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QUANTIFYING LONG RUN AGRICULTURAL RISKS AND EVALUATING FARMER RESPONSES TO RISK

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RISK ANALYSIS IN THE USMP REGIONAL AGRICULTURAL MODEL

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INTRODUCTION

The USMP regional agricultural model has long had risk as an optional feature, but it is a feature which has not been used for several years. I implemented and used risk analysis in USMP in the early 1980's (House, Miller et. al.). At that time I saw risk as a solution for the specialization problems which plagued mathematical programming models which relied heavily on linear functions and flexibility constraints. After some experience in this formulation, I concluded somewhat similarly to Newbery and Stiglitz that risk was important, but not that important. The specialization problem was better solved by use of nonlinear production functions. Lacking a comprehensive set of nonlinear production functions, in 1983 I turned to positive mathematical programming or PMP (Howitt and Mean). This was as at least a step in the right direction.

But for policy modelers, risk remains a seductive concept for several reasons. Commodity programs direct billions of dollars of transfers in part to protect producers from uncertainties, and yet we still find it necessary to enact disaster programs every few years. Instability in commodity markets seems to be growing if anything. And possible global "policy reforms" might result in more market instability for some.

USMP is a convenient framework with which to analyze risk impacts on producers and risk effects of policy changes. I have partially updated USMP's risk features in order to demonstrate this and provide a tool for experimentation. This report provides a brief overview of USMP, and then focuses on how risk is implemented in the model. In particular, there are interesting opportunities for modeling how policy changes affect the net returns variability faced by producers. The report concludes with numerical examples of how USMP results differ depending on whether the risk features are turned on or off.

USMP MODEL OVERVIEW

The U.S. Agriculture Sector Mathematical Programming (USMP) Model is a spatial and market equilibrium model. USMP predicts how changes in farm or trade policy will affect regional supply of crops and livestock, commodity prices and demand, use of production inputs, farm income, and government expenditures. Sector models such as USMP are not designed for forecasting, but rather for comparative static analysis. Comparative statics explains how the sector changes between a base period and several years later when the change has worked itself out and the sector returns to equilibrium.

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Methodology and Assumptions

USMP solves for prices and quantities consistent with competitive market equilibrium (not a forecast for a specific date in the future). Production activities are represented by fixed coefficient production functions. The supply side of the system is aggregated into production units specified for a large geographic area (e.g. a state or region). Resource and input supply are represented with price a fixed or increasing function of quantity supplied. Demand in various markets is represented with price an inverse function of quantity demanded.[1]

USMP is designed to be a consistent analytical framework in which readily available data are combined to permit "near" general equilibrium analysis of agriculture sector policy issues.[2] Most data used in USMP are collected and published by USDA; the bulk of model coefficients, the commodity production budgets, are developed from the annual ERS Farm Costs and Returns Survey.[3]

Units of Analysis

A rich variety of commodities, factor inputs, natural resources, production/consumption regions, and supply/demand markets can be analyzed with USMP. The model contains 41 commodities, comprising the principal U.S. crop and livestock commodities: primary agricultural products (such as soybeans or hogs for slaughter) and processed products (such as soybean meal or retail cuts of pork) (table 1). Geographically, the model separates the United States into 10 Farm Production Regions. Markets for supply of land and irrigation water are specified on a regional level. Land is separated into crop and pasture classes. Some 23 other inputs such as fertilizer, seed, and labor are modeled with fixed, national level prices (table 2).

Four commodity final demand sectors are specified separately: domestic consumption, export, commercial stocks, and government stocks. For most analyses, we use an aggregate version of USMP where each of the 10 regions has production activities for each primary commodity produced there. We also maintain production enterprise data with which we can generate a more disaggregate model where each of the 48 continental States has production activities for each primary commodity produced there. For each crop produced in a geographic unit, production activities are specified for each combination of dryland, irrigated, participating in Government programs, and nonparticipating. Each production activity is an average of production techniques in the geographic area it represents. The aggregate model contains 309 primary commodity production activities. USMP contains 25 production

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[1] The theory and formulation of such models are presented in House 1983 and McCarl and Spreen. USMP formulation is described in House 1983 and Hickenbotham and House 1989. The GAMS modeling language specification of USMP is presented in House 1987.

[2] Equilibrium is only "near" general because changes in agricultural sector income are not translated back into changes in final demand.

[3] Data used in USMP are specified in House, 1983.

activities for secondary or processed commodities which are specified at the national level. The aggregate model tableau measures 81 equations by 509 variables; 360 of the variables are nonlinear.

Government farm programs modeled in USMP include the target price, acreage reduction, acreage diversion, CCC loan, marketing loan, dairy product purchases, export enhancement (EEP), and the conservation reserve (CRP). Other programs such as generic certificates, and farmer owned reserve (FOR) are embedded in USMP, but lack specific adjustable instruments. No accounting is made of programs for commodities not in the model. Crop program participation is determined endogenously, in response to market forces affecting production returns and costs, and Government program benefits and participation costs.

Table 1--USMP crop and livestock commodities

Crops	Livestock
Primary commodities	
cotton	fed beef for slaughter
corn	nonfed beef for slaughter
soybeans	beef calves for slaughter
wheat	beef feeder yearlings
sorghum	beef feeder calves
rice	cull beef cows
barley	cull dairy cows
oats	cull dairy calves
silage	milk
hay	hogs for slaughter
	cull sows for slaughter
	feeder pigs
	poultry
	other livestock
Secondary commodities	
soybean meal	fed beef
soybean oil	nonfed beef
livestock feed mixes	veal
dairy feed supplements	pork
swine feed supplements	butter
	American cheese
	other cheese
	ice cream
	nonfat dry milk
	manufacturing milk

Table 2--USMP Production Inputs

Input
Regional inputs
cropland
pasture land
irrigation water
National inputs
nitrogen fertilizer
potassium fertilizer
potash fertilizer
lime
other variable costs
public grazing land
custom farming operations
chemicals
seed
interest on operating capital
machinery and equipment repair
veterinary and medical cost
marketing and storage
cash ownership costs
noncash ownership costs
management costs
land taxes
general farm overhead
variable noncash costs
irrigation water application
energy costs
insurance
land rent
labor

E-V RISK IS USED IN THE USMP AGRICULTURAL MODEL

Several approaches have been used to include risk in mathematical programming models of agricultural production. USMP incorporates the mean-variance (E-V) approach. Other approaches are reviewed in Boussard.[4] The mean-variance approach has certain limitations (discussed by Newbery and Stiglitz, pp. 85-92), but is still a useful tool for analysis of decisionmaking under risk (Robison).

