnities paid out, on average, equal total premiums and the insurance program "breaks even."

Adverse selection—A situation in which an insured has more information about his or her risk of loss than does the insurance provider, and is better able to determine the soundness of premium rates.

Agricultural Resource Management Study (ARMS)—A probability-based annual survey of farmers and ranchers in the contiguous 48 States conducted by the Economic Research Service and the National Agricultural Statistics Service of USDA. The sample data can be expanded by using appropriate weights to represent all farms. The ARMS was previously known as the Farm Costs and Returns Survey (FCRS).

Basis—The difference between a specific futures price and a specific cash price for the same or related commodity.

Basis contract—A forward contract that calls for the price to be determined by applying a specified difference (the basis) to a particular futures contract price to be observed at a future time, as selected by one of the trading parties. Both contracting parties are left with price level risk until the final price is established.

Basis risk—The risk associated with an unexpected widening or narrowing of the basis between the time a hedging position is established and the time that it is lifted.

Call option—An option contract that entitles the holder the right, without obligation, to buy a futures contract at a specified price during a specified time period. The buyer pays a premium to the seller for this right. A call option is purchased to protect against, or with the expectation of, a potential rise in the futures price.

Cash renting—A type of land rental agreement between a landlord and tenant. Typically, the tenant rents the land for a fixed amount per acre that is pre-specified in the agreement.

Certainty equivalent—The certain return that would provide an individual the same level of satisfaction as a specified uncertain prospective return. The largest certainty equivalent outcome is preferred when comparing alternative risky choices.

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[30]For additional definitions on futures and options terms, see Heifner, Glauber, Miranda, Plato, and Wright; Commodity Futures Trading Commission.

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Coefficient of variation (c.v.)—A measure of variability in a data set. It is calculated as the standard deviation of the data, divided by the mean (or average). The lower the c.v., the smaller the relative variability of that data set.

Commodity Futures Trading Commission—The Federal agency established in 1974 that regulates futures and commodity options trading under the Commodity Exchange Act.

Contract payments—Direct payments to producers of program crops authorized by the 1996 Farm Act. These payments are in effect for fiscal years 1996-2002, totaling $35 billion over that time horizon. Contract payments do not vary depending on market prices or production levels. They are also known as Agricultural Market Transition Act (AMTA) payments.

Cooperative State Research, Education, and Extension Service—A U.S. Department of Agriculture agency that helps fund and administer research and educational programs done jointly with land grant universities and other institutions.

Deficiency payments—A government payment initiated under the 1973 Farm Act and eliminated with the 1996 Farm Act. Deficiency payments were made to farmers who participated in wheat, feed grains, rice, or cotton programs. The payment rate (expressed in per bushel or per pound terms) was based on the difference between the price level established by law (the target price) and the higher of the market price during a period specified by law or the price per unit at which the Government provided loans to farmers to enable them to hold their crops for sale at a later date (the loan rate). The payment equalled the payment rate, multiplied by the acreage planted for harvest, up to the maximum payment acres, and then multiplied by the program yield established for the particular farm.

Deferred price contract—(1) Any forward contract where price is left to be determined later. (2) A forward contract that transfers ownership before price is determined.

Delayed price contract—A forward contract that transfers ownership of a commodity from a farmer to a buyer while providing for price to be set and payment to be made at a later date. May also be called a "deferred price contract" or a "price later" contract.

Delayed payment contract—-A forward contract that establishes price and transfers ownership of a commodity from the farmer to the buyer while providing for payment to be made at a later date. Used by farmers for shifting income between years for tax purposes. May also be called a "deferred payment contract."

Efficient market—A market in which price fully reflects all relevant information.

Empirical probability distribution—A table or figure describing the likelihood of events that is based entirely on observed relative frequencies without making any assumptions about the shape of the distribution.

Exercise (or strike) price—The price specified in an option contract at which the option holder can buy (call) or sell (put) a futures contract.

Farm Service Agency—The U.S. Department of Agriculture agency that administers various farm programs, including contract payments and farm ownership and operating loans.

Flat (or fixed) price contract—A forward contract that establishes the specific price to be paid by the buyer to the seller.

Forward contract—An agreement between two parties calling for delivery of, and payment for, a specified quality and quantity of a commodity at a specified future date. The price may be agreed upon in advance, or determined by formula at the time of delivery or other point in time.

Forward pricing—Agreeing on price for later delivery. "Forward pricing" is used broadly in this report to refer both to hedging in futures or options, or forward contracting.

Futures contract—An agreement priced and entered on an exchange to trade at a specified future time a commodity, or other asset, with specified attributes (or in the case of cash settlement, an equivalent amount of money).

Hedge-to-arrive contract—An agreement between a farmer and buyer that calls for the farmer to deliver and the buyer to pay for a commodity on a future date at the current futures price plus a differential (basis) to be determined at delivery time. Some hedge-to-arrive contracts allow for rolling over to later maturing futures contracts. From a farmer's standpoint, a hedge-to-arrive contract is similar to a short hedge in that the futures price is fixed but the basis is left to be determined later.

Hedging—Taking a position in a futures or options market which tends to reduce risk of financial loss from an adverse price change.

Idiosyncratic risk—Risk that is specific to an operation and that is not common to all producers in the area. A broken water pipe, for example, reflects idiosyncratic risk.

In-the-money option—An option contract that would yield a positive return to the holder if exercised. An option is in-the-money if the strike price exceeds the market price for a put, or is less than the market price for a call. The magnitude of this difference is the intrinsic value of the option.

Indemnity—The compensation received by an individual for qualifying losses paid under an insurance program. The indemnity compensates for losses up to the level of the insurance guarantee.

Intrinsic value—The value of an option if immediately exercised. The amount by which the current price for the underlying commodity or futures contract is above the strike price of a call option, or below the strike price of a put option.

Leverage—Use of borrowed funds to finance a business, such as farming, or an investment.

Liquidity—The extent to which assets can be quickly converted to cash without accepting a discount in their value. An asset is perfectly liquid if its sale generates cash equal to, or greater than, the reduction in the value of the firm due to the sale. Illiquid assets, in contrast, cannot be quickly sold without a producer accepting a discount, reducing the value accruing to the firm by more than the expected sale price.

Long hedging—Purchasing a futures contract or a call option to offset the risk of a price increase in the cash market.

Margin—The money or collateral guaranteeing the customer's futures or options trades, deposited by a customer with his or her broker for the purpose of insuring the broker against a loss on an open futures contract. The initial margin is the amount required to

enter a futures position. The maintenance margin is the amount required to continue a futures position without receiving a margin call.

Margin call—A request from a broker to a customer for additional margin to cover the customer's futures position after a price change unfavorable to the customer. The broker may close out the customer's position if the margin call is not met.

Marketing contract—A verbal or written agreement between a processor or handler and a grower establishing an outlet and a price, or a formula for determining the price, for a commodity before harvest or before the commodity is ready to be marketed.

Minimum price contract—A contract providing the farmer with protection against a decline in price below a minimum level, while leaving the final pricing until a later date.

Moral hazard—The ability of an insured to increase his or her expected indemnity by actions taken after buying the insurance.

Natural hedge—A tendency for yield and price deviations from expectations to offset each other in their effects on crop revenue. This tendency is strongest in major growing areas.

Normal distribution—A symmetric, bell-shaped mathematical distribution that is widely used in statistical analysis because it closely approximates many observed distributions. Normal distributions are fully described by their means and variances.

Off-exchange option—An agreement between two parties entered without the services of an organized exchange that gives one party the right to buy or sell an asset at a specified price over a specified time interval.

