Module 5

Risk, Probability, and Managing Income Variability

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Topics

Introduction

Risk is defined as the probability or chance of a loss. Farmers have always been exposed to some risk of loss because future crop yields and prices cannot be predicted with certainty. For example, what will be next year's crop yields and price levels for my farm? Since expected yield times the expected prices generates an estimate of future gross revenues, financial risk is also tied to yield and price risks. Subtracting costs from the expected gross revenues provides an estimate of the anticipated profits and/or losses.

The worst outcome or the greatest loss occurs when both yields and prices are relatively low, an experience that has occurred in the eastern cornbelt when crop failure occurred in the eastern region of the cornbelt and excellent weather conditions in the western cornbelt cause prices to fall. Some combinations of low (high) yields and high (low) prices may also decrease gross revenues resulting in financial losses. Losses in any one year may be ruinous for those farming operations that are highly leverage when family living standards cannot be maintained and cash flow obligations cannot be met. These problems are exacerbated with the curtailment of the government safely nets and the growing volatility in free trade world markets.

To effectively anticipate and respond to downside yield, price, and/or revenue risks, innovative management and marketing plans are a must. This module provides background information in order that future lessons can describe how to manage risk using alternative marketing tools and insurance products, examines how to measure risk, and illustrates how different marketing alternatives and insurance products modify the risk distribution pattern for a farming operation.

Farmers have a wide variety of "risk transfer" tools at their disposal. Although they are not discussed here, they include named (e.g., hail, frost) and multiple-peril crop insurance (MPCI) products. These risk limiting products will be discussed by Professors Barnaby and Edwards in future modules. Further, there are a variety of new insurance products that limit gross income risk. Barnaby and Edwards and Babcock and Hayes will discuss these products. Finally, there are replacement cost products which build on MPCI and revenue insurance concepts.

The replacement cost products are designed to complement the pre-harvest pricing strategies that are used by farmers. The pre-harvesting alternatives and strategies include cash forward contracts, hedge contracts, minimum price contracts, put options on futures contracts, and combinations of options and hedging strategies. Effectively combining the insurance products and market alternatives to limit risk and enhance profits requires that each respective farmer describe and quantify the anticipated risk exposure for the farm(s).

Quantifying Risk

*(or go to **Topics**)*

How a farmer manages risk depends upon a number of factors. First, one’s management style is influenced by the farm’s risk bearing capacity. Professor Edwards examined these issues in Module Three. Remember that Mr. and Mrs. Owner could sustain significantly more risk than could the Renters! Secondly, your family psyche or willingness to accept risk will influence your choices. There are few, if any, economic principles that provide guidelines for managing this factor. Thirdly, one’s expectations or forecasts of future weather patterns, demand volatility, and national and international policies will influence the risk decision framework. Finally, the costs to manage risk cannot be ignored.

These costs are both "out of pocket" costs, such as premiums, and "opportunity" costs, such as the possibility of higher prices. Premiums tend to reduce the price that will be received when grain is sold. Opportunity cost represents the benefit of a forgone alternative and is considered to be the cost of the action that is selected. That is, if grain is priced now, using hedges or forward contracts, the opportunity to lock in or to sell grain at higher prices is foregone. A second opportunity cost occurs when farm businesses use credit reserves to self insure rather than to invest in the next best alternative. This might include giving up the opportunity to buy more land and/or equipment and thus the higher returns that could be associated with these alternative investments.

Risk was defined above as the likelihood that a loss will occur in some future time period as a result of either low yields and/or low prices. The question is, how can these risks be quantified? Probability is the "language" that is used to answer this question. Therefore, for example, what is the probability that crop yields will be 10% below or above average yields? Alternatively, what is the probability that prices will vary by 10% from today’s prices? How can the two sets of probabilities be combined to estimate probable outcomes for profits and losses? Successful use of risk management tools including insurance products and marketing alternatives, singularly and in combination, requires an understanding of how the tools change the probabilities of financial outcomes -- particularly unfavorable ones. In the following sections, these concepts are examined in conjunction with selected risk transfer tools.

WAIT!! Don't get scared off. We're not going to introduce a college statistics course or teach complex statistical concepts. Many of you have been doing these calculations in your head for years. Since you've had extensive experience growing crops and have observed your neighbors' farming practices, you can intuitively estimate average yields and expected variations in yields for your farm(s) and county. You've also experienced the variation in prices over the course of the crop year, as well as between years. This means that you can already estimate an expected price average for some future period. Tying the two sets of probabilities together allows you to intuitively estimate probabilities for gross farm revenues. Even if you have not been maintaining precise production cost estimates, you do have the information to estimate the probabilities of profits or losses. In the next sections, the "language" of probability is "tightened" a bit in order that you can better quantify these risks to make sound risk management decisions.