Introduction of producer risk into an agricultural model requires a specification of a behavioral model of producer decisionmaking under uncertainty. More specifically, this requires a) a preference or utility theory which deals with uncertainty, b) a way of quantifying the risky events in terms of the utility function, and c) a way of representing the decisionmaker's attitudes toward risk. For further discussion of these issues see House (1983) or Anderson, et. al. (1977).

THE AGGREGATE MODEL INCORPORATING RISK

USMP is presented in <u>extremely</u> summary form in (1). The maximand, Z, is social welfare. X is a vector of enterprise activity levels and M is a diagonal matrix of expected stochastic yields. Hence X'M is a vector of output by commodity. X'M(A - 0.5BMX) is sector revenue (the area under commodity demand functions) and X'(C + 0.5D'X) is sector costs (the area under supply functions). A and B are demand function intercepts and slopes. C and D are input supply and positive mathematical programming (PMP) cost function intercepts and slopes. For detailed discussion of these sector model components see House (1983), Duloy and Norton (1975), or McCarl and Spreen (1980).

V is a variance-covariance matrix of enterprise revenues, and $\hat{a}$ is the risk aversion parameter. $(\hat{a}/2)X'VX$ is the risk premium and is included in the sum of areas under the supply functions (Hazell and Scandizzo, 1974).

G is a matrix of technical constraint coefficients (such as factor usage), and R is the right hand side vector of constraint (factor) availabilities.

$$\text{Maximize} \quad Z = X'M(A - 0.5BMX) - X'(C + 0.5D'X) - (\hat{a}/2)X'VX \qquad (1)$$
$$\text{Subject to } GX \leq R$$

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[4] One of these is game theoretic modeling which has interesting potential, but has demonstrated little practical utility for farm management or policy analysis modeling (Boussard: 77). Others include security-based theories of behavior such as Roy's "safety-first" model and Boussard and Petit's "focus of loss" approach where the concerns are achieving minimum income levels and avoiding disasters. Experimental work on risk behavior by Binswanger yielded results inconsistent with the security approaches, but consistent with expected utility maximization (Newbery and Stiglitz: 105).

Producer Risk Specification

The model's risk formulation requires specification of the variance, covariance matrix of activity net returns (V) and a coefficient of risk aversion (â). In this section we first consider the types and definitions of risk which affect agricultural producers and then the specific measure of risk used in this study. Next we present the methods used to estimate the activity net returns variance, covariance matrix and the risk aversion parameter.

Types and Sources of Risk

We define risk as the uncertainty of returns associated with the decision to produce a given commodity. Two major types of risk facing farmers may be distinguished: business risk and financial risk (Gabriel and Baker, 121). Business risk refers to the uncertainty of the flows of net income. The sources of enterprise business risk are output prices, input prices and availability, and yield variability.[5]

Yield uncertainty is affected by such things as weather, plant and insect infestations, and the cultural management ability of the producer. The business and marketing ability of the producer is also a potential source of business risk.

The second major type of risk affecting producers is financial risk. This is the, "...added variability of the net cash flows of the owners of equity that results from the fixed financial obligation associated with debt financing and cash leasing" (Gabriel and Baker). Financial risk also encompasses the risk of cash insolvency and, the risk of being unable to meet cash obligations given the levels of a firm's net cash flows, fixed obligations, and available liquid assets. Income tax laws and rulings also affect financial risk (Eidman).

Gabriel and Baker note that total risk is composed of both business and financial risk and hypothesize that each component will adjust in response to a shock or change in the other. Based upon empirical testing they tentatively conclude that in the aggregate, "..farmers make financial adjustments leading to decreased (increased) financial risk in response to a rise (fall) in business risk."

Measure of Risk Used in the USMP Model

Business risk or variation in enterprise net returns is the measure of risk used in USMP. This measure is commonly observed in the risk literature. It has proven to be a useful way of introducing risk in programming models and does not make unreasonable demands in terms of data requirements or methodological complexity.

This measure of risk considers only business risk. A more complete treatment of risk would include such financial factors as interest rates, debt-to-equity ratios, liquidity levels, tax payments, and their interactions.

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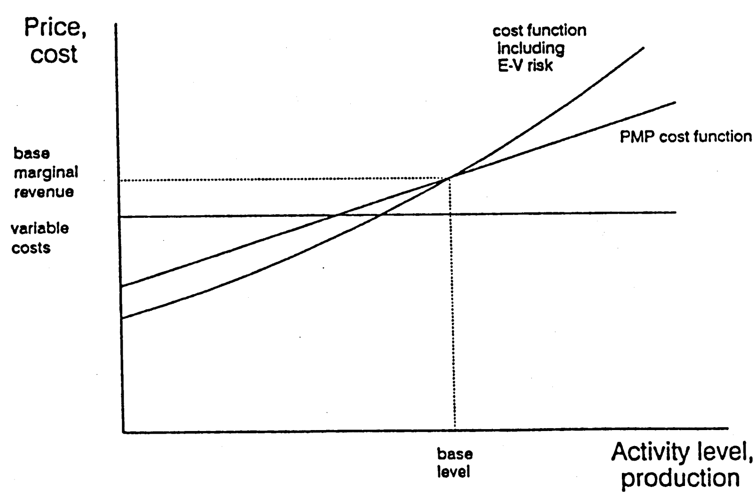
[5] Perfect competition is assumed; hence, producers are price takers in both product and factor markets.

Such an effort would require methodological development and empirical testing beyond the scope of the present work.

In the USMP model, the risk formulation is applied only to the major crops and not to silage, hay, rice, and livestock production enterprises. Other enterprises are not riskless. We assume that a premium for bearing production risk exists for all USMP enterprises. But only for the major crops does this premium explicitly vary as a quadratic function of enterprise activity levels and the covariance of enterprise net returns.[6] This compromise is due to a lack of necessary data for hay, silage, rice, and livestock, and additional complexities of modeling livestock producer behavior under risk. Livestock producers adjust both their production technical coefficients and their capital stock levels in response to changing market conditions during the production period. Another complication is the impact of federal income tax laws on net returns from livestock enterprises.

We assume that in the base year equilibrium situation, production costs, including risk premiums, and receipts including factor returns are in balance. The base-year equilibrium risk premium is not added on top of other costs, rather it is already accounted for by the linear factor cost and positive mathematical programming (PMP) cost functions. Using the PMP formulation the model's base solution is not affected by the E-V risk components of the model (since the base solution matches historical values). Only when the model is "shocked" with some policy or market change does the risk formulation affect the results (fig. 1).

