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]

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.

[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.

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
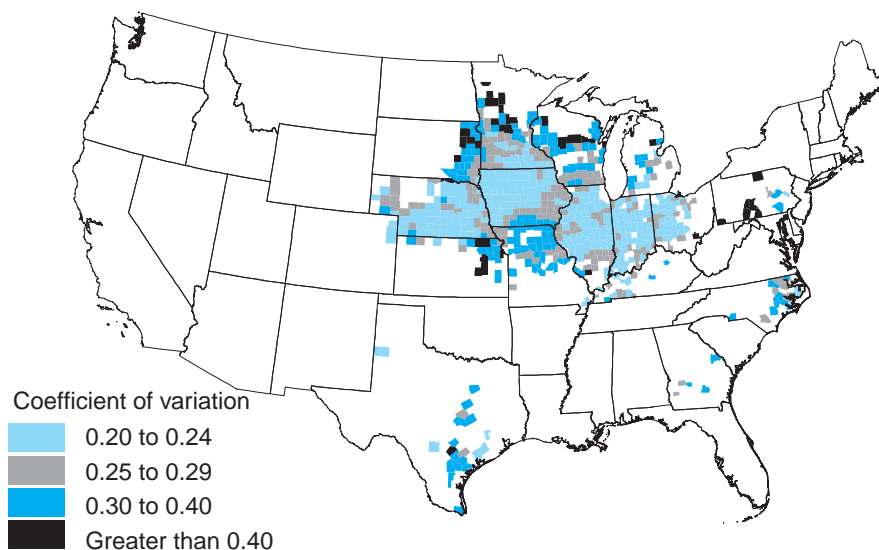
Notes: Shaded areas include counties with at least 500 acres planted to corn. Lower corn yield variability indicates that farm yields fall within a narrower range. Based on farm-level data, 1985-94, and long-term county-level trend.
Source: Constructed by ERS from USDA, NASS electronic county yield files, 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-

> 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.

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

Figure 2

Volatility of December corn futures by month, averages for 1987-96
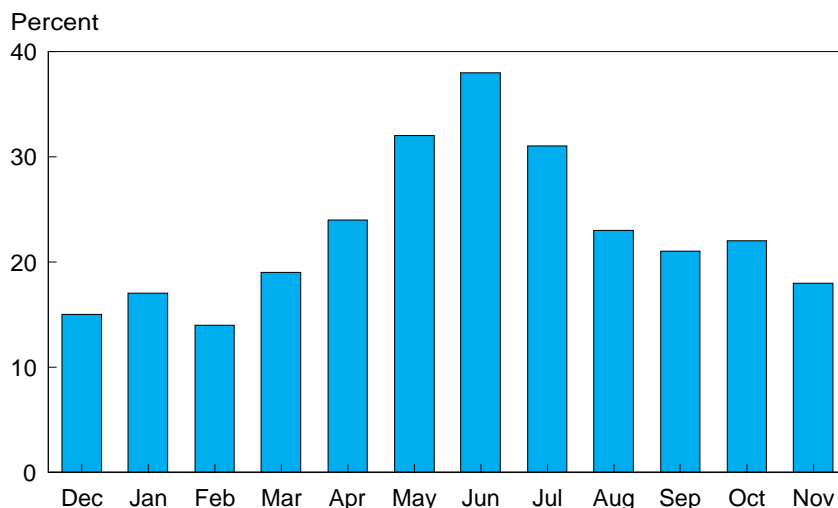
Percent