To examine probabilities of one event (yield probabilities for example) from a gaming perspective, let's reflect on what happens when a coin is flipped or tossed. The probability is 50% that a head will appear and 50% the flip will result in a tail with the results totaling 100%. If you bet that a head will appear on the next flip, there is a 50% chance that you will win and 50% that you will lose. Thus, the risk of failure is 50%.

Rolling two die, another gaming activity, explains how to examine joint probabilities or the probabilities of two events (prices and yields). It is known that there is 1/36 of a chance that "snake eyes" will appear or 1/36 of a chance that the sum from tossing the two die will equal "twelve". It is also known that the most likely summed outcome (1/6 of a chance) from tossing two die is the number, "seven." The probabilities of all other combinations of numbers that may appear when two die are tossed can be accurately estimated. In a similar vein, the joint probabilities for yield and price outcomes can also estimated. Even though the probabilities developed for the various outcomes (probability of a combined low price and yield, for example) may not be as exact as the probability from throwing two die, enough accuracy can be achieved to help make sound risk management decisions.

Think of your own farm yield history. If I asked you to predict next year's yield within a 10 bushel per acre range, you could do it. If I asked for your yield history for the past 10-15 years, most of you could respond. You could answer questions such as, "What percent of the time will my expected corn yield be less than 50 bushels per acre? With some guidance, you can develop an estimate of the probabilities of all alternative farm yields. In this module, a yield distribution is used for the example . Note, there are systematic methods and computer "decision aid" available such as ELICIT to aid in the calculation yield probability distributions for a farming operation. This program is available on the CD and more information can be acquired by contacting Dr. Roy Black, Department of Agricultural Economics, Michigan State University, East Lansing, MI 48824-1039.

Yield Probabilities *(or go to* ***Topics*** *)*

Probabilities of alternative price, yield, and gross revenues can be created by several methods. Frequency of events or relative frequency (chances in 100) is one such method. Since this approach involves using a histogram, it will be familiar to those who use spreadsheets and/or are involved with experimental plots on their farms. Probability and relative frequency are commonly used interchangeably. **Figure 1** is a farm corn yield probability based on a farm in Southwestern Iowa. The vertical axis is the percent of time an event is expected. The horizontal axis describes the event.

In this example, corn yields are expected to occur in the 130 - 140 bushels per acre range most frequently -- a little over 16 years out of 100, or 16% of the time. Most of the time, yields are near or above this expected average but sometimes adverse weather conditions or pest problems cause yields to be substantially below normal. Corn yields can approach zero although the chances are small. Alternatively, yields can be as high as 170 to 180 bushels per acre although the probabilities of such occurrences are also relatively small. Notice that the "tail" in **Figure 1** is longer on the left side than on the right. This means that yields can decline from the expected 130 to 140 bushel average to zero (0) bushels when weather conditions or plant disease creates a major disaster. In contrast, excellent weather and growing conditions will increase output above the expected average by only 40 bushels per acre.

The events of the last two decades illustrate how yields vary. There are areas in the U.S. where farmers have had two or three years in succession where the percentage yield shortfalls have been below normal. Over the last 100 years and given current technology, the expected yields would have been the 130 to 140 bushels of corn per acre. Instead, corn yields averaged 120 bushels per acre. The difference is due to the long downside tail pulling the average down. Since the shape of yield distributions varies widely by soils and rainfall area, this example farm was chosen to illustrate the range of features that exist and the need for the reality check that yield events will meet expectations most of the time, but downside yield risks are possible.

A second method for analyzing risk is the cumulative frequencies or cumulative probabilities. Both forms of probability can be expressed in either a table form or a graph form. The cumulative probabilities of the yields from **Figure 1** are displayed in **Table 1**. They are easy to read and interpret; they are the summation (cumulation) of the relative frequencies / probabilities. In the first column of **Table 1**, the percentages represent the likelihood that yields will be equal to or less than the number in the second column. For example, there is a 90% chance the yield will be lower than 152 bushels per acre, a 50% chance yield will be below 124 bushels per acre, and a 10% chance the yield will be below 69 bushels per acre. Stated alternatively, there is a 50% chance that yields will be higher (lower) than the observed medium of 124 bushels per acre.

You can create similar yields charts or tables for your farm by either intuitively estimating your average yield and the probabilities (chances) that yields will vary from that the historic average. Alternatively, you can examine your annual yield records for at least a 10 year period to calculate the average. Then, you can estimate the percentage of time that different yield levels vary from that average. It is important that yield probabilities be determined for your specific farm because specific weather patterns and soil conditions will influence the outcomes.