Figure 1--USMP production activity cost function



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[6] Livestock returns depend upon quantity demanded, price, and production costs. Livestock product demand is largely domestic and free of the short term shifts which affect field crop demand. Prices are thus largely determined by supply which is affected by longer run production cycles. While the present formulation does not explicitly recognize livestock production risks, these are generally of a smaller magnitude than for crops. This leaves production costs, which are probably the major source of uncertainty in livestock returns. Livestock production costs are affected by risk in crop production, which shows up as increased cost of feed grain factor inputs.

A Net Returns Sample for each Production Activity

The risk measure, variation in enterprise net returns, is calculated by constructing a time series sample of net returns for each production activity (subject to risk) in the model. Enterprise net returns are defined as commodity production times regional market price less the costs of production, calculated on a production unit level. In order to calculate the variances and covariances of production activity net returns, it would be ideal to have a cross sectional sample of enterprise net returns with a minimum of 30 observations in each enterprise stratum. Unfortunately, data are not available in this form. Our procedure, therefore, involves using time series observations on regional enterprise yields, production costs, and product prices to construct the sample.

The risk measure desired is not precisely sample enterprise net returns variation, but rather farmers' subjective expectations of enterprise net returns variation. The risk measure is used to help explain the production decision process; therefore, it must reflect the fashion in which farmers' expectations as to enterprise net returns are formed. We assume that these expectations are based largely upon previous behavior of prices and yields. In terms of the definition of net returns, we assume that prices and yields are stochastic and that production costs are nonstochastic. We further assume that the distribution of net returns is normal.

The production activity net returns measure is specified as

$$H_j = P_j Y_j - C_j \tag{2}$$

where H_j, P_j, Y_j and C_j are net returns, product prices, yields and costs for enterprise j. The expected activity net returns samples are formed from price, yield, and cost samples. A set of price observations is obtained by using a time series sample of regional annual commodity price values adjusted to base year levels using the gross national product (GNP) deflator price index (Council of Economic Advisors, 1981). This provides samples of actual annual commodity prices shifted to base year nominal levels.

A set of yield observations over the same sample period is calculated by adding to the base year observed yield, the residuals obtained from simple linear or semi-log regressions of yield against time. This regression is meant to be a model of farmers' subjective predictions of what crop yields will be. The deviations of the actual from predicted yield levels then represent the unexpected variation in yield. When added to the base-year yield level, this becomes a detrended sample of potential yield levels shifted to base-year yield levels.

Finally, the enterprise base year cost figure is used in each sample (base-year production cost is assumed to be nonstochastic). The constructed observation for each year is formed as the product of the adjusted price and yield, less the constant production costs.

The time series data used to estimate the net returns series cover the 23-year period 1958-1980 (U.S. Department of Agriculture, 1982). Time did not permit updating the nearly 140 price and yield series (7 crops by 10 regions) and reestimating the nearly 70 yield deviation regressions. The original yield deviation sample series were used without change.

The yield sample series do not distinguish between dryland and irrigated yields. Initial runs of the 1986 base risk model use the same yield series for both dryland and irrigated activities. Subsequent runs will differentiate dryland and irrigated yields based upon empirical estimates, or--lacking data--some professional judgement such as irrigated yield variance equals one third dryland yield variance.

The price observations used to compute returns differ for government program participating activities. If a target price program is in effect for a commodity, then the greater of the sample market price or the announced target price is used. If a scenario is run simulating, say, a policy change such as reducing or eliminating the target price, then the net returns series and variance-covariance must be recomputed, based on the new policy design.

The mean and variance of the distribution are estimated from the constructed base-year net returns sample. The expected value and variance of net returns for enterprise j are, for example,

$$E(H_j) = (1/n) \left(\sum_{i=1}^{n} H_{ij}\right) = \Pi_j$$

$$Var(H_j) = E[(H_j - E(H_j))^2] = E(H_j^2) \; \Pi_j^2 \qquad (3)$$

where E and Var are the expectations and variance operators, n is the number of years in the sample, and Π_j is mean net returns. The covariance of net returns between any two enterprises j and k, $Cov(H_j, H_k)$, is expressed as

$$Cov(H_j, H_k) = E[(H_j - E(H_j))(H_k - E(H_k))] \; . \qquad (4)$$

The enterprise net returns variance, covariance matrix, V, is computed according to relation (5). We assume that the covariance of enterprise net returns affects producer decisionmaking only insofar as the enterprises are in the same region.

$$V_{jk} = \begin{cases} Cov(H_j, H_k) & \text{for enterprises j and k in the same region} \\ 0 & \text{for enterprises j and k in different regions} \end{cases} \qquad (5)$$

The net returns formulation used in USMP was selected because it fits the theoretical model well and the necessary data were readily available. More complex formulations were rejected partly for practical reasons due to the number of crops and regions involved. Using this formulation we treat the product of price and yield as a single random variable. Other formulations have been used.[7]

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[7] The price and yield variables can be treated separately, each with its own distribution. This requires specifying and working with joint

THE COEFFICIENT OF RISK AVERSION

All of the components in the agriculture sector model specified in (1) correspond to standard economic and production concepts. These items can all be readily estimated from sample and agricultural experiment data with the exception of â, the Pratt, Arrow coefficient of absolute risk aversion. This is specified as the negative of the ratio of the producer utility function's second and first derivatives:

$$\hat{a}(W) = - U_2(W) / U_1(W) \tag{6}$$

where the subscripts denote derivatives and W represents income. The coefficient of absolute risk aversion depends upon the units in which income is measured. Further, since â is a function of income, any particular value corresponds to a specific income level. Absolute risk aversion coefficients cannot be compared with one another unless the income level is known. For this reason, a related concept, the coefficient of relative risk aversion (which we denote as 'ϕ'), is often used. This is specified in (7) and may be thought of as an elasticity of the marginal utility of income. As an elasticity it is unitless and therefore useful for comparing risk aversion levels.

$$\phi(W) = - WU_2(W) / U_1(W) = W\hat{a} \tag{7}$$

Either type of risk aversion coefficient is somewhat abstract, being a description of the curvature of producer utility functions. The coefficient of risk aversion is not the sort of datum which one can request from producers and its specification in agricultural models has long been a problem. To make the coefficient less abstract we will compare aversion coefficients used and how they were specified in several farm and sector agricultural studies.