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

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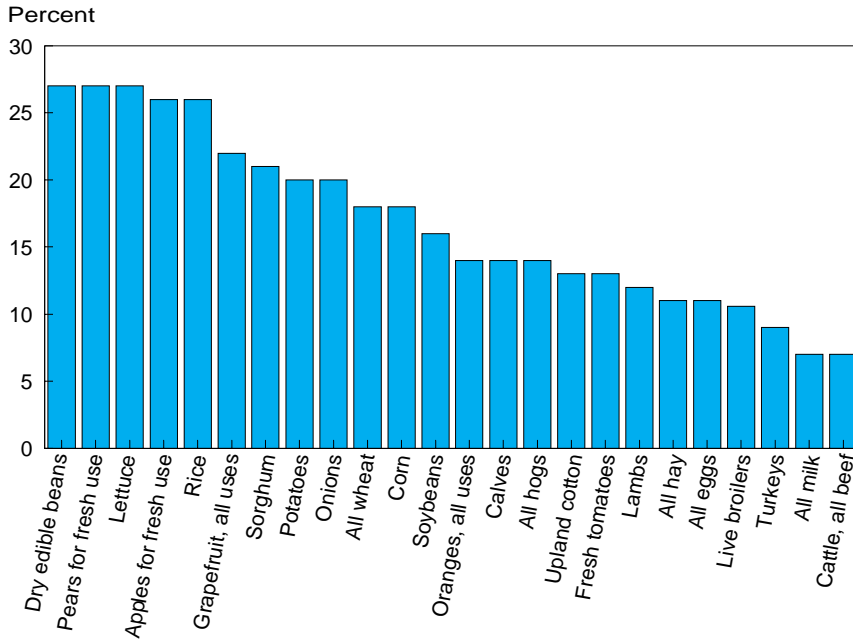
Percent

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.

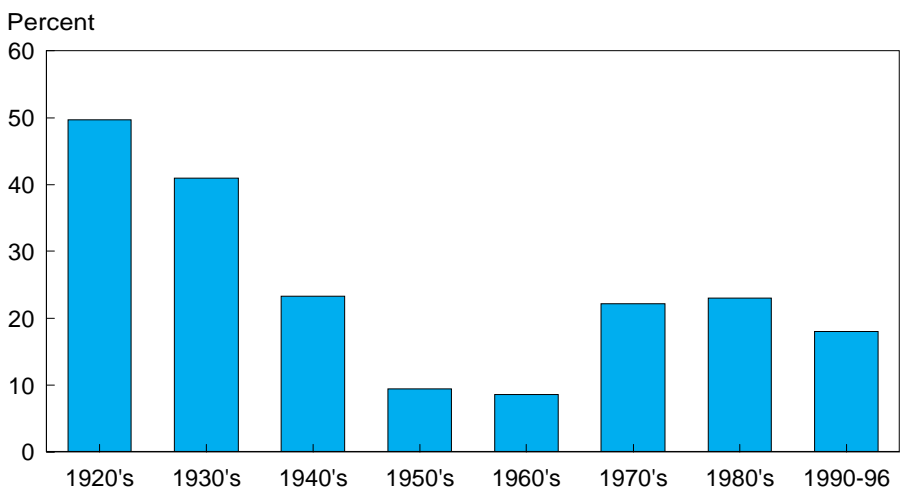## Yields and Prices Tend To Move in Opposite Directions

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
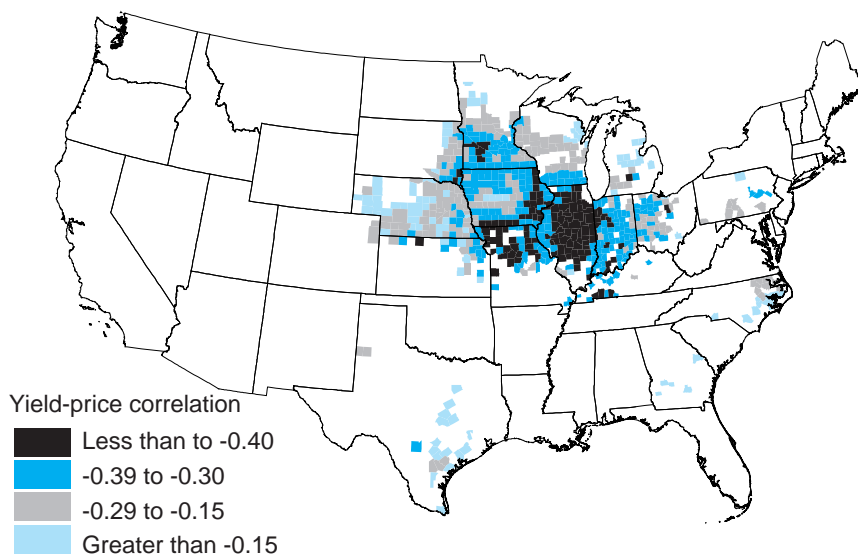
Note: Shaded areas include counties with at least 500 acres planted to corn.
Source: Constructed by ERS from USDA, NASS electronic county yield files, 1997, and USDA, RMA electronic experience and yield record database.