Futures Price Probabilities *(or go to* ***Topics****)*

In a similar vein, it is also possible to estimate the probabilities of alternative futures prices. One choice is to use historical futures price data. One could calculate the average December futures price in November for the 1970 to 1996 period. Then, one could calculate the percentage of time prices were above and below that average based on $0.20 increments to create the probability distribution. That's a starting point, but the year to year economic conditions varied widely over the period and do influence expected price outcomes for any one year. So unless the December futures price in March for the year you are examining is the same as the historic average and the risk situation relatively equal, this method may not provide the most accurate results for this specific year. This method does; however, show past price averages and distributions and allows you, the producer or educator, to calculate what is the probability(s) that the current futures price or price range would have appeared in the historic series and what were the probabilities that prices declined below this level.

A second method, which does not rely on historic averages, is to use current futures prices and options premiums to estimate the December futures probability distribution for November. Think of how insurance companies calculate crop insurance premiums. They gather lots of yield data and calculate the premium that is required to pay crop damages (losses) over time. Put options are like a crop yield insurance contract. The put option premium that is negotiated in the pit at the futures exchange represents the estimated cost to cover downside futures price risk for some specified time period. In simple terms, instead of looking at the yield risk to calculate the insurance premium, we turn the formula around and use the futures option premium to give us an estimate of the chances of alternative futures prices.

The larger the premium for a given strike price, at a given futures price level, the larger the perceived risk by the market. This method assumes that the December futures price in March is an unbiased and accurate estimate of what the price will be next November. The premium is an unbiased estimate of the corresponding risk. **Figure 2 and Table 2** provide outcomes for calculating a distribution using this method. For example, prices are expected to be in the $2.60 to $2.70 range; each price is expected to appear about 10% of the time. Further, it is estimated that prices will be below and above $2.75 per bushel 50% of the time respectively. Finally, this method estimates that there is a 5% probability that prices will be below $2.03 per bushel and a 5% chance that prices will be above $3.73. Other probabilities for other price ranges are displayed in **Figure 2 and Table 2.**

It is not important that you can calculate the distribution, but rather that you know it is available. Price probability histograms for selected contracts are available on the Michigan State University Agricultural Economics webpage. The address is **http://www.msu.edu/user/hilker/**. Yield and price probability histograms can be generated from the **AgRisk** software. AgRisk is a user-friendly, Windows 95 program designed to assist corn, soybean, and wheat farmers to manage harvest-time revenue risk. AgRisk was developed by Gary Schnitkey, MarioMiranda, and Patrick Moran of the Ohio State University and Scott Irwin of the University of Illinois with funding provided by The Risk Management Agency, U.S. Department of Agriculture.

Probabilities and Risk Transfer Tools *(or go to **Topics**)*

In this section, how selected risk transfer tools modify the probability (risk) of undesirable revenue outcomes is examined. It is assumed that the farmer is raising corn; it is around the first of March; and a MPCI insurance purchase decision must be made by March 15 (true for much of the U.S.). The farmer is also considering pricing a portion of the new corn crop which will be planted in April or May. The farmer carefully estimated his/her farm businesses balance sheet and cash flow needs, and collects the probability information that is needed to help make sound risk management decisions. If you have not completed these tasks, you may want to return to module three (3).

For this analysis, the probabilities of alternative farm yields from **Figure 1 and Table 1** and the probabilities of alternative prices shown in **Figure 2 and Table 2** are used to illustrate how selected tools change the probabilities of alternative price, yield, and gross revenue outcomes. The price probabilities are derived from the December futures price and the December option premiums from the early March 1997 period. All futures prices must be adjusted by the local basis to obtain the cash price. Since the basis concept is discussed in modules six and eleven, this adjustment is not made here. The December futures price in the first part of March 1997 was $2.80, and a corresponding put premium was $0.17 per bushel for a $2.70 strike price. As displayed in **Figure 2 and Table 2** , there are many possible futures price outcomes that lie around the $2.80 futures price estimate. **Figure 2** shows there is a greater chance for very high prices than for very low prices. Thus, there is a long tail to the right. In contrast, the long tail for crop yields suggests that there is a greater change of low yields compared to high yields.

Figure 2 showed that in early March 1997 there was a 10% chance that futures prices would be between $2.63-2.75 at harvest (November). There was only a 7% chance that prices would range between $2.25-2.37per bushel, the price range that was recently being traded in the December futures market. This is an example of why we must look at price distributions when making decisions and not just the expected price. That is, the expected price is based upon the current markets estimate of supply and demand relationships for some future period (November in this example) while the total distribution estimates alternative prices for differing supply and demand outcomes. For example, there is some probability or chance that prices will be above the expected level at harvest time because there is some chance that demand will increase and/or supply will decrease by harvest time.

1. Forward Contracting and Probability Distribution *(or go to* ***Topics****)*

The next step is to show how the above distributions change when one of the alternative risk management tools is used. For example if a forward contract is used to price corn and the yield risk is ignored (joint yield and price risks will be discussed in a later section), the probability distribution basically becomes one number or a 100% chance that the price received in November will be the contract price. This choice eliminates all downside price risks. The opportunity cost of the forward contract is the foregone opportunity to price corn at a higher price that may appear prior to harvest. Therefore, the choice to forward contract depends upon the probability estimate that prices will be higher than the forward contract price by November, the amount of risk that can be tolerated by the farming operation, and the amount of psyche risk that the manager is willing to accept.

