Rob King

RISK ANALYSIS FOR AGRICULTURAL PRODUCTION FIRMS: CONCEPTS, INFORMATION REQUIREMENTS AND POLICY ISSUES

Proceedings of a Seminar Sponsored by
Southern Regional Project S-180
"An Economic Analysis of Risk Management Strategies for Agricultural Production Firms"
New Orleans, Louisiana
March 25-28, 1984

Department of Agricultural Economics
Agricultural Experiment Station
College of Agriculture
University of Illinois at Urbana-Champaign

July, 1984

AE-4574

DISCUSSION: IRRIGATION AND PEST CONTROL AS RISK REDUCING INPUTS

Douglas L. Young

The papers by Boggess and Carlson on irrigation and pest control, respectively, as risk-reducing inputs are interesting and informative. I will devote somewhat more attention to Boggess' paper than to Carlson's. I received Boggess' paper earlier which gave me more time to reflect on it and also I am more familiar with the topic of irrigation than with pest control.

My discussion will focus on the following four areas:

1. Boggess' general stochastic profit model
2. Some methodological issues regarding operationalization of Boggess' model
3. The impact of irrigation on long-run versus short-run risk
4. An extension of Carlson's conclusions regarding pest control as a risk-reducing input

Boggess' Fully Stochastic Profit Model

Expression (1) summarizes the fully stochastic profit model Boggess used to analyze the irrigation strategy selection decision.

$$(1) \quad \tilde{\Pi}_i = \tilde{P}\tilde{Y}_i - \tilde{R}\tilde{X}_i$$

$\tilde{\Pi}_i$ is stochastic net returns over variable costs for irrigation strategy i. $\tilde{P}$ is the stochastic output price. $\tilde{Y}_i$ is stochastic soybean yield in the Florida study area under strategy i. $\tilde{R}$ is the stochastic price of irrigation water. $\tilde{X}_i$ is the stochastic quantity of irrigation water applied using strategy i.

Boggess notes that "Because irrigation scheduling costs are a function of water requirements and subsequently are not fixed at the beginning of the production period, such costs introduce a stochastic element unlike non-irrigated production." In other words, the quantity of irrigation water applied under a given strategy depends upon the weather. This renders the input level stochastic, in contrast to many agricultural production decisions.

Although Boggess' general model assumes that irrigation water price, $\tilde{R}$, is stochastic, it is unclear whether this was true for his empirical application. However, it would be possible for R to be stochastic if, for example, a variable-pricing scheme depending on weather and water availabilities was in effect for irrigation water. The existence of competitive

---

Douglas Young is an Associate Professor in the Department of Agricultural Economics at Washington State University, Pullman.

soybean markets and variable yield response to water applications ensure the stochasticity of P and Y_i. Boggess' general theoretical model also permitted statistical dependence among all components of the profit model.

Expression (1) provides an elegant and comprehensive conceptual framework for risky production decisions in comparison to the more limited models which have generally appeared in the literature. Anderson, Dillon, and Hardaker's treatment, for example, permits only output price and yield to be stochastic and potentially nonindependent.

I, for one, plan to start teaching the more general stochastic profit model in my graduate production course. Developing the variance of Π_i will stretch some students' command of the algebra of expectations, but the greater generality justifies the slight increase in complexity. The only possibly unfamiliar result required for deriving the variance of Π_i is the covariance between two products of nonindependent random variables. As noted by Boggess, Bohrnstedt and Goldberger derived this covariance, under the assumption of multivariate normality, in a 1969 article.

Methodological Issues

At this point, I will digress to briefly discuss two important methodological choices which must be made to operationalize a theoretical risk model such as that described in expression (1). The first issue concerns how expectations, variances, and potentially higher moments, of net returns for alternative decision strategies are to be operationally calculated. For example, Boggess notes that "The expectation of profit is calculated from a 17-year series of prices and simulated yields." This step of the analysis requires important choices regarding several data preparation and variable specification questions which can drastically influence the outcome of empirical risk analyses. Important questions which must be answered include: Which source of data should be used? How long a time period should be encompassed by the utilized data series? Should monetary values be deflated (or inflated) to constant base-year dollars? Should yield, cost, and/or return data series be detrended before expectations and variance are calculated? If so, how? Exactly which computational definitions should be used in calculating expectations and variances?