Optimal hedge—The size of the futures or options position that minimizes a hedger's risk. Often expressed as a ratio of the futures or options position to the cash position. Yield risk and/or basis risk generally cause the optimal hedge ratio to be less than 1.0.

Option contract—A contract that gives the holder the right, without obligation, to buy or sell a futures contract at a specific price within a specified period of time, regardless of the market price of the futures.

Out-of-the-money option—An option contract that cannot be profitably exercised at the current market price. An option is out-of-the-money if the market price exceeds the strike price for a put or is less than the strike price for a call.

Premium—An amount of money paid to secure risk protection. Option buyers pay a premium to option sellers for an options contract. Similarly, the purchaser of an insurance policy pays a premium in order to obtain coverage.

Price-yield correlation—A statistical measure of the closeness of the relationship between prices and yields.

Production contract—A verbal or written agreement between a processor (integrator) and a grower that usually specifies in detail the production inputs supplied by the processor, the quality and quantity of a particular commodity that is to be delivered, and the compensation that is to be paid to the grower. In return for relinquishing complete control over decisionmaking, the producer is often compensated with a price premium or lower market risk.

Put option—An option contract that gives the holder the right, without obligation, to sell a futures contract at a specific price (the "strike price") within a specified period of time, regardless of the market price of the futures. A put option normally is purchased to protect against a cash price decline (hedger) or with the expectation of a futures price decline (speculator).

Reinsurance—A method of spreading insurance companies' risk over time and space. For approved agricultural insurance programs (Federal crop insurance and approved revenue insurance products), the Risk Management Agency shares the risk of loss with each private insurance company delivering policies to producers. Private reinsurance is also available, where one insurance company transfers part of the risk to another company by agreements, which vary as to the terms applicable to the risk transferred.

Revenue insurance—An insurance program offered to farmers that pays indemnities based on revenue shortfalls. As of 1998, three revenue insurance programs were offered to producers in selected locations. These three programs (Crop Revenue Coverage, Income Protection, and Revenue Assurance) are subsidized and reinsured by the Risk Management Agency.

Risk—Uncertainty in outcomes that are not equally desirable to the decisionmaker, and that may involve, among other outcomes, the probability of making (or losing) money, harm to human health, repercussions that affect resources (such as credit), or other types of events that affect a person's welfare. Risk is uncertainty that "matters."

Risk aversion coefficient—A measurement of an individual's preference for a certain outcome over an uncertain outcome with equal expected value.

Risk Management Agency—The U.S. Department of Agriculture agency that provides oversight, subsidization, and reinsurance for approved risk management programs, such as the Federal multi-peril crop insurance program and various revenue insurance programs.

Share renting—Renting land under a contract that calls for the crop to be divided between the tenant and the landlord in fixed percentages. May also provide for sharing certain inputs.

Short hedging—Selling a futures contract to offset the risk of a price decline in the cash market.

Standard deviation—One of the most widely used measures of dispersion, calculated as the square root of the variance.

Time value—The portion of an option's premium that exceeds the intrinsic value. It reflects the probability that the option will move in-the-money, or deeper in-the-money. The longer the time remaining until expiration of the option, the greater its time value.

Unbiasedness—Characterizes an estimate, forecast, or forward (including futures) price that is neither systematically high or low, but correct on average.

Uncertainty—Lack of sure knowledge or predictability because of randomness.

Utility function—A mathematical expression that can be used to represent a decisionmaker's risk preferences.

Variance—One of the most widely used measures of dispersion, calculated as the average squared deviation from the mean or expectation.

Appendix 1: Techniques for Measuring Risk

Understanding how risk is measured is a starting point for helping farmers make choices about the most appropriate strategies for their individual situations. This appendix provides information on the different approaches that can be used to quantify risk, and illustrates how probability distributions can be used to characterize the outcomes associated with risky choices. In order to make the best decisions for their individual operations, farmers and other decision-makers often use historical and current information about prices, yields, weather conditions, and other variables to estimate future risk.

Risk must be quantified in order to evaluate whether various risk management tools and strategies are effective in achieving producers' risk reduction goals. This process involves measuring uncertainty and quantifying the relationship between uncertainty and an individual's well being. This section discusses how risks can be quantified and provides representative estimates for selected locations—focusing on price variability, yield variability, and the correlation between prices and yields (the extent to which prices and yields move together).

Measuring Uncertainty

The measurement of uncertainty involves estimating the probabilities of future outcomes. Estimates may be made, for example, of the probability of yield less than 100 bushels per acre, the probability of price falling below $2.25 per bushel, or the probability of revenue less than $200 per acre. More generally, one would like to estimate the joint probability distribution of yield, price, and revenue so that one might, for example, specify the probability of revenue falling below any specified level. To estimate such probabilities, we generally start by observing his-

torical outcomes and separating random variability from systematic variability.

To illustrate, appendix figure 1 (and appendix table 1) show corn yields for Iroquois County, Illinois (in the east central part of the State) for the years 1956-95. The jagged line links the actual yields, averaged across the county, for each year, while the straight line represents the systematic upward trend in yields. This upward trend may be considered to be a "known" source of variation that will repeat itself in the future. It has been caused by several factors, including the development of higher yielding varieties and the introduction of improved chemicals and fertilizers. In contrast, the yield deviations from trend—mainly caused by weather—constitute the random variability.[31]

Quantifying yield randomness generally involves summarizing what

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[31]Whether the yields shown are adequately represented by a linear trend can be questioned. Linear yield trends often are used for forecasting, but there is no strong reason why yield trends should be linear, or follow any other specific mathematical form. Trend projections inevitably involve a degree of subjectivity, not only in choosing the mathematical function to use, but also in selecting the years to be included in calculating the trend.

Appendix figure 1
Actual and trend-adjusted corn yields, Iroquois County, Illinois, 1956-95

Bushels per acre
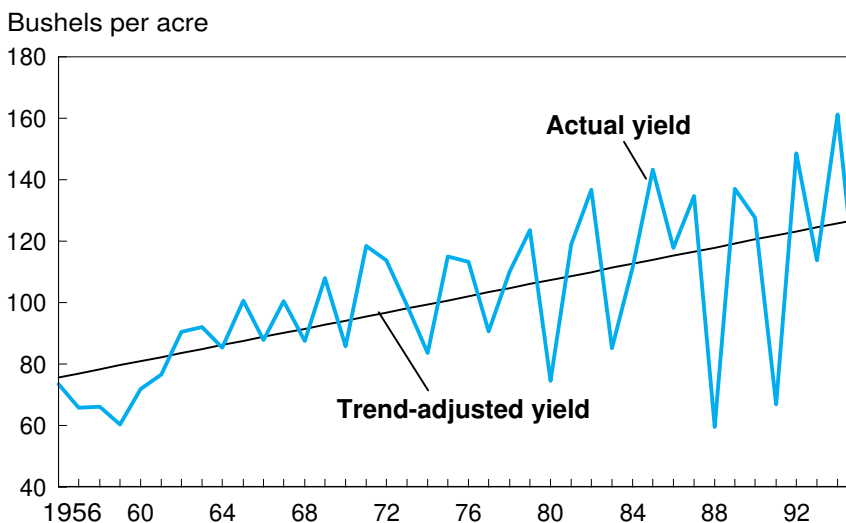
Note: Actual yield is county average.
Source: Constructed by ERS from USDA, NASS electronic county yield files, 1997.

is known about deviations from expected yields, as measured by trend. Randomness can be described by converting such deviations into a frequency distribution, or histogram, as depicted in appendix figure 2.[32] Each bar on the figure shows the number of times that yield deviations from trend in Iroquois County fell within a particular 10-bushel-per-acre range. For example, the bar labeled "-5 to +5" illustrates that yields fell between -5 bushels and +5 bushels from trend in 7 of the 40 years between 1956 and 1995, and the bar labeled "5 to 15" illustrates that yields fell between 5 bushels and 15 bushels above trend in 9 of the years. Frequencies are greatest near the middle and the least at the lower and upper ends, which is typical of yields, prices, and revenues. This is because extreme weather events— such as the 1988 drought—are less likely than weather events having a more modest effect.