Comparison of Risk Aversion Coefficients

Most studies report only the absolute risk aversion coefficient, which, as we noted earlier, are not directly comparable. We will compare these and, where possible, we will convert coefficients to relative risk aversion values which are comparable. We mention both farm and sector level studies, since the risk coefficients are comparable. Hazell and Scandizzo (1977: 205) and Hazell (1982: 388) suggest that the sector level coefficient of risk aversion should be a "suitable average" of individual farm risk aversion parameters.

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distributions which most researchers have rejected as an unnecessary complication (Anderson, et. al., 1977). For certain analytical topics the added complexity may be necessary. For example, this author treated price and yield distributions separately for an analysis of export demand variability analysis (House, 1983)). Some researchers such as Hazell and Scandizzo have specified only yields as stochastic. They reason that stochastic yields imply stochastic supply which, given some fixed demand function, necessarily implies stochastic prices (Hazell and Scandizzo, 1974). Other researchers have considered only prices as stochastic (Paris, 1979).

In an earlier application of USMP, this author applied a technique suggested by Paris (1979) to calculate sector risk aversion parameters based upon actual producer decisions (House 1983, 1983a). The coefficient of absolute risk aversion was 0.00022706 and the coefficient of relative risk aversion was estimated at 2.5. In the current work the coefficient of absolute risk aversion is estimated at 0.00020844 and the coefficient of relative risk aversion at 3.41 (see appendix).

Freund (1956) described the selection of the absolute risk aversion coefficient as a purely subjective task. He felt that the value should lie between 0.0004 and 0.0002, but selected 0.0008 since he felt that his revenue variances were underestimated (1956: 258). Evaluated at his optimum model solution income level of $9121, this implies relative risk aversion coefficients of from 1.8 (at $\hat{a}$=0.0002) to 7.3 (at $\hat{a}$=0.0008).

In a recent analysis of agricultural commodity policy, Calvin econometrically estimated coefficients of absolute risk aversion for individual Iowa cash grain producers. Her estimates ranged from 0.0005318 for small (100 to 179 acres) to 0.00009812 for large (1000 acres and greater) farms. She found that the coefficients of absolute risk aversion decreased with farm size (a proxy for wealth) and relative risk aversion coefficients increased with farm size, ranging from .080 to .129 for the small and large groups above (Calvin, pp. 65-75).

In an analysis of farm planning under uncertainty, King and Oamek selected absolute coefficients between 0.0 and 0.00002. For their problem they termed absolute risk aversion coefficients of 0.00001 as representing slightly risk averse decisionmakers and coefficients of 0.00002 as representing moderately risk averse decisionmakers. The average of their reported simulations' mean net cash flows was $39,683. This implies relative risk aversion coefficients in the neighborhood of 0.4 (at $\hat{a}$=0.00001) to 0.8 (at $\hat{a}$=0.00002).

In an example using the Duloy-Norton CHAC model, Hazell and Scandizzo (1977: 206-208) tried various coefficients between 0.0 and 2.0 and reported that 1.0 gave the best model fit. Their risk formulation is mean, standard deviation--as opposed to mean, variance--so their risk aversion coefficients, θ, are equivalent to the product of the absolute coefficients and the standard deviation of income, or $\theta = \hat{a}s$, where s is the standard deviation of income. The implicit relative risk aversion coefficient, θ, will depend upon the relationship between firm income mean, Π, and standard deviation, s: $\phi = (\Pi/s)\theta$. If, for example, income standard deviation is half the mean level, then the relative risk aversion coefficient corresponding to their best fit value would be 2.0.

Several other studies have applied a "best fit" criterion to select the value of the risk aversion coefficient. (That is, try several values and choose the one which produces the best model fit to observed data.) In a sector model of Mexican vegetable exports incorporating mean, standard deviation risk, Simmons and Pomareda tested values between 0.0 and 1.5 and chose 0.5 which gave the best fit with actual historical production levels. This corresponds to relative risk aversion levels of perhaps 1.0 if average income is twice the standard deviation of income. In a model of U.S. peanut production Niewoudt, et. al. used the coefficient as a "method of fine-tuning the predictive ability of the model" (p. 488). They tested mean, standard deviation risk aversion coefficients between 0.0 and 3.0 and found that 2.0 gave the best fit. If average income is twice its standard deviation, this implies a relative risk coefficient of 4.0. In a sector model of Senegalese agriculture incorporating mean, standard deviation risk, Jabara and Thompson tried values between 0.0 and 2.5 for the coefficient. They modeled the aversion of policymakers to price risk on internationally traded commodities and noted that the larger values appeared to give results more consistent with policy maker objectives (p. 195). The relative risk aversion coefficient would be around 5.0, again if mean income is twice its standard deviation.

Best fit methods of specifying a sector model's coefficient of risk aversion have little theoretical foundation unless the rest of the model is nearly perfect. With this approach the coefficient probably ends up accounting for various specification, sampling and aggregation errors in a model. Best fit approaches have been criticized for these reasons (Easter: 106, 190; Hazell 1982: 388).

EFFECTS OF RISK FORMULATION ON MODEL RESULTS

To gauge the effects of E-V risk we will examine a typical USMP scenario and compare results of three alternatives: 1) no explicit risk, 2) the E-V formulation described above, and 3) the E-V risk formulation plus some policy or market change which doubles the standard deviation of net returns. The alternative scenario which illustrates these alternatives assumes removal of most commodity programs and increased demand for grains and certain dairy products. We are interested not in the scenario impacts, but in how model results differ depending on the risk formulation.

The third alternative, doubled net returns deviation, can only be examined if risk is explicitly included in the model. Doubling net returns deviation is very easy: we merely multiply the variance-covariance array by 4 (doubling deviation corresponds to four times the variance of net returns since variance equals the square of the deviation).

Doubled deviation is just an assumption for this example, but what does it mean? Doubled deviation implies, for example, that net return levels (assumed to be normally distributed) which used to fall within a certain range about 95 percent of the time (plus or minus two standard deviations from the mean) will fall into that same range only about 68 percent of the time (plus or minus one standard deviation from the mean).

Commodity price and production impacts

Adding E-V risk to the base USMP formulation has almost no effect on predicted changes in commodity prices and production levels (tables 3-5). This result holds for all classes of USMP products: crops, livestock, and processed products.