In the past, I have devoted considerable time to thinking about, reviewing literature on, and doing sensitivity analyses of the consequences of varying answers to questions like these (Young, 1981). My review of the empirical risk literature revealed a varied array of ad hoc choices by different researchers on these questions. Choices on these questions have more often been made on the basis of tradition and/or convenience than on the basis of consistent theoretical criteria. Furthermore, the absolute and relative magnitudes of expectations and variances of alternative strategies showed great sensitivity to these data preparation and specification choices. Research has also shown that the composition of risk efficient E-A or E-V frontiers is very sensitive to these choices (Adams et al.; Frankfurter et al.; Persaud and Mapp).

I have offered tentative recommendations regarding some of these choices elsewhere (Young, 1981 and 1984). However, there is an important continuing need for additional thinking and guidance on these issues if the recommendations and predictions which emerge from empirical risk studies are to be more than artifacts of arbitrary choices on data preparation and variable specification. For the purposes of permitting comparison between studies, it is also crucial that researchers carefully document the procedures they use.

The second methodological issue I would like to address relates to the choice between fixed versus adaptive strategies. Boggess' approach was to examine fixed irrigation strategies. Once a given irrigation strategy--described in terms of percent water remaining in the soil profile when irrigation is initiated, and centimeters of water to be applied per application--is identified as being preferred from a risk management perspective, a farmer is presumably recommended to stick with it in a given season and over future seasons. However, is this the way farmers behave? Or are farmers more adaptive? Do they, or should they, change strategies within a year? Should they adopt different strategies in different years based upon available information? More rigorously, can a farmer who follows some decision rule to adapt and modify his strategy during a season in response to changing weather conditions "do better" in a long-run net return sense than one following a fixed risk-efficient strategy throughout? Comparisons of fixed versus adaptive strategies for marketing storable crops with risky intra-season prices has favored the adaptive approach (Young et al.). Comparisons of this type might also be a fruitful area of research for irrigation decisions.

Is Irrigation a Risk-Reducing Input?

Boggess observes that "Numerous studies have shown that irrigation reduces yield variability and thus income variability." However, I will argue in this section that the fact that irrigation is a risk-reducing input in the short-run is not very important for behavioral determination. I will argue that it frequently is of much greater importance to farmers and policymakers that irrigation is often a risk-increasing input in the long-run.

As an incentive to adopt irrigation, much of the evidence indicates that short-run risk-reducing impacts of irrigation may be less important than old fashioned profit maximization. Most of the studies cited by Boggess support this hypothesis. Harris and Mapp showed that irrigating sorghum in Oklahoma more than doubled expected net returns. Burt and Stauber showed a 34 percent increase in expected net returns from irrigating corn in Missouri. Boggess' Table 1 shows irrigating soybeans in Florida increased expected net returns from $334 to $554 per acre, a profit increase of 61 percent. An exception is Apland et al.'s study which showed an increase of only two percent in expected net returns from irrigating corn in Illinois, while showing substantial reductions in income variability.

The same conclusion emerges from examining the location of Boggess' dryland soybean strategy in E-V space within his Figure 1. The dryland strategy is badly dominated in a risk-efficiency sense. It is further from the risk-efficient frontier than any other strategy.

Boggess' results for soybean irrigation in Florida also indicate that once the decision to irrigate has been made, relatively little is to be gained in strategy selection by considering risk. As shown in Table 1, the expected profit maximizing strategy (70 percent threshold, one centimeter applications) differs relatively little in its risk consequences from other examined risk-efficient irrigation strategies. By comparison, the risk reduction benefits from moving down the E-V frontier are much greater for the pea and lentil marketing example presented in the same table. However, the risk return tradeoff may be quite different for irrigation in settings other than Florida soybeans.

As noted above, the impact of irrigation on risk may be much more important in the long-run than in the short-run. Some of these long-run considerations were briefly discussed by Boggess under investment, institutional, and management risks. However, my remarks will go beyond these considerations and, in fairness to Boggess, apply more to irrigation in the arid and semi-arid western United States than in climatically humid Florida.

In many settings, I believe it is reasonable to argue that risk will be increased in the long-run by the decision to adopt irrigation. Several arguments support this hypothesis. First, if expected short-run net returns, which presumably refer to net returns to labor and management, are as high as indicated by many earlier studies, then both economic theory and historical evidence indicate that in the long-run these "abnormal profits" will be capitalized into land values. Consequently, long-run net returns to labor and management will return to normal equilibrium levels. However, costs will generally be higher on the irrigated farms than they were under previous dryland conditions. Consequently, potential losses are higher in the event of output price declines or crop failure.