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[32]To construct appendix figure 2, randomness was assumed to have remained unchanged, although appendix figure 1 suggests that it may be increasing over time.

The degree of randomness is reflected in the width of the distribution and in the number of observations that are distant from the mean. Note that appendix figure 2 is not symmetrical (like the traditional bell curve), but that the lower tail is longer than the upper tail. This so-called negative skewness is typical of yield distributions. This shape occurs because devastating weather can cause very significant yield declines (as low as zero), while very good weather is likely to only moderately boost yields above trend due to the physiological limitations of the plant.

For many purposes, a single number is a more convenient measure of randomness (or dispersion) than is an entire distribution. The most widely used measures of randomness are the variance and its square root, the standard deviation. Variance is the average squared deviation from the mean, or trend. By using the variance of deviations from trend, a large part of the systematic variation is removed.

One problem with the variance and standard deviation is that

Appendix table 1—Calculation of yield variability for Iroquois County, Illinois

Year	Actual yield	Trend-adjusted yield	Deviation (actual minus trend)
		Bushels per acre	
1956	73.4	75.7	-2.2
1957	65.8	77.0	-11.1
1958	66.1	78.3	-12.2
1959	60.2	79.6	-19.4
1960	71.8	80.9	-9.1
1961	76.6	82.3	-5.7
1962	90.4	83.6	6.9
1963	92.0	84.9	7.1
1964	85.3	86.2	-0.9
1965	100.6	87.5	13.0
1966	87.8	88.9	-1.0
1967	100.4	90.2	10.2
1968	87.6	91.5	-3.9
1969	108.0	92.8	15.2
1970	85.8	94.1	-8.3
1971	118.6	95.5	23.1
1972	113.8	96.8	17.0
1973	99.1	98.1	1.0
1974	83.5	99.4	-15.9
1975	115.0	100.7	14.2
1976	113.3	102.1	11.2
1977	90.7	103.4	-12.7
1978	110.1	104.7	5.4
1979	123.6	106.0	17.5
1980	74.6	107.3	-32.8
1981	118.9	108.7	10.2
1982	136.7	110.0	26.7
1983	85.3	111.3	-26.0
1984	111.4	112.6	-1.3
1985	143.2	113.9	29.3
1986	117.9	115.3	2.6
1987	134.7	116.6	18.1
1988	59.6	117.9	-58.3
1989	137.1	119.2	17.8
1990	127.6	120.5	7.0
1991	66.9	121.9	-54.9
1992	148.6	123.2	25.5
1993	113.7	124.5	-10.8
1994	161.2	125.8	35.4
1995	99.0	127.1	-28.1

Note: The equation estimated from these data for detrending yields is: $E(Y_t) = 1.72 + 1.32(T)$, where T is the year, minus 1900.

Source: Calculations made by ERS from USDA, NASS, electronic county yield files, 1997.

they are difficult to interpret without knowing the level or magnitude of the underlying variable. A variance of 10 bushels, for example, has quite different implications for the tightness of the distribution when the mean yield (adjusted for trend) is 50 bushels per acre than when it is 160 bushels. As a result, proportional variability—or variability relative to the mean—is often measured to facilitate comparisons. The most commonly used measure of relative variability is the coefficient of variation, which equals the standard deviation divided by the mean.

The variance (or alternatively, the standard deviation or coefficient of variation) is a good measure of variability for approximately symmetric, bell-shaped distributions. It fully describes the variability in a normal distribution, which is a particular bell-shaped mathematical distribution that closely approximates many observed distributions. Most yield distribu-

Appendix figure 2
Frequency distribution of corn yield deviations from trend, Iroquois County, Illinois, 1956-95

Frequency (number of occurrences)

10-bushel ranges below and above trend
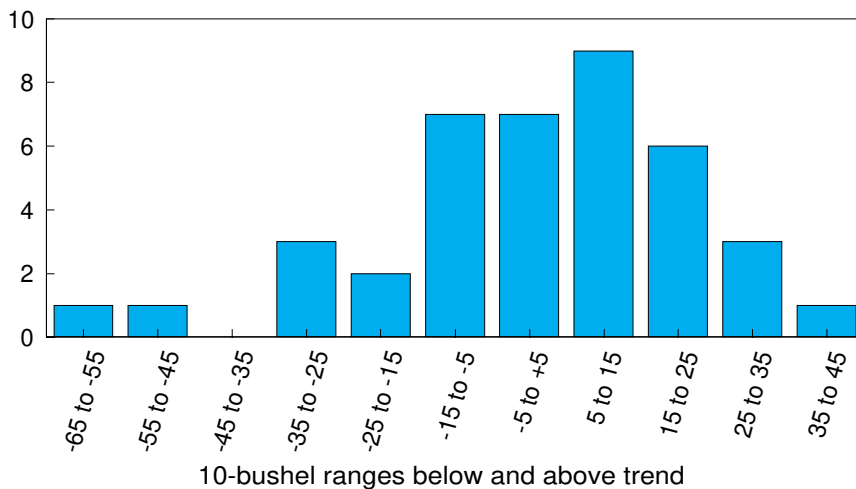
Source: Constructed by ERS from USDA, NASS electronic county yield files, 1997.

tions, however, appear to be non-normal with long lower tails as shown in appendix figure 2. Moreover, some tools used to manage farmers' risks, particularly crop insurance and commodity options, impose non-normality by setting bounds or limits on the lower tails of the yield or price distributions realized by the farmer. Producers generally prefer yield and price distributions that are bounded from below because it limits their losses. However, the standard deviation may not provide a satisfactory measure of risk under such distributions, which clearly are non-normal.

Other measures of variability or dispersion may be useful for distributions that are clearly non-normal. One such measure is the probability of outcomes below some critical level. The probability of yield less than 70 percent of its expectation, for example, might be a useful measure of risk for some farmers. If the trend yield is 127 bushels per acre, the 70 percent point would equal 0.70 * 127, or 89 bushels per acre. This is 38 bushels below trend. In appendix figure 2, the probability of such a

yield (or lower) is two occurrences in 40 years, or a probability of 2/40 = .05. Individual farmers might choose higher or lower cutoff points, depending on their differing financial circumstances and degrees of risk aversion.

Estimating Probabilities of Future Events

Farmers, like other decisionmakers, are fundamentally concerned with randomness in future events, not the distribution of past outcomes as illustrated in the previous section. They are concerned about the probabilities of outcomes to be observed in the future and the effects of these outcomes on their economic welfare. The probability associated with any given outcome indicates the strength of one's belief that such an outcome will occur, ranging from zero (which represents no possibility) to 1 (representing absolute certainty).

Two sources of information about such probabilities are available: logic and experience. In pure games of chance, logic rules. For example, in flipping a coin, two equally likely outcomes are possi-

ble—heads or tails—and thus a probability of 0.5 can be assigned to each. In business decisions, however, historical observations often must be relied upon to estimate probabilities. Each of the frequencies illustrated in appendix figure 2, for instance, could be divided by the total number of years, 40, to obtain estimates of the probabilities of yields within each of the intervals. The resulting distribution is often referred to as an "empirical" probability distribution because it is estimated through the use of a specific set of historical observations. Suppose that the projected mean yield is 130 bushels per acre. Referring to appendix figure 2, the estimated probability of the yield falling between 115 and 145 bushels (that is, between -15 and +15 bushels from the trend expectation) is 23/40 = 0.575.