Doubling net returns deviation, however, has a significant effect on crops impacts. This alternative clearly reflects the distinctive impact of increased risk on supply: commodity supply functions shift upward and to the left. Predicted changes in crop prices are roughly double the changes of the no risk and straight E-V risk formulations. The difference is minor for cotton, and nil for the three crops which are not given E-V risk treatment: rice, silage, and hay.

With the base and straight E-V formulation, crop production is generally predicted to increase. With doubled deviation, the predicted increases switch to predicted declines for some crops (corn, sorghum, wheat, and soybeans) and smaller increases for others (barley and oats).

The doubled deviation impacts on crops are transmitted to the livestock and processed products sectors via crop use as inputs to other production processes. Generally, the more expensive feed and crop products translate to greater price increases and lesser output of livestock, soybean, and dairy products.

Crop acreage impacts

The effects of risk formulation on acreage planted are much the same as the effects on crop production (table 6). Results with the E-V risk formulation differ little from those of the basic non-risk USMP formulation.

Only in the double net returns deviation formulation does E-V risk make a difference. Overall, acreage planted declines, compared to increased or constant acreage in the basic and straight E-V risk runs. Evident from the regional acreage results of the double deviation run, is the fact that E-V risk effects differ by region and by crop. For example, although corn acreage declines overall, the decline is concentrated in the Corn Belt and North Plains regions, while corn acreage rises in other regions. Similarly for wheat, the U.S. acreage decline is reflected in four regions, while wheat acreage rises in the other six regions.

Income impacts

Table 7 presents a gross returns less variable costs income measure for each region. Again, the effect of E-V risk on this measure are nil. In the double deviation run, income changes are in the same direction as in the other runs, but are smaller. Crop income declines are 10 to 50 percent less than under the other runs; livestock income gains are substantially less.

DIFFERENCES IN RISK PREMIUMS DETERMINE THE RISK EFFECT

The simple E-V risk formulation doesn't affect the model results because production activity risk premiums do not increase much in the example scenario. As described earlier, the base non-risk model is assumed to have the base risk premium levels built in--they just do not vary as production activity levels change. The only impact of the risk formulation on model results will come from how much activity risk premiums increase or decrease in a model run. The double deviation greatly affects model results because by construction the activity risk premiums are increased greatly over the base and simple E-V formulations.

Table 8 compares the three formulations in terms of individual activity risk premiums per acre.[8] It is evident why the simple E-V risk formulation has little affect on results: the corn risk premiums increase as little as 5 cents per acre (Appalachia) and rise only 21 cents per acre in the Corn Belt. In the E-V run, the relative differences among regional risk premiums per acre do not matter--what matters are the relative differences among <u>increases</u> in risk premiums over the base run.

With the double deviation run, however, increases in risk premiums are much, much greater. They range from nearly $3 per acre to almost $60 per acre for the Corn Belt. These increases enter production decisions as increases in production costs and have the effect of shifting commodity supply functions up and to the left. Also, with the double deviation formulation not only are the risk premium increases greater, the regional differences among risk premium increase are also great. This explains the differential regional effects of the double deviation run on crop acreage and income.

CONCLUSIONS

An E-V risk formulation will not necessarily improve the predictions of a regional programming model such as USMP. In an example scenario involving large changes in commodity policy and export demand, addition of standard E-V risk barely affect model results. Validated on base period, historical levels of price, production, and so on, the base model implicitly already incorporates any effect of risk on production decisions and market outcomes. Further, with a PMP formulation such as that used in USMP, production costs vary directly with production levels--a typical result of an E-V type formulation.

The key issue is the extent to which risk premiums change significantly and/or differently from how the base model's enterprise costs change under a simulated scenario. Only if the changes are "significant" will the E-V have a significant effect. If producer reaction to changes in risk are not captured in a policy model, then model's predictions might be seriously flawed. On the other hand, overestimation of risk effects can lead to equally serious errors.

With E-V risk, risk premiums will change significantly if enterprise net returns variability changes significantly. Clearly, certain policy and market shifts might significantly affect the producers' net returns variability. The challenge for the policy analyst is to correctly translate a policy or market change into adjustments to producers' subjective expectations of their net returns variability.

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[8] Variable costs per acre for the three production activities are included in the table for comparison.

Table 3--Crop price and production under alternative scenario: non-risk versus alternative risk assumptions

	PRICE			PRODUCTION		
PRODUCT	NON RISK	E-V RISK	DOUBLE DEVIATION	NON RISK	E-V RISK	DOUBLE DEVIATION
			--PERCENT CHANGE--			
CORN	12.2	12.4	24.9	3.7	3.7	-1.0
SORGHUM	13.7	13.9	26.6	11.5	11.3	-4.4
BARLEY	9.6	9.7	18.6	9.0	8.9	5.0
OATS	6.5	6.6	14.9	3.6	3.6	3.1
WHEAT	9.9	10.0	18.6	4.8	4.6	-1.7
RICE	3.2	3.2	3.2	2.0	2.0	2.0
SOYBEANS	-0.3	-0.2	4.9	0.0	-0.1	-5.5
COTTON	8.1	8.2	10.8	7.9	7.8	5.8
SILAGE	0.0	0.0	-0.1	5.2	5.2	4.5
HAY	-0.2	-0.2	-0.3	3.9	3.9	3.5

Table 4--Livestock product price and production under alternative scenario: non-risk versus alternative risk assumptions

	PRICE			PRODUCTION		
PRODUCT	NON RISK	E-V RISK	DOUBLE DEVIATION	NON RISK	E-V RISK	DOUBLE DEVIATION
			--PERCENT CHANGE--			
CLDARYCF	7.5	7.5	6.8	3.8	3.8	3.5
CLDARYCW	13.2	13.2	12.7	3.8	3.8	3.5
MILK	0.4	0.4	1.3	3.9	3.9	3.6
FEEDERPIG	3.6	3.6	5.5	4.3	4.3	3.4
CULLSOW	5.3	5.3	6.8	5.0	4.9	4.2
HOGSLAUGH	6.0	6.0	7.7	5.0	5.0	4.3
LIVCALF	7.5	7.5	6.8	3.8	3.8	3.4
BFYRLINGS	5.0	5.0	4.7	2.4	2.4	2.4
CALFSLA	0.0	0.0	0.0	0.0	0.0	0.0
CLBFCOW	13.2	13.2	12.7	3.9	3.8	3.5
CLBULLSTA	13.2	13.2	12.7	3.6	3.5	3.2
NONFDSL	13.2	13.2	12.7	0.0	0.0	0.0
FEDSLA	9.4	9.4	10.4	2.8	2.8	2.3
POULGCAU	0.0	0.0	0.0	0.0	0.0	0.0