Secondly, and more importantly, the irrigation farmer becomes exposed to serious long-term risks that future cost increases will out pace increases in returns. The irrigation farmer also shoulders the risk that water supplies will be reduced or eliminated in the future. Several environmental and institutional factors underly these long-run risks:

1. Depletion of groundwater aquifers is a serious problem in several areas. As groundwater tables fall, lifting costs become an increasingly severe burden. Future depletion of the Ogalalla aquifer could potentially force some irrigation farmers there to convert back to dryland farming accompanied by substantial windfall losses in land values.

2. Independently from aquifer depletion, exogenous increases in real energy prices could put many irrigation farmers in a severe cost-price squeeze.

Table 1. Comparison of E-V Risk-Efficient Irrigation Strategies and Seasonal Marketing Plans.

Risk-Efficient Plan	Soybean Irrigation in Florida[a]	Seasonal Marketing Plans for Dry Pulses, Washington State[b]			
		Lentils	Yellow Dry Peas	Green Dry Peas	Black Dry Peas
$E\Pi$ Max	70%, 1 cm (100,100)[c]	January (100,100)	November (100,100)	November (100,100)	October (100,100)
Intermediate[d]	60%, 2 cm (96,95)	February (91,72)	September (92,72)	September (94,64)	August (96,46)
Risk Min.	50%, 2 cm (90,89)	Contract (53,33)	July (90,41)	July (89,48)	July (94,42)

[a]Source: Boggess, W. "Risk Aspects of Irrigation Decisions." Paper presented at S-180 annual meeting, New Orleans, LA, March 28, 1984. The plans are described in terms of percent water remaining when irrigation is initiated and cm of water applied per application.

[b]Source: Young, D., J. Landon, R. Mahama. Strategies for Managing Marketing Risk for Palouse Dry Pea and Lentil Growers. Ag. Research Center Research Bulletin XB 0940, Washington State University, 1984.

[c]The first number in parentheses expresses the expected returns of the listed plan as a percentage of the expected returns of the expected-return-maximizing plan for that decision problem. The second number expresses the riskiness (measured as standard deviation) of net returns of the listed plan as a percentage of the riskiness of the expected-return-maximizing plan for that decision problem.

[d]The intermediate plan is a risk-efficient plan which lies between the $E\Pi$ Max and Risk Min plans. For the marketing analysis, the intermediate plan was described as the risk-efficient plan "beyond which very small gains in average returns involve rather large increments in risk."

3. Institutional or political changes such as the stronger enforcement of acreage limitations on federal water projects, reduced public subsidies on federal water projects, water reallocations away from agriculture to municipal and industrial users, power generation, fisheries, recreation, navigation, or in favor of Indian water rights, to name several possibilities currently worrying western farmers in various locations, could strongly affect the feasibility of irrigation farming in the long-run.

Furthermore, I hypothesize that these potential increases in long-term risk are seriously considered by many farmers while pondering the decisions of whether to convert to irrigation and, if so, which irrigation technology to use. In many areas of the western United States at least, I suspect that these long-term risks are more important than any short-term income variability reductions in making the decision to convert to irrigation. In these settings, realistic modeling of the irrigation decision process would require balancing expected short-run profit increases against long-term risk increases. This would represent a difficult modeling task and I know of no past studies which have done this. However, the distinction between short and long-run risk impacts could be important in several resource management problems.

Pest Control as a Risk-Reducing Input

As a newcomer to the area of pest control economics, I was impressed by Carlson's description of the complexity required for realistic modeling of pest control decisions. The simplistic expected utility maximizing model in which "pest control" is incorporated as a "risk-reducing input" is shown by Carlson to be inadequate and misleading. Unfortunately, perhaps, this simplistic model provides an appealing classroom example in which "pesticide application" (whatever that means) decreases the riskiness of profit and, consequently, risk-averse producers will "overapply" (exceed the expected-profit-maximizing level) of pesticides.

My reading of Carlson's discussion of past modeling efforts indicates that the key components in pest control decision models include:

1. A complete understanding of the dynamics of the particular pest control problem, including the critical importance of timing of pest control activities.

2. An understanding of the spatial distribution and movement of the pests under consideration and the relationship of these phenomena to control of the pests.