An alternative way to describe dispersion graphically is to plot probabilities of outcomes falling at or below specific values. This is called a cumulative distribution. Appendix figure 3 is a cumulative distribution of the Iroquois County yield deviations. Cumulative distributions are particularly useful for representing continuous variables because probabilities can be read directly from the vertical axis instead of by summing areas under a curve. Cumulative distributions are useful in safety-first analysis and stochastic dominance analysis, which are discussed in the next section of this report.

Relative frequencies derived from historical observations are not necessarily the best estimates of future probabilities. Sometimes, the decisionmaker has additional information—such as regarding recent rainfall or temperature conditions—which needs to be taken into account. Moreover, most historical series include events that have small probability of recurring, or fail to catch events, that though uncommon, have a non-zero likelihood. To reduce the impacts of such sampling errors, forecasters often impose smoothness and a degree of symmetry by fitting mathematical distributions to historical observations.

The normal distribution, which is symmetrical and bell-shaped, is frequently used as an approxima-

Appendix figure 3
Cumulative probability of corn yield deviations from trend, Iroquois County, Illinois, 1956-95

Cumulative probability

10-bushel ranges below and above trend
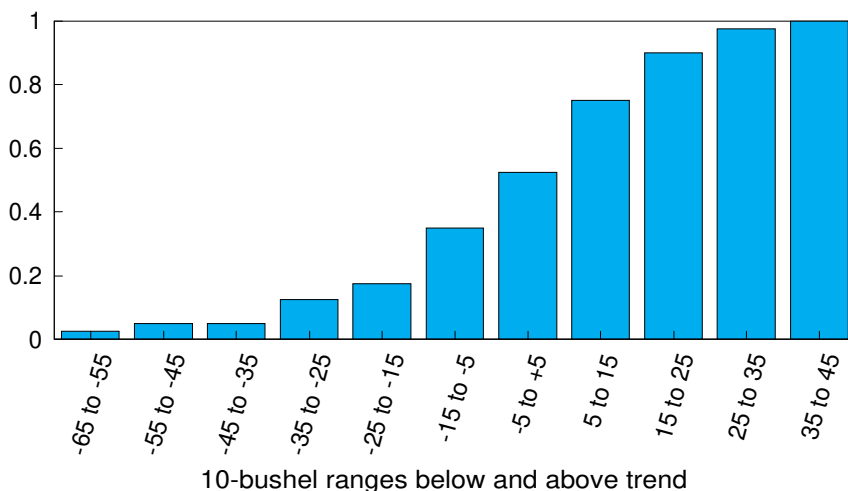
Source: Constructed by ERS from USDA, NASS electronic county yield files, 1997.

tion. Although yield distributions are typically negatively skewed, as discussed earlier, the normal distribution is computationally convenient because it is fully described by its mean and variance. In addition, yield deviations from normality may not be great. The mean and variance in appendix table 1, for example, can be used as parameters of a normal distribution of yield deviations from trend. Appendix figure 4

illustrates realized corn yields for Iroquois County over the 1956-95 period and a projected probability density function for the 1997 yield. The projected distribution reflects the belief that the true probability function is continuous and recognizes that observed historical observations between 1956 and 1995 are only a sample of the possible outcomes.

Appendix figure 4
Projected 1997 corn yield distribution for Iroquois County, Illinois, based on 1956-95 observations

Bushels per acre
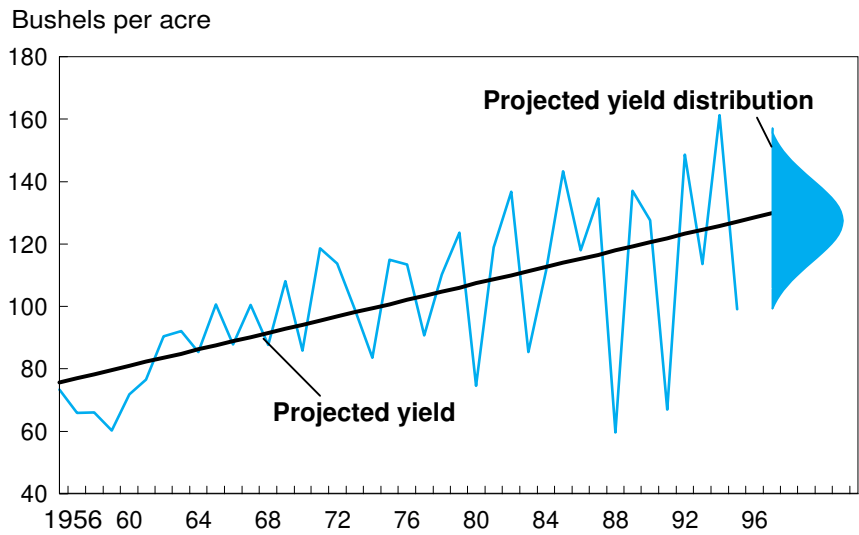
Source: Constructed by ERS from USDA, NASS electronic county yield files, 1997.

Appendix 2: Analytical Tools for Assessing the Effectiveness of Risk Management Strategies

Different modeling approaches are used by economists to capture decisionmaking in risky situations. These approaches are based on the idea that each risky strategy offers farmers a different probability distribution of income, and that determining the best strategy involves describing the different distributions and developing rules to choose among them. These approaches differ, however, in the ways in which they incorporate risk attitudes, and in the degree of flexibility allowed in specifying risk-return trade-offs.

The following sections examine selected approaches that are commonly used by economists in analyzing decisionmaking under risk. The approaches discussed here range from one of the simplest (the "safety-first" approach) to one of the more complex (the use of "expected utility"). "Certainty equivalence" also is discussed, which involves measuring risk in terms of differences in expected income. The use of these different approaches allows researchers to rank alternative strategies, and to help producers make optimal choices in different situations.

The "Safety-First" Approach

The "safety-first" approach to risk management applies if a decision-maker first satisfies a preference for safety (such as minimizing the probability of bankruptcy) when making choices as to the firm's activities. Only when the safety first goal is met at a threshold level can other goals (such as maximizing expected returns) be addressed. Thus, attaining the highest-priority goal serves as a constraint on goals that have successively lower priorities (Robison, Barry, Kliebenstein, and Patrick).

Safety-first methods are particularly applicable where survival of an individual or business is the paramount concern. However, in most business risk management situations, the use of safety-first methods is somewhat arbitrary because no single goal is clearly dominant.

The safety-first criteria can be specified in various ways in empirical applications. One of the first uses of this approach was developed in 1952, and involves choosing the set of activities with the smallest probability of yielding an expected return (Y) below a specified disaster level of return (Y-min) (Roy). To aid in understanding the various safety-first criteria, appendix table 2 shows the expected income and the probability of income less than the disaster level, which is assumed to be $50,000, for three hypothetical strategies, A, B, and C. For strategy B, for example, the expected return is $500,000, and the probability that returns under this strategy will fall below $50,000 is 4 percent. Strategy A has the highest expected return and the highest risk among the strategies illustrated, while strategy C has the lowest expected return and lowest risk.

Appendix table 2—Comparison of Roy's safety-first approach with Telser's safety-first approach

Strategy	Expected income E(Y)	Minimum disaster return (Y-min)	Probability of falling below minimum disaster return (P)
	Dollars		*Percent*
A	1,000,000	50,000	5
B	500,000	50,000	4
C	200,000	50,000	3

Source: Hypothetical example developed by ERS.