Table 5--Processed product price and production under alternative scenario: non-risk versus alternative risk assumptions

PRODUCT	PRICE NON RISK	PRICE E-V RISK	PRICE DOUBLE DEVIATION	PRODUCTION NON RISK	PRODUCTION E-V RISK	PRODUCTION DOUBLE DEVIATION
	--PERCENT CHANGE--					
FLUIDMLK	0.3	0.3	1.1	0.0	0.0	-0.2
MFGMILK	0.4	0.4	1.4	6.1	6.1	5.7
BUTTER	-50.2	-50.1	-49.1	50.9	50.9	50.5
AMCHEESE	0.4	0.4	1.4	-4.8	-4.8	-5.2
OTCHEESE	0.2	0.2	0.7	-19.9	-19.9	-20.3
ICECREAM	0.1	0.2	0.5	-0.1	-0.1	-0.4
BEANMEAL	-0.2	-0.2	3.8	-2.2	-2.2	-2.9
BEANOIL	-0.3	-0.2	5.3	1.3	1.3	0.3
FEDBEEF	5.8	5.8	6.3	2.8	2.8	2.3
NONFDBEEF	6.7	6.7	6.4	5.8	5.8	6.1
VEAL	3.7	3.7	3.4	-14.2	-14.1	-12.9
PORK	2.5	2.5	3.2	5.0	5.0	4.3
NFDMILK	95.6	95.6	96.4	50.9	50.9	50.5

Table 6--Acreage planted by region under alternative scenario: non-risk versus alternative risk assumptions

CROP	FORMULATION	NORTH EAST	LAKE STATES	CORN BELT	NORTH PLAINS	APPALACHIA	SOUTH EAST	DELTA STATES	SOUTH PLAINS	MOUNTAIN	PACIFIC	US TOTAL
		--PERCENT CHANGE--										
CORN	NON-RISK	9.9	3.8	1.3	6.1	4.4	6.3	17.5	18.1	14.4	18.3	4.0
	E-V RISK	10.0	3.8	1.3	6.0	4.5	6.4	17.6	17.8	14.3	18.0	3.9
	DBL.DEV.	16.5	1.5	-4.0	-4.5	5.4	9.3	27.0	11.8	16.2	22.8	-0.4
WHEAT	NON-RISK	9.9	7.6	4.1	2.0	6.2	4.8	8.3	1.9	4.5	13.2	3.8
	E-V RISK	9.9	7.4	4.1	1.8	6.2	4.8	8.3	1.9	4.4	12.8	3.7
	DBL.DEV.	14.4	-5.0	-3.7	-7.2	9.0	8.0	12.2	-0.6	1.2	9.7	-1.9
SOYBEANS	NON-RISK	-0.2	-0.1	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	E-V RISK	-0.3	-0.2	0.0	-0.5	0.0	0.0	0.0	-0.2	0.0	0.0	-0.1
	DBL.DEV.	5.1	-1.6	-6.7	-14.0	2.1	1.8	2.0	2.1	0.0	0.0	-4.4

Table 7--Income by region under alternative scenario: non-risk versus alternative risk assumptions

CROP	FORMULATION	NORTH EAST	LAKE STATES	CORN BELT	NORTH PLAINS	APPALACHIA	SOUTH EAST	DELTA STATES	SOUTH PLAINS	MOUNTAIN	PACIFIC	US TOTAL
		--PERCENT CHANGE--										
CROPS	NON-RISK	-34	-43	-39	-52	-145	98	-96	-146	-57	-47	-52
	E-V RISK	-33	-43	-39	-52	-144	98	-96	-145	-57	-47	-52
	DBL.DEV.	-21	-33	-30	-47	-96	82	-87	-122	-51	-45	-44
LIVESTOCK	NON-RISK	64	159	74	81	17	43	10	33	22	16	39
	E-V RISK	64	159	74	81	17	43	10	33	22	16	39
	DBL.DEV.	47	135	63	65	7	30	-2	26	18	9	29
CROPS AND LIVESTOCK	NON-RISK	-10	-31	-31	-36	-13	10	-62	-25	-17	-25	-30
	E-V RISK	-10	-31	-31	-36	-13	10	-62	-25	-17	-25	-30
	DBL.DEV.	-5	-23	-23	-34	-12	-1	-60	-21	-16	-25	-26

Table 8--Comparison of variable costs and risk premiums for selected dryland, nonprogram enterprises by region

CROP	ITEM	FORMULATION	NORTH EAST	LAKE STATES	CORN BELT	NORTH PLAINS	APPALACHIA	SOUTH EAST	DELTA STATES	SOUTH PLAINS	MOUNTAIN	PACIFIC
			--DOLLARS PER ACRE--									
CORN	VARIABLE COSTS		130.65	129.30	147.30	65.92	165.48	127.47	111.91	71.58	52.22	82.03
	RISK PREMIUM	NON-RISK	0.83	5.57	21.12	7.79	1.70	0.68	1.22	3.17	1.13	2.78
		E-V RISK	0.90	5.78	21.37	8.10	1.75	0.71	1.28	3.37	1.21	3.15
		DBL.DEV.	3.82	22.30	79.99	28.83	7.12	2.91	5.31	13.15	4.73	12.39
	CHANGE IN PREMIUM	NON-RISK	0	0	0	0	0	0	0	0	0	0
		E-V RISK	0.07	0.21	0.25	0.31	0.06	0.03	0.06	0.20	0.08	0.37
		DBL.DEV.	2.98	16.74	58.88	21.04	5.42	2.23	4.09	9.98	3.60	9.61
WHEAT	VARIABLE COSTS		120.80	59.82	89.26	42.12	101.60	105.68	82.71	47.17	40.79	47.00
	RISK PREMIUM	NON-RISK	0.57	3.74	3.63	7.32	0.40	0.14	0.45	1.51	1.65	1.73
		E-V RISK	0.62	3.90	3.69	7.60	0.42	0.15	0.48	1.58	1.77	1.95
		DBL.DEV.	2.62	14.94	13.81	27.14	1.70	0.62	1.98	6.14	6.91	7.64
	CHANGE IN PREMIUM	NON-RISK	0	0	0	0	0	0	0	0	0	0
		E-V RISK	0.05	0.16	0.06	0.28	0.02	0.01	0.04	0.07	0.12	0.22
		DBL.DEV.	2.05	11.21	10.18	19.82	1.30	0.47	1.53	4.64	5.26	5.92
SOYBEANS	VARIABLE COSTS		85.04	57.36	59.14	50.89	78.88	97.58	70.94	66.63		
	RISK PREMIUM	NON-RISK	0.61	3.37	13.36	6.32	1.13	0.39	0.64	0.48		
		E-V RISK	0.65	3.48	13.48	6.57	1.15	0.40	0.65	0.52		
		DBL.DEV.	2.76	13.48	50.38	23.24	4.68	1.62	2.70	2.05		
	CHANGE IN PREMIUM	NON-RISK	0	0	0	0	0	0	0	0	0	0
		E-V RISK	0.04	0.10	0.12	0.25	0.03	0.01	0.02	0.05	0.00	0.00
		DBL.DEV.	2.15	10.10	37.02	16.92	3.55	1.23	2.07	1.57	0.00	0.00