2. Put Option and Probability Distribution *(or go to* ***Topics*** *)*

Figure 3 and Table 3 show the impact on the prior probability distributions if a $2.70 put option with a $0.17 per bushel premium is purchased. Prices displayed in the figure and table are net the option premium. The effect of the put on the futures price is analogous to the effect of the multiple-peril crop insurance on yield. That is, both eliminate the possibility of a large loss. In this example, the put places a price floor that is just above the $2.50 per bushel level ($2.70 strike - $0.17 premium) eliminating downside price risk (**Figure 3 and Table**

3).

The put option changes the shape of the probabilities distribution. There is a 50% chance that the net price -- futures less put premium -- after using the put will be about $2.50-2.60 per bushel. That contrasts with the probabilities in **Table 2** where there is a 30% chance of prices falling below $2.50/ bushel. **Table 2** could also be read as saying there is a 10% chance that futures prices could be over $3.49/ bushel in November. In contrast when using a $2.70 put option, there is a 10% chance that prices will be over $3.32. Notice the difference between the $3.49 and $3.32 is the $0.17 per bushel option premium.

Joint Yield and Futures Price Probability Distributions *(or go to* ***Topics*** *)*

In the above examples, yield and price probability distributions were treated separately. Although this is a good start, the important issue is to determine how risk management tools affect the probabilities of alternative gross revenues and cash flow requirements. Since both prices and yields determine gross revenues etc., the joint yield and price probabilities must be determined. **Figure 4** shows the probabilities of alternative gross incomes based on the probabilities laid-out in **Figures 1** and **2**. In **Table 4**, the cumulative probabilities are displayed. In this example, it is assumed that prices and yields are not correlated; in contrast, in states such as Iowa there is a negative association between price and yield. When the yield are low or are less than the expected average over a large area of the western cornbelt, futures prices will increase and will be well above the expected average. As the negative correlation increases, the spread of the distribution also decreases.

If in Iowa, crop conditions are well below the average, this will have a major impact on the total U.S. supply of grain. Thus, U.S. prices will increase and will offset at least part of the loss from the poor crop conditions. The opposite is also true, higher yields in Iowa often cause lower U.S. prices. In Michigan and in other parts of the eastern Cornbelt, for example, this is usually not the case. Farm yields in Michigan do not have a significant impact on the total U.S. supply of grain and thus have little effect on U.S. prices. This means the income distribution for a Michigan farm would be larger than for an Iowa farm even if the yield distributions in Iowa and Michigan are the same.

To illustrate how these risk management tools limit downside financial losses, the farmer must first estimate how much financial risk is acceptable. Remember as explained in module three by Professor Edwards, the Owners and Renters had different financial risk tolerances. Assume that the farmer in this example is unwilling to accept more than a 5% chance that gross revenue per acre will be below $200. When risk management tools are not used, there is a 13% chance that gross revenue will be below this figure (**Figure 4 and Table 4**). The probability or chance of a loss is reduced by employing both a put option and MPCI crop insurance (**Figure 5**). Alternatively, a revenue insurance product could have been used.

Figure 5 shows that a 70% coverage (30% deductible) MPCI policy and $2.70 put option purchased for average production will reduce the chance of a loss to the acceptable level. It shows all but 3% of the tail below $200 has been chopped off using this combination of risk management tools. The gross revenue is adjusted for the extra cash costs of the insurance and option premiums. That is, the gross returns in the upper portions of the distributions is reduced by the amount of the insurance and option premiums.

In **Module 10** and **Module 12**, Babcock and Hayes will discuss the consequences of alternative price-yield correlations on the impact of price, yield, and gross revenue protection insurance. Increased negative correlations form somewhat of a natural hedge. Or in other words, if yields in Iowa are below average (poor), the resulting higher prices will offset part of the losses, provided that there is some crop to sell. If you had a significant portion of your production contracted at a fixed price, you could actually increase your income risk. Using options however, to establish a price floor did not increase net income risks for the 1985 to 1996 period for case study farms in Iowa and Ohio (see **Module 14**).

As discussed through all the lessons to this point, future yield, price, and gross revenue risks in farming are increasing. To survive, it is important to estimate the amount of acceptable financial risk that can be tolerated by your farm business, define what the risks are (as shown in this module), and to select and use the appropriate risk management tools in order to create a sound risk management plan. Future lessons will examine in more detail the advantages and disadvantages of the alternative insurance products, marketing alternatives, and financial strategies.

End of Module *(or go back to* ***Topics*** *)*

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