Under Roy's safety-first criteria, the optimal activity choice occurs where the probability of expected return falling below the $50,000 threshold is minimized. Strategy C, which has the lowest probability of disaster, best meets this criteria. When returns are normally distributed, the solution occurs where the disaster level (Y-min) is the greatest number of standard deviations away from the expected income. Roy's criteria can be expressed mathematically as:

$$\text{Minimize Prob } (Y < Y\text{-min})$$

A second type of approach, introduced by Telser in 1955, assumes that the decisionmaker maximizes expected returns, E(Y), subject to the constraint that the probability of a return less than or equal to a specified minimum disaster level (Y-min) does not exceed a given probability (P). Mathematically, Telser's approach is expressed as:

$$\text{Maximize } E(Y)$$
$$\text{subject to: Prob } (Y < Y\text{-min}) \leq P$$

To apply the Telser criterion to the example in appendix table 2, suppose that the critical probability is 4 percent. Then, the Telser criterion would choose strategy B, which maximizes expected income among those strategies for which P is not greater than 4 percent. Alternatively, if the critical probability were 3 percent, then strategy C would be selected, while if it were 5 percent, strategy A would be selected. This example illustrates that safety-first results can be quite sensitive to initial assump-

tions about what constitutes a critical loss.

The topics that have been addressed by these various types of safety-first criteria vary widely. They include: optimal hedging (Telser), dynamic cropping decisions in southeastern Washington (Van Kooten, Young, and Krautkraemer), farm extension programs (Musser, Ohannesian, and Benson), and attitudes toward risk regarding fertilizer applications among peasants in Mexico (Moscardi and de Janvry).

The safety-first approach has both advantages and disadvantages. It does not require the specification of a farmer's risk aversion coefficient (see accompanying box on risk aversion, p. 119), and it is not limited to specific distributional assumptions, other than that utility increases with returns (subject to varying constraints depending on the specification) (appendix table 3). As a result, it is straightforward to use. On the downside, however, it is limited in its ability to address producers' varying levels of aversion to risk (although the threshold probability can serve as a proxy for risk aversion), and difficulties can also arise in choosing the critical cutoff level for disaster returns. In addition, any outcome below the cutoff is treated as equivalent to any other. In reality, observations far below the cutoff disaster level are more adverse to the farmer than those that are nearer the cutoff point.

The "E-V" Approach and Quadratic Programming

A classic problem in risk analysis involves determining an optimal allocation of resources across an array of risky alternatives. The problem was first solved by Markowitz in the context of selecting optimal stock portfolios. His solution was to find the set of allocations that maximize expected total return for different levels of variance of total return. This is called the "expected value-variance (or E-V) efficient" set or frontier. The heavy line in appendix figure 5 represents an E-V efficient frontier. On this frontier, expected return can be increased only by accepting a larger variance of return. The optimal portfolio is presumed to come from this frontier and depends on the decision-maker's preference tradeoffs between expected return and variance of return.[33]

[33]The E-V efficient set will include the portfolio that maximizes expected utility if the decisionmaker's utility function is quadratic or returns on all activities are normally distributed. See subsequent section on "The Expected Utility Approach."

Appendix table 3—Methods for ranking probability distributions, and assumptions and parameters required for each

| Method	Assumptions required about utility	Parameters required to use method
Roy's safety-first	Increases with prob (Y > L)	Prob (Y < L)
Telser's safety-first	Increases linearly with Y if prob (Y < L) < P, is zero otherwise	E(Y) and prob (Y < L)
E-V efficiency	Increases with Y at a decreasing rate plus normality or quadratic utility	E(Y) and Var(Y)
1st degree stochastic dominance	Increases with Y	Complete distribution of Y
2nd degree stochastic dominance	Increases with Y at a decreasing rate	Complete distribution of Y
Expected utility and certainty equivalents	Known function of Y	Complete distribution of Y and utility function

Note: Y = income; E(Y) = expected income; L = critical level of income; P = critical probability.

Source: Compiled by ERS.

Appendix figure 5
Example E-V efficient frontier and indifference curves

Expected income

Variance of income
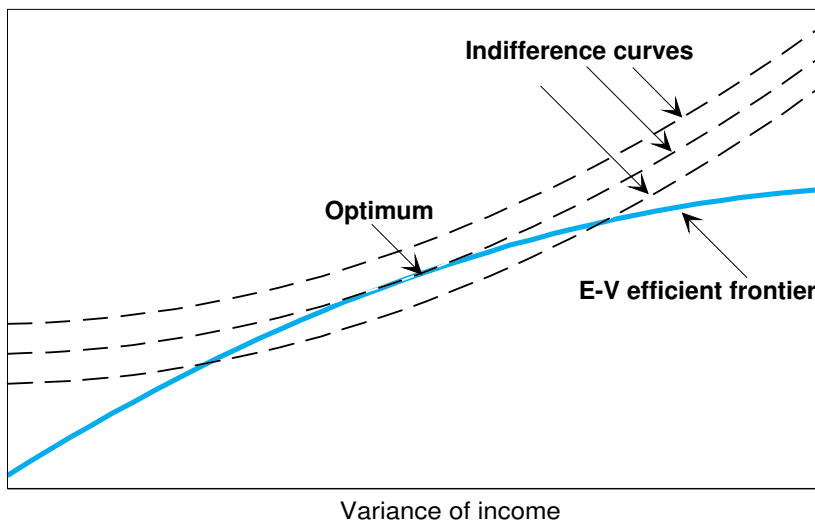
Source: Hypothetical example developed by ERS.

The E-V efficiency criterion can be used in allocating a farm's resources among alternative risky enterprises. A risk-averse farmer desires high expected return and low variance of return, which involves moving upward and/or to the left in the figure. The optimal combination of activities for the farmer occurs at the point on the E-V frontier that provides the preferred combination of expected return and variance of return. To illustrate the farmer's preferences, three indifference curves are shown as dashed lines. Each connects combinations of risk and expected return that are equally desirable to the producer. The optimal point on the E-V frontier is the point that touches the highest attainable indifference curve.

This approach has on many occasions been applied to farming decisions, particularly to decisions about enterprise choice and diversification. E-V efficient combinations of crop and livestock enterprises can be identified and the combination that offers the preferred mix of expected return and variability of returns can be chosen. Determining E-V efficient combinations requires estimates of the variances in returns and the correlations of returns for those enterprises under consideration, as well as estimates of expected returns for those enterprises.

The attractiveness of E-V analysis is that it leads to relatively convenient solutions using quadratic programming. The exact formulation of the problem can vary. One approach is to maximize a quadratic function of activity levels subject to linear constraints as follows:

$$\text{Maximize} \sum_{i=1}^{n} x_i u_i - \lambda \sum_{i=1}^{n} \sum_{j=1}^{n} x_i x_j$$

subject to:

$$\sum_{i=1}^{n} a_{ji} x_i \leq b_j \quad j = 1, 2, \ldots m$$

$$x_i \geq 0, \quad i = 1, 2, \ldots n$$

where:

x_i = the level of the ith activity;

u_i = the expected return per unit of the ith activity;

λ = the risk-return trade-off;

σ_{ij} = the covariance of return on activities i and j;

a_{ji} = coefficients in m linear constraints on the activity levels.

b_j = levels of the linear constraints.

To trace out the E-V frontier, the quadratic programming problem must be solved parametrically as the risk aversion coefficient, λ, varies from 0 to ∞. This is a rather complicated problem, but computer algorithms are available. If the farmer is risk neutral ($\lambda=0$), the problem collapses to a an income maximization problem, which can be solved with ordinary linear programming. As risk becomes increasingly important, the risk aversion coefficient increases and the E-V portfolio becomes increasingly diversified (Anderson, Dillon, and Hardaker). Other factors, such as limitations imposed by resource constraints, may also lead to a diversified portfolio.