Table 9--Fragment of net returns variance-covariance array: corn versus other enterprises, all regions

		--Regions--									
		NT	LA	CB	NP	AP	SE	DL	SP	MN	PA
CORN	CORN	1808.5	2746.7	3658.8	1302.5	1944.3	1393.7	2452.1	2831.9	451.7	5746.5
CORN	SORGHUM	0.0	0.0	1882.0	969.9	1150.4	549.6	1279.8	1023.8	135.1	2260.7
CORN	BARLEY	467.6	946.7	0.0	632.0	173.5	69.3	0.0	408.7	150.9	1187.0
CORN	OATS	526.9	270.4	150.9	182.8	77.8	55.8	298.5	112.9	61.9	623.7
CORN	WHEAT	1209.0	1762.5	668.2	1085.0	482.7	176.2	440.9	721.9	527.0	2741.1
CORN	SOYBEANS	1144.8	1339.4	1725.3	1111.7	1060.1	661.0	896.7	737.8	0.0	0.0
CORN	COTTON	0.0	0.0	-29.0	0.0	648.8	1232.5	-239.9	947.1	460.0	0.0
CORN	ICORN	2405.0	3231.2	3879.9	2142.3	0.0	1838.7	4324.3	4216.3	1231.4	6572.3
CORN	ISORGHUM	0.0	0.0	2225.1	1484.8	0.0	0.0	1551.1	1627.1	592.1	3413.3
CORN	IBARLEY	0.0	0.0	0.0	629.0	0.0	0.0	0.0	473.9	379.3	1889.3
CORN	IOATS	0.0	0.0	0.0	200.9	0.0	0.0	0.0	157.1	118.3	101.0
CORN	IWHEAT	0.0	0.0	772.7	1577.9	0.0	254.4	0.0	1090.7	1248.8	5041.7
CORN	ISOYBEANS	0.0	1489.5	1677.6	1510.8	0.0	823.3	1101.8	1298.5	0.0	0.0
CORN	ICOTTON	0.0	0.0	0.0	0.0	0.0	1232.5	-141.3	1077.9	1595.6	4404.8
CORN	PCORN	1808.5	2746.7	3658.8	1302.5	1944.3	1393.7	2452.1	2831.9	451.7	5746.5
CORN	PSORGHUM	0.0	0.0	1882.0	969.9	1150.4	549.6	1279.8	1023.8	135.1	2260.7
CORN	PBARLEY	467.6	946.7	0.0	632.0	173.5	69.3	0.0	408.7	150.9	1187.0
CORN	POATS	526.9	270.4	0.0	182.8	77.8	55.8	298.5	112.9	61.9	623.7
CORN	PWHEAT	1209.0	1762.5	668.2	1085.0	482.7	176.2	440.9	721.9	527.0	2741.1
CORN	PSOYBEANS	1144.8	1339.5	1725.3	1111.7	1060.1	661.0	896.7	737.8	0.0	0.0
CORN	PCOTTON	0.0	0.0	-29.0	0.0	648.8	1232.5	-239.9	947.1	460.0	0.0
CORN	IPCORN	2405.0	3231.2	3879.9	2142.3	0.0	1838.7	4324.3	4216.3	1231.4	6572.2
CORN	IPSORGHUM	0.0	0.0	2225.0	1484.8	0.0	0.0	1551.1	1627.1	592.1	3413.3
CORN	IPBARLEY	0.0	0.0	0.0	629.0	0.0	0.0	0.0	473.9	379.3	1889.3
CORN	IPOATS	0.0	0.0	0.0	200.9	0.0	0.0	0.0	157.1	118.3	101.0
CORN	IPWHEAT	0.0	0.0	772.7	1577.9	0.0	254.4	0.0	1090.7	1248.8	5041.7
CORN	IPSOYBEANS	0.0	1489.4	1677.6	1510.8	0.0	823.3	1101.8	1298.5	0.0	0.0
CORN	IPCOTTON	0.0	0.0	0.0	0.0	0.0	1232.5	-141.3	1077.9	1595.6	4404.7

APPENDIX

ESTIMATING RISK AVERSION COEFFICIENTS WITH AVAILABLE DATA

Empirical attempts to measure risk aversion include direct and indirect methods. Direct measurement through measuring individual's responses to hypothetical choices (von Neuman and Morgenstern and others) and actual choices (Binswanger) are discussed by Newbery and Stiglitz (pp. 100-110). The alternative or indirect approach involves estimation of the risk parameter from observed behavior and other available information. Calvin's recent estimation of risk aversion coefficients was based on producers' decisions whether or not to participate in government commodity programs (Calvin). An approach suggested by Paris (1979) is applied in USMP.