3. An understanding of the interaction between weather and pest control effectiveness.

4. Consideration of the value of improved monitoring and forecasts of pest incidence.

5. Incorporation of critical biological complexities into the modeling process.

For the sake of provoking thought, I will venture some possible conclusions related to incorporating risk in pest control models which are similar in direction but go further (or at least are stated more bluntly) than Carlson's. First, making risk a central focus of pest control decisions--given the simplistic way it is often incorporated given data and model specification limitations--might do more harm than good. Excessive emphasis on risk considerations could draw research resources and intellectual focus away from modeling the critical biological/physical complexities critical to the pest control process. An expected-profit-maximizing model that incorporates a more sophisticated view of biological processes may be more useful and practical than using an expected-utility-maximizing approach. I suspect that while incorporating producer risk-aversion indices into a pest control study may help get the study published, it may not enhance the practical utility of the model. Very possibly, incorporating risk preferences will absorb researcher effort that could have a higher payoff elsewhere.

Using expected utility maximization as a paradigm to explain farmer pest control behavior could also be misleading. This approach could suffer some of the same errors of inference characterizing the "observed economic behavior method" for measuring farmers' risk preferences (Young, 1979).

Carlson calls attention to this problem in the concluding paragraph of his paper:

> Farmers often seem to be applying high rates of pesticides. Assuming that unusually high levels of pesticide use are associated only with risk-averseness and the risk-reducing nature of pesticides. . . blinds researchers to other explanations for this phenomenon.

In summary, I recommend Carlson's paper as a good review of the importance and role of risk in pest control decisions. However, do not expect it to offer easy answers or to be comfortable reading that fits nicely into familiar risk paradigms.

References

Adams, Richard M., Dale J. Menkhaus, and Bruce A. Woolery. "Alternative Parameter Specification in E,V analysis: Implications for Farm Level Decision Making." W. J. Agr. Econ. 5(1980):13-20.

Anderson, Jock R., John J. Dillon and Brian Hardaker. Agricultural Decision Analysis. Ames: Iowa State University Press, 1977.

Apland, Jeffrey, Bruce McCarl and William Miller. "Risk and Demand for Supplemental Irrigation: A Case Study in the Corn Belt." Amer. J. Agr. Econ. 62(1980):142-145.

Boggess, W. "Risk Aspects of Irrigation Decisions." Paper presented at S-180 annual meeting, New Orleans, LA, March 25-28, 1984.

Bohrnstedt, George W. and Arthur S. Goldberger. "On the Exact Covariance of Products of Random Variables." Amer. Stat. Assoc. J. 64(1969):1439-1442.

Burt, Oscar R. and M.S. Stauber. "Economic Analysis of Irrigation in Subhumid Climate." Amer. J. Agr. Econ. 53(1971):33-46.

Carlson, Gerald A. "Risk Reducing Inputs Related to Agricultural Pests." Paper presented at S-180 annual meeting, New Orleans, LA, March 25-28, 1984.

Frankfurter, G., H. Phillips, and J. Seagle. "Portfolio Selection: The Effects of Uncertain Means, Variances and Covariances." Journal of Finance and Quantitative Analysis, 4(1971):1251-1262.

Harris, Thomas R. and Harry P. Mapp, Jr. "A Control Theory Approach to Optimal Irrigation Scheduling in the Oklahoma Panhandle." S. J. Agr. Econ. 12(1980):165-172.

Persaud, Tillak and Harry Mapp. "Effects of Alternative Measures of Dispersion on Risk-Efficient Farm Plans in a MOTAD Framework." Paper presented at the Annual AAEA Meeting, Pullman, Washington, July 29-August 1, 1979.

Young, Douglas L. "Risk Preferences of Agricultural Producers: Their Use in Extension and Research." Amer. J. Agr. Econ. 61(1979):1063-1070.

Young, Douglas L. "Measurement of Objective Probabilities from Time Series Data." Paper presented at W-149 annual meeting, San Diego, CA, January 6-8, 1981.

Young, Douglas L. "Risk Concepts and Measures for Decision Analysis." Chapter 3 in Barry, Peter (editor), Risk Management in Agriculture, Ames: Iowa State University Press, 1984 (forthcoming).

Young, Douglas, John Landon, and Ramatu Mahama. Strategies for Managing Marketing Risk for Palouse Dry Pea and Lentil Growers. Ag. Research Center Research Bulletin XB 0940, Washington State University, 1984.