The quadratic programming approach has been applied to farm enterprise selection by many researchers. The first application, for example, involved the evaluation of four production activities and several resource constraints on a representative farm in eastern North Carolina (Freund). Quadratic risk programming has since been applied to many other evaluations of optimal farm enter-

prise choice, including studies by Barry and Willman, and Musser and Stamoulis.[34]

The use of the E-V approach has both advantages and disadvantages. As in the case of "safety-first" analysis, E-V analyses may or may not include an explicit measure of the producer's risk aversion (as illustrated in the example above). E-V analysis is limited, however, in that it assumes that the producer has an outcome distribution that is normal[35] or, alternatively, a utility function (which expresses risk preferences) that is quadratic. In addition, the farmer is assumed to always prefer more (rather than less) of the variable in question (such as income), and is assumed universally not risk preferring with respect to that variable (Hardaker, Huirne, and Anderson). As with various approaches to risk analysis, estimation of the variance-covariance matrix can present methodological pitfalls (Mapp and Helmers).

The Stochastic Dominance Approach

Unlike E-V analysis, which is based on the mean and variance of

a distribution, stochastic dominance involves comparing points on two or more entire distributions. That is, when stochastic dominance is used, alternatives are compared in terms of the full distributions of outcomes. Because comparisons must be made at each specified point along each distribution in a pairwise fashion, the conceptual complexity and computational task associated with this approach are greater than when E-V analysis is used (Hardaker, Huirne, and Anderson).

The first concept of stochastic efficiency was formalized in the early 1960's, and is known as "first-degree" stochastic dominance. This approach rests on the notion that decisionmakers prefer more of a given variable (such as income) to less. Using an example, suppose there are three plans, A, B, and C, each having a probability distribution of income outcomes, "x." The cumulative density functions (CDFs) associated with the plans are F_A (x), F_B (x), and F_C (x), respectively, as shown in appendix figure 6. The CDFs reflect the "accumulated" area under the probability density function (PDF) at each level of income for each plan. At the extreme right side of the chart, the entire PDF is summed, and the probability of realizing an income for any of the plans that is equal to or less than the amount designated on the axis is 1.00.

For one plan to dominate another in the first-degree sense, the CDF for the first plan must nowhere be higher than the CDF for the second plan, and it must lie below the CDF for the second plan at some point. Mathematically, first degree stochastic dominance (FSD) can be expressed, for two representative plans A and B, as:

$$F_A (x) \leq F_B (x), \text{ for all levels of x}$$

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[34]Other risk programming methods are available. MOTAD programming, for example, minimizes the mean absolute deviation in net income, which simplifies the problem to one of linear programming (Hazell). Target MOTAD, developed in 1983, minimizes deviations from a target level of income (Tauer). Discrete stochastic programming can also be used to determine efficient enterprise choices for farmers. For a discussion of the advantages and disadvantages of these approaches, as well as examples, see Hardaker, Huirne, and Anderson; Musser, Mapp, and Barry; Mapp, Hardin, Walker, and Persaud; and Walker and Helmers.

[35]The normality assumption may be reasonable, particularly if the number of risky prospects is not too small and the risky prospects are diverse (Anderson, Dillon, and Hardaker). In addition, several studies have concluded that the E-V approach is quite robust to violations of the normality assumption (Levy and Markowitz; Kroll, Levy, and Markowitz).

In appendix figure 6, $F_C(x)$ dominates $F_A(x)$ in the first-degree sense, meaning that the probability of exceeding any given level of income is greater under plan C than plan A, and that plan A cannot be a member of the first-degree stochastic dominant (FSD) set. Because the CDF for plan B crosses both plans A and C, plan B does not dominate, and is not dominated by, either A or C in the first degree sense (Hardaker, Huirne, and Anderson).

Second-degree stochastic dominance (SSD) is applicable if the decisionmaker is risk averse and prefers higher incomes to lower incomes. In contrast to first-degree stochastic dominance, SSD involves the comparison of areas under the CDFs for various plans, and, in general, has more discriminatory power than does FSD (King and Robison). For a representative plan, A, to be SSD over another plan, B, requires that:

$$\int_0^\infty F_A(x) \leq \int_0^\infty F_B(x), \text{ for all}$$

values of x.

In appendix figure 6, for example, note that the accumulated area under $F_B(x)$ is less than under $F_A(x)$ at all levels of income. Thus, B exhibits SSD over A. C also exhibits SSD over A. However, C does not exhibit SSD over B because there is a range in the lower tail where the accumulated area under C exceeds that under B. This example illustrates the stronger discriminatory power of SSD compared to FSD while showing that SSD does not discriminate among all distributions.

As with other approaches to risk analysis, the use of stochastic dominance methods has both pros and cons. Although it provides a rigorous assessment, the number of efficient sets may remain unduly large. SSD is more discriminating than FSD, but nearly one-half of randomly generated farm plans in one study, for example, were found to be within the SSD set (King and Robison). The assumption of risk aversion required by SSD may not always hold, and the pairwise comparisons that are necessary in determining the efficient set can be computationally burdensome.

Appendix figure 6
Cumulative income distributions under three alternative strategies

Cumulative probability
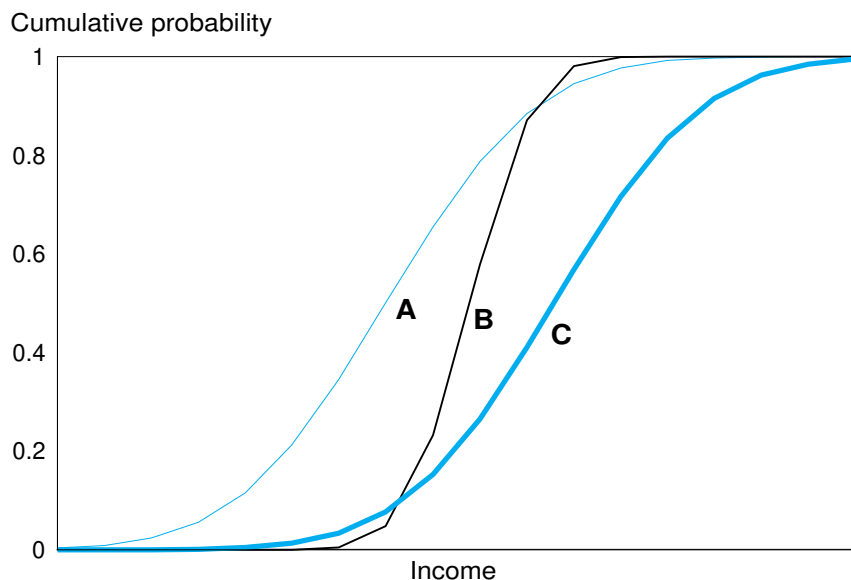
Source: Hypothetical example developed by ERS.

Different Approaches Can Be Used to Estimate Risk Aversion

To determine a farmer's best risk management strategy, information is needed about his or her risk preferences among the different income distributions generated by those alternative strategies. Individuals who accept a lower average return to reduce the variability of returns are said to be risk averse. Many individuals are believed to be risk averse, as evidenced by the widespread demand for automobile, property, and health insurance. Premium costs for these products generally exceed expected indemnities due to administrative costs, but buyers often find the price acceptable to mitigate potentially disastrous outcomes.

While risk aversion is acknowledged as widespread, the degree of risk aversion varies among individuals and is difficult to ascertain. Two general approaches typically have been used in empirical analyses. The first approach measures risk aversion directly by confronting the decisionmaker with a choice (either actual or hypothetical) among several alternatives, at least some of which involve risk (Newbery and Stiglitz). Such approaches have been used to determine risk aversion among farmers in northeast Brazil (Dillon and Scandizzo) and rural India (Binswanger), among others.