The theoretical model

It is intuitively appealing that knowing actual decisionmaker production decisions and the activity revenue variance-covariance coefficients which they faced, one should be able to infer something about their implicit risk aversion behavior. Such a method to determine the coefficient of risk aversion is used with USMP, and will be briefly described in terms of a farm model (8). p is a vector of expected market prices, M is a diagonal matrix of expected stochastic yields, x is a vector of enterprise activity levels, c is a vector of constant enterprise unit costs, V is a variance-covariance matrix of enterprise revenues, and $\hat{a}$ is the risk aversion parameter. Commodity production levels depend upon yields and enterprise activity levels: Mx. F is a matrix of technical constraint coefficients (such as factor usage), and r is the right hand side vector of constraint (factor) availabilities.

$$\begin{aligned}&\text{Maximize} \quad (p'M - c')x - (\hat{a}/2)x'Vx \\ &\text{Subject to } Fx \le r\end{aligned} \tag{8}$$

It is necessary to first state some preliminary results. In the primal production optimization problem (8), (pM - c') evaluates to a vector of net revenue per activity to match Paris' formulation. We assume that prices are normally distributed; since the cost vector c' is a constant the enterprise net revenue vector (p'M - c') is normally distributed. The dual of problem (8) may be written as

$$\begin{aligned}&\text{Minimize} \quad r'q \\ &\text{Subject to } F'q + \hat{a}Vx \ge Mp - c\end{aligned} \tag{9}$$

where q is a vector of resource constraint shadow prices, $\hat{a}Vx$ is a vector of activity level risk premiums and (Mp - c) is the transpose of (pM - c'). The primal problem requires the maximization of production enterprise net returns minus the risk premium subject to the factor input restrictions. The economic interpretation of the dual problem is to minimize the imputed (shadow price) value of factor inputs used in production, subject to the conditions that the imputed value of factor use in a production enterprise plus a marginal risk premium due to uncertain returns is greater than or equal to the market value of output from the enterprise.

Paris (1979: 271) rewrites the dual constraints of (9) in probabalistic or chance constrained form:

$$\text{Prob}((p'M - c')x - q'Fx < 0) \leq (1 - b) \tag{10}$$

This has the economic interpretation that entrepreneurs will insist that enterprise revenues fall below or equal imputed enterprise costs with a probability of (1-b) or less. In other words, producers are willing to accept a loss with (1-b) probability. The probability (1-b) is normally specified to be small, for example, 0.1. This is an appealing way of stating the risky production problem since the acceptable level of probability of a loss (1-b), say ten percent, has much more intuitive meaning to producers and economic analysts than does the Pratt coefficient of risk aversion, $\hat{a}$.

Paris then relies on the assumption that enterprise revenue is normally distributed and the theory of chance constrained programming (1979: 270, 271; Vajda 1972: 75-84) to derive the deterministic equivalent of (10):

$$q'Fx \geq (p'M - c')x + T(x'Vx)^{-\frac{1}{2}} \tag{11}$$

where T is a specified probability level on the net revenue distribution. Additionally, Paris defines a Lagrangean function (which will not be reproduced here) for the primal problem (8) and derives its complementary slackness condition:

$$x'(\delta L/\delta x) = x'(Mp - c) - \hat{a}x'Vx - x'F'q = 0 \tag{12}$$

From (11) and (12) and rearranging terms Paris finally demonstrates that

$$\hat{a} \leq -T \;/\; (x'Vx)^{\frac{1}{2}} \tag{13}$$

where $\hat{a}$ is the risk aversion coefficient and T is a parameter chosen to represent a subjective probability level (1-b). As Paris (1979: 273) notes, using actual production levels, x^*, this relation may be applied to estimate the coefficient of risk aversion:

$$\hat{a}^* = -T \;/\; (x^{*\prime}Vx^*)^{\frac{1}{2}} \tag{14}$$

Values of T may be read from a cumulative normal distribution table for specified probability levels b. Paris cites several advantages of this approach. First, the probability level b in (10) is much easier for decisionmakers and analysts to specify than is the risk aversion parameter $\hat{a}$. Second, a unique estimate of $\hat{a}$ is determined (unlike an earlier approach due to Weins, 1976). Third, the method does not require use of the technical coefficient matrix F, which means that $\hat{a}^*$ is estimated without "direct implications of using a linear technology" (Paris: 273).

<u>Specifying the Probability with which Producers Are Willing to Accept a Loss</u>

A key issue is the selection of the proper value for (1-b), the probability with which producers are willing to accept a loss. Easter applied this methodology in a five region model of Australian crop and livestock and assumed, without any particular justification, a b value of .95. This value appears to be too high for U.S. agriculture since it implies that farmers operate such that they will accept expected costs exceeding expected returns only one year in 20. In this work we assume substantially lower values for b, such as 0.80, or of producers operating under the presumption that a loss will be incurred no more than one year in five. Some researchers feel that even this level of risk aversion is unrealistically high for certain types of U.S. agriculture. Miller, for example, reasons that for Great Plains wheat farmers, the b value is closer to 0.60, or that positive expected returns are required three years out of five.

It is likely that average levels of risk aversion are different for different regions and types of agriculture. For example, in the Corn Belt or for irrigated crop production, where agriculture is more input intensive and inputs such as land have a relatively high opportunity cost, producers may insist upon nonnegative expected returns in four years out of five. In agricultural areas such as the Great Plains where inputs are less intensively used, producers may insist on positive expected profits only three years out of five. Indication of the levels of risk aversion for different regions and commodities can be elicited through surveys, but little such data have been collected. The risk formulation in USMP allows for alternate b values which do not vary by region or product.

Following the previous theoretical development, the coefficient of risk aversion is specified according to relation (14) where $\hat{a}^*$ is the estimated coefficient, T is a parameter corresponding to the specified probability b with which producers are willing to accept a loss, X^* is the vector of observed production activity levels, and V^* is the estimated net returns variance, covariance matrix for production enterprises. The risk parameter is estimated for the aggregate model's crop production subsector at the national level. Observed production activity levels for the model's 1986 base year were used to calculate the expression $(X^{*\prime}V^*X^*)^{\frac{1}{2}}$. This evaluated to .00024767. Estimates of $\hat{a}^*$ and the relative coefficient ϕ^* corresponding to several probability levels b are presented in table A1.

Table A1--Estimated Coefficients of Absolute and Relative Risk Aversion $\hat{a}^*$ and ϕ^* Corresponding to Varying Probability Levels b

Probability b of not Accepting a Loss	Corresponding Normal Distribution Parameter T	Absolute Risk Parameter $\hat{a}^*$ $=-T/(X^{*\prime}V^*X^*)^{\frac{1}{2}}$	Relative Risk Parameter ϕ^* $=\$16353\hat{a}^*$ 1/
.60	-0.25335	0.00006275	1.03
.70	-0.52440	0.00012988	2.12
.80	-0.84162	0.00020844	3.41
.90	-1.28115	0.00031730	5.19
.95	-1.64485	0.00040738	6.66
.99	-2.32634	0.00057617	9.42

1/ These approximations are based upon the 1986 average U.S. net business income per farm of $16353 ($35,585 million, 2.176 million farms) as reported in USDA, Economic Indicators of the Farming Sector: National Financial Summary, 1987, EIFS-NFS87 7-1, October 1988, (tables 2,6; pp. 8,13).

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