Measuring risk preferences directly can, however, lead to unstable results. Interview methods, in particular, are faced with the inevitable problem that individuals may not be able to reveal their attitudes toward decisions they have never taken or seriously contemplated (Binswanger). In addition, such studies have typically focused on a small-scale basis. Recently, work has been undertaken to measure farmers' risk attitudes on a large-scale basis, using rating scales of risk management questions to ascertain farmers' risk preferences (Bard and Barry).

The second approach does not involve interviews with decisionmakers or experimental determination of attitudes toward risk. Rather, this category involves: 1) focusing on testing hypotheses econometrically regarding risk preference structure; or 2) directly estimating utility functional forms or risk aversion coefficients using data on actual firm choices (Saha, Shumway, and Talpaz; Antle; Love and Buccola). Several studies have used this second category, with estimates of relative risk aversion ranging widely.

More technically, measures of either "absolute" or "relative" risk aversion can be used to quantify an individual's attitude toward risk. Both measure the curvature of the utility function, and represent the degree to which the satisfaction obtained from an additional unit of income declines as income increases. The units of measurement must be considered in interpreting estimates of absolute risk aversion, whereas relative risk aversion is unit free.

Varying estimates of relative and absolute risk aversion result from different approaches and data sets. Researchers generally agree that a reasonable relative risk aversion coefficient, for example, is in the neighborhood of 2.0, or "rather risk averse." Relatively risk-averse farmers would be likely to maintain substantial financial reserves as protection against income shortfalls, while those who are less risk averse would be inclined to borrow to near their limit in order to increase their expected incomes (Hardaker, Huirne, and Anderson).

Further, once the efficient set of plans is determined, identification of the optimal choice within this set depends on knowing more about a decisionmaker's preference than merely that an unquantified aversion to risk exists (Anderson, Dillon, and Hardaker).

The Expected Utility Approach

If a decisionmaker's risk preferences can be described mathematically and the probability distributions associated with each risky alternative are known, his or her choice among the risky alternatives can be optimized directly. Expected utility provides a convenient way to represent risk preferences. The basic idea is that decisionmakers maximize expected utility, where utility is an indicator of satisfaction measured in arbitrary units. Utility increases less than proportionately with income for decisionmakers who are risk averse. In other words, utility is an increasing, but downward bending, function of income for such persons (Anderson, Dillon, and Hardaker; Robison and Barry; Laffont; Takayama).

Many different specifications can be used to capture the curvature of the utility function, and each represents the degree to which the satisfaction obtained from an additional unit of income changes as income increases. One such utility function specification can be expressed as:

$$U = 100 - (1,000,000/Y)$$

As can be seen from this equation, an increase in Y, say from $20,000 to $30,000 (50 percent), results in an increase in utility from 50 to 67 (32 percent). This utility function exhibits constant relative risk aversion, which means that the degree of risk aversion decreases with income. The coefficient of relative risk aversion in this example is 2, which is considered by many economists to be about average.

To illustrate the use of expected utility, suppose that Farmer Smith, whose utility function is specified as above, is choosing between two strategies: (1) continuing to farm, and (2) taking a job in town. Under the first strategy, Smith has an 80-percent chance of a net income of $70,000 and a 20-percent chance of a net income of $20,000. Working in town provides a sure income of $55,000. The expected income and standard deviation in income for each strategy are shown in appendix table 4. Neither strategy dominates the other from the standpoint of E-V efficiency because the first strategy has the highest expected income, while the second has the lowest standard deviation in income (zero in this case).

Using Smith's utility function, the resulting utilities for each level of income shown in the table are:

Income	Utility
$20,000	50.0
$55,000	81.8
$70,000	85.7

Appendix table 4—Expected income and standard deviation of income under two strategies available to Farmer Smith

Strategy	Probabilities of expected incomes			Expected income	Standard deviation of income
	$20,000	$55,000	$70,000		
	Percent			Dollars	
1	0.2	0.0	0.8	60,000	20,000
2	0.0	1.0	0.0	55,000	0

Source: Hypothetical example developed by ERS.

Certainty Equivalence Allows Estimation of Risk in Dollars of Expected Income

Decisionmakers often would like the losses from risk or the gains from risk reduction to be measured in terms of dollars of expected income. A sure outcome that an individual finds equally desirable to a given risky prospect is called a certainty equivalent outcome (Anderson, Dillon, and Hardaker; Laffont). Knowing certainty equivalent outcomes allows one not only to rank risky alternatives, but also to estimate the cost of risk, or the premium that the individual would pay to avoid the risk. Certainty equivalence simultaneously accounts for the probabilities of the risky prospects and the preferences for the consequences (Anderson, Dillon, and Hardaker). Because decisionmakers seldom have similar attitudes toward risk, certainty equivalents vary among individuals, even for the same risky prospect (Hardaker, Huirne, and Anderson).

Certainty equivalents can be calculated when E-V analysis is used or when the utility function is known and expected utility analysis is used. In the latter case, a certainty equivalent can be calculated by first calculating expected utility and then finding the sure outcome that would provide equal utility. This involves applying the inverse of the utility function to expected utility. For the utility function above this gives:

$$CE(Y) = 1,000,000 / [100 - E(U)]$$

Applying this inverse function to the expected utilities calculated in the accompanying table gives the estimates shown in the accompanying table. These results, shown in the last column, indicate that the first strategy yields a certainty equivalent income of $46,667, compared to an expected income of $60,000. In other words, the cost of uncertainty in farming for Smith is $60,000 - $46,667 = $13,333. Thus, Smith prefers the second strategy, which gives a certainty equivalent income of $55,000, and is $8,333 higher than obtained if he had chosen the first strategy.

Certainty equivalent estimates must be used with care, primarily because they tend to convey an unwarranted sense of precision. They must be taken as rather rough approximations, and depend heavily on how accurately the underlying utility functions and probability distributions are estimated. Utility functions, in particular, differ markedly among individuals, are not directly observable, and are likely estimated with substantial errors in most cases.

Certainty equivalent income under two strategies for farmer Smith

Strategy	Expected utility	Certainty equivalent income
		Dollars
1	78.6	46,667
2	81.8	55,000

Source: Hypothetical example developed by ERS.

Expected utility under each strategy is calculated by weighting each utility level by its probability. The results for the two strategies, shown in appendix table 5, indicate that the second strategy yields a slightly higher expected utility and is therefore preferred. Expected utility results can also be used to estimate certainty equivalents (see accompanying box, p. 121).

The use of expected utility has both advantages and disadvantages. One advantage is that this approach is quite generalizable, allowing a wide choice of utility functions and probability distributions. Unlike stochastic dominance and E-V efficiency criteria, which typically leave some alternatives unranked, expected utility generally ranks all alternatives. The major drawback of the approach is that utility functions are difficult to estimate and known only approximately, at best. Moreover, it assumes that decisionmakers exhibit a high level of rationality, which does not always seem to be the case.

Appendix table 5—Example calculation of expected utility under two strategies for farmer Smith

Strategy	Probabilities of expected utilities			Expected utility
	50.0	81.8	85.7	
	Probability			
1	0.2	0.0	0.8	78.6
2	0	1.0	0	81.8

Source: Hypothetical example developed by ERS.

The accompanying tables illustrate the mechanics of several types of federally-subsidized crop and revenue insurance. These types are:

Catastrophic (CAT) coverage—A type of Federal crop insurance that guarantees 50 percent of the producer's actual production history (APH) yield at 55 percent of the price election under crop insurance reform. Producers pay a processing fee of $60 per crop. The processing fee is tied to persons who have an interest in the land, not the acreage itself.

"Additional" (or Buy Up) coverage—A type of Federal crop insurance that refers to coverage that equals or exceeds a 50-percent yield guarantee at 100 percent of the price election. Farmers must pay a processing fee and a premium in order to receive added coverage.

Income Protection (IP)—A type of revenue insurance that protects producers against reductions in gross income when a crop's price or yields decline from early-season expectations. Indemnities are paid if the producer's gross income (as measured by the product of the producer's realized yield and the harvest futures price) falls below a predetermined guarantee. Threshold trigger levels are based on a producer's APH yield and a planting-time price for the harvest futures contract. Coverage is based on enterprise units. Coverage options in most areas range from 50 to 75 percent in 5-percent increments.

Crop Revenue Coverage (CRC)—A type of revenue insurance that provides revenue insurance plus replacement-cost protection to producers. Indemnities are paid if the producer's gross income (as measured by the product of the producer's realized yield and the actual harvest price) falls below a predetermined guarantee (as measured by the product of the producer's APH yield and the higher of the early-season price projection or the actual harvest price). Since CRC uses the higher of the planting-time price for the harvest futures contract or the actual futures contract quote at harvest, the producer's guarantee may increase over the season, allowing the producer to purchase "replacement" bushels if yields are low and prices increase during the season.

**Appendix table 6—Example of a Catastrophic Crop Insurance Policy
for YIELD Loss
50 percent yield coverage and 55 percent of price election
The producer pays no premium**

Step	Item	Unit	A Yield #1 (30)	B Yield #2 (13)	C Yield #3 (0)
1	**Net indemnity to producer**	$/acre	0	15.40	44.00
2	**= Indemnity paid to producer**	$/acre	0	15.40	44.00
3	**= Calculated yield loss**	bu/acre	0	7	20
4	= Yield guarantee	bu/acre	20	20	20
5	= percent of yield coverage	percent	50.0	50.0	50.0
6	* APH yield guarantee	bu/acre	40	40	40
7	- Actual harvested yield	bu/acre	30	13	0
8	*** Producer price election**	$/bu	2.20	2.20	2.20
9	= percent of price election	percent	55.0	55.0	55.0
10	* FCIC price election	$/bu	4.00	4.00	4.00
11	**- Producer premium**	$/acre	0	0	0
12	**= Total premium per acre**	$/acre	4.50	4.50	4.50
13	**- Premium subsidy per acre**	$/acre	4.50	4.50	4.50
14	= Subsidy percent	percent	100	100	100
15	* Total premium per acre	$/acre	4.50	4.50	4.50

Source: Excerpted from Jagger, Craig, and Joy Harwood. "Module 6: Crop Insurance and Revenue Insurance," *USDA's Crop/Commodity Programs After the 1996 Farm Act*. USDA Graduate School Course, winter quarter, 1999.

**Appendix table 7—Example of a Multi-Peril Crop Insurance Policy
for YIELD Loss
The producer chooses: percent yield coverage and percent of price election
The producer pays part of the premium**

Step	Item	Unit	A Yield #1 (30)	B Yield #2 (13)	C Yield #3 (0)
1	**Net indemnity to producer**	$/acre	-3.50	48.50	100.50
2	**= Indemnity paid to producer**	$/acre	0	52.00	104.00
3	**= Calculated yield loss**	bu/acre	0	13	26
4	= Yield guarantee	bu/acre	26	26	26
5	= percent of yield coverage	percent	65.0	65.0	65.0
6	* APH yield guarantee	bu/acre	40	40	40
7	- Actual harvested yield	bu/acre	30	13	0
8	*** Producer price election**	$/bu	4.00	4.00	4.00
9	= percent of price election	percent	100	100	100
10	* FCIC price election	$/bu	4.00	4.00	4.00
11	**- Producer premium**	$/acre	3.50	3.50	3.50
12	**= Total premium per acre**	$/acre	6.00	6.00	6.00
13	**- Premium subsidy per acre**	$/acre	2.50	2.50	2.50
14	= Subsidy percent	percent	41.7	41.7	41.7
15	* Total premium per acre	$/acre	6.00	6.00	6.00

Source: Excerpted from Jagger, Craig, and Joy Harwood. "Module 6: Crop Insurance and Revenue Insurance," *USDA's Crop/Commodity Programs After the 1996 Farm Act*. USDA Graduate School Course, winter quarter, 1999.

Appendix table 8--Example of an Income Protection Insurance Policy for REVENUE Loss
The producer chooses: percent of revenue coverage
The producer pays part of the premium

Step	Item	Unit	A Yield #1 Price #1	B Yield #1 Price #2	C Yield #1 Price #3
1	**Net indemnity to producer**	$/acre	10.68	-3.32	-3.32
2	**= Indemnity paid to producer**	$/acre	14.00	0	0
3	**= Revenue guarantee** **= planting guarantee**	$/acre	104.00	104.00	104.00
4	= Harvest price as projected at planting time	$/bu	4.00	4.00	4.00
5	* APH yield	bu/acre	40	40	40
6	* Revenue coverage level	percent	65.0	65.0	65.0
7	**- Realized revenue**	$/acre	90.00	120.00	150.00
8	= Realized harvest price	$/bu	3.00	4.00	5.00
9	* Actual yield	bu/acre	30	30	30
10	**- Producer premium**	$/acre	3.32	3.32	3.32
11	**= Total premium per acre**	$/acre	5.70	5.70	5.70
12	**- Premium subsidy per acre**	$/acre	2.38	2.38	2.38
13	= Subsidy percent	percent	41.7	41.7	41.7
14	* Total premium per acre	$/acre	5.70	5.70	5.70

Source: Excerpted from Jagger, Craig, and Joy Harwood. "Module 6: Crop Insurance and Revenue Insurance," *USDA's Crop/Commodity Programs After the 1996 Farm Act*. USDA Graduate School Course, winter quarter, 1999.

Appendix table 9--Example of a Crop Revenue Coverage Insurance Policy for REVENUE Loss
The producer chooses: percent of revenue coverage
The producer pays part of the premium

Step	Item	Unit	A Yield #1 Price #1	B Yield #1 Price #2	C Yield #1 Price #3
1	**Net indemnity to producer**	$/acre	8.35	-5.66	-5.66
2	**= Indemnity paid to producer**	$/acre	14.00	0	0
3	**= Revenue guarantee** **= higher of (a) or (b)**	$/acre	104.00	104.00	104.00
4	(a) Harvest guarantee	$/acre	78.00	104.00	130.00
5	= Realized harvest price	$/bu	3.00	4.00	5.00
6	* APH yield	bu/acre	40	40	40
7	* Revenue coverage level	percent	65.0	65.0	65.0
8	(b) Planting guarantee	$/acre	104.00	104.00	104.00
9	= Harvest price as projected at planting time	$/bu	4.00	4.00	4.00
10	* APH yield	bu/acre	40	40	40
11	* Revenue coverage level	percent	65.0	65.0	65.0
12	**- Realized revenue**	$/acre	90.00	120.00	150.00
13	= Realized harvest price	$/bu	3.00	4.00	5.00
14	* Actual yield	bu/acre	30	30	30
15	**- Producer premium**	$/acre	5.66	5.66	5.66
16	**= Total premium per acre**	$/acre	7.80	7.80	7.80
17	**- Premium subsidy per acre**	$/acre	2.15	2.15	2.15
18	= Subsidy percent	percent	27.5	27.5	27.5
19	* Total premium per acre	$/acre	7.80	7.80	7.80

Source: Excerpted from Jagger, Craig, and Joy Harwood. "Module 6: Crop Insurance and Revenue Insurance," *USDA's Crop/Commodity Programs After the 1996 Farm Act*. USDA Graduate School Course, winter quarter, 1999.