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Non-Parametric and Semi-Parametric Techniques for Modeling and Simulating Correlated, Non-Normal Price and Yield Distributions: Applications to Risk Analysis in Kansas Agriculture

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ABSTRACT

Parametric, non-parametric, and semi-parametric approaches are commonly used for modeling correlated distributions. Semi-parametric and non-parametric approaches are used to examine the risk situation for Kansas agriculture. Results from the model indicate that 2000 will be another difficult year for Kansas farmers, although crop income will increase slightly from 1999. However, unless another supplemental infusion of government payments occurs, crop income is expected to be the lowest since 1992.

Key Words: *correlated distributions, non-parametric modeling, semi-parametric modeling, Kansas agriculture*

Kansas annual rainfall varies from 15 inches in the west to nearly 45 inches in the east, which implies that its agriculture ranges from semi-arid to corn belt. The standard deviation of rainfall varies from 3 inches to 10 inches with standard deviations generally increasing from west to east. The most important crops in Kansas are wheat, corn, milo (grain sorghum), soybeans, and hay. The crop mix and the production practices used to produce these crops also vary dramatically from west to east. In addition to yield variability, which is primarily driven by weather, climatic conditions, and production practices, increased price variability has substantially impacted income variability.

The Federal Agricultural Improvement and Reform (FAIR) Act of 1996 shifted the risk environment of the agricultural economy. Under the FAIR Act, key government payments are no longer directly tied either to production levels or commodity prices. As a result, government payments no longer act as an income stabilizer, rising in years of declining crop prices and falling during years of rising crop prices. Thus, because of increased income variability it is no longer adequate to analyze the agricultural economy without appropriately considering risk.

This article discusses the use of non-parametric and parametric techniques to model and simulate correlated price and yield distributions within the context of a model of the Kansas agricultural economy. The results of this model have been used in agricultural outlook (Featherstone, Mintert, and Kastens), to ex-

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amine the effect of FAIR on the Kansas agricultural economy (Kastens and Featherstone, 1997), and to examine the effect of government program payments on tax revenue (Kastens and Featherstone, 1999).

The paper begins with a brief discussion of parametric, semi-parametric, and non- parametric approaches for modeling correlated random variables. Next, the approaches used in our model are discussed, followed by a presentation of selected results from the model. Finally, the article concludes with a discussion of future modeling enhancements.

Parametric, Non-parametric, and Semi-parametric Approaches

Three approaches are often used to model random variables: the parametric, non-parametric, and semi-parametric. To a large extent, these approaches represent a continuum with the parametric at one end of the spectrum and the non-parametric at the other end, with semi-parametric approaches in the middle. Consider the following relationship:

$$y = f(x, \epsilon, \beta)$$

where y is a variable to be simulated, x are the observed variables, ϵ are the unobserved variables (or errors), and β are the unknown parameters. The parametric approach assumes that the distribution of x and ϵ are restricted to a parametric family (normal, uniform, etc.) and the functional form of $f(x, \epsilon, \beta)$ is known. The non-parametric approach assumes the distribution of x and ϵ are not restricted to a parametric family and the functional form of $f(x, \epsilon, \beta)$ is unknown.

The parametric approach has been most often used in the agricultural economics literature (Ramirez; Featherstone, Moss, Baker, and Preckel; and Featherstone, Preckel, and Baker). The parametric approach assumes a specific distributional relationship (e.g., normal, triangular, uniform, beta) to model risk. The literature has reported both univariate and multivariate approaches. The advantage of the parametric approach is that it provides a fairly succinct way to summarize large amounts of information and many times allows for closed-form solutions in analytic studies. The major drawback to the parametric approach is the possibility of specification error. Incorrect assumptions with regard to specification could result in incorrect inferences. Appropriate sampling from the distribution, once it had been estimated, was problematic in the past; however, the Gaussian quadrature approach (Miller and Rice, and Preckel and DeVuyst) has reduced the problems associated with inappropriate sampling.

The non-parametric analytical method is distribution-free (Hogg and Craig). The advantage of the non-parametric approach with no distributional assumptions and no assumed functional relationship, $f(x, \epsilon, \beta)$, is that it is free from specification error of the distributional assumptions or the functional relationship. Thus non-parametric methods could result in more accurate and robust economic models. However, using a non-parametric approach can be problematic when only small amounts of data are available or if the data are of a large dimension. If the number of random variables is large, it is necessary to have a long time series of data unless some simplifying assumptions are made such as independence. In agricultural economics, non-parametric distributional assumptions most commonly have been applied in econometric work where confidence intervals for random variables are bootstrapped (Eakin, McMillen, and Buono; and Efron). Non-parametric approaches have been applied by Featherstone, Moghnieh, and Goodwin; and Tauer in the agricultural economics literature.

The semi-parametric approach incorporates both parametric and non-parametric components. In the semi-parametric approach, the problem with mis-specification of the functional relationship, $f(x, \epsilon, \beta)$, is dealt with by allowing some of the components of the model to be unconstrained by distributional or functional relationships. Newey classifies several types of semi-parametric models used in the economic and statistical literature, including parametric response functions, semi-parametric response functions, duration models, and time-series models. The parametric response function type of semi-parametric model assumes a parametric response function f(x, ϵ, β) with non-parametric distributions of x and/or ϵ. The example discussed in this paper most closely fits into this classification.

Much of the economic theory presented in Varian does not require a well-behaved known specific functional relationship, f(x, ϵ, β). Thus, it is often desirable to weaken those functional assumptions, f(x, ϵ, β), which results in Newey's semi-parametric response function classification. For example, Berends, Featherstone, and Kastens have used genetic algorithms to impose technology constraints on a cost function using a neural network estimator. Duration models use non-parametric assumptions on both distribution and functional response relationships (Newey). Semi-parametric estimation methods were used very early in time series applications (Hannan), where the autocorrelation function comprised the non-parametric portion of the model.

The choice between the use of parametric, non-parametric, and semi-parametric methods is often not clear cut because of the continuum that exists. Trade-offs exist between each type of model. As computing power grows, methods will likely move toward non-parametric specifications if data are readily available. However, given the limitations of data in agriculture, especially the annual nature of crop production, parametric methods will still prove fruitful.

The following sections of the paper address the questions regarding expected income levels, income variability, and regional differences for the Kansas agricultural economy. A simulation model is developed to estimate impacts over time on Kansas farm income under various price and yield scenarios.

Empirical Income and Risk Projection Model for Kansas

In the empirical framework developed here, income distributions over time arise as interactions between variables whose time paths (e.g., 1999–2005) are predetermined and recursive variables whose values in one year depend on their values in the preceding year, and ultimately on their values in 1998. The only recursive variables are crop prices and crop yields. All other variables are either predetermined or simulated. Each crop price and each crop yield is associated with its own recursive model. The models are simple mean-reverting models that provide a convenient way to characterize expected empirical distributions over time that do not depend on normality or predetermined distributional functions. That is, relationships between variables are implicitly embedded within the observed data. Because data are developed at various scales, to match the need, this framework can provide income and income risk projections at resolutions ranging from the county to the USDA crop reporting district (CRD) to the state.

Recursive Models

Recursive models are estimated by regressing 1989–1998 values for a yield or price series on one-year lags, providing an intercept estimate, a slope estimate, and nine residuals. For example, applying 1998's wheat price to the wheat model gives an expected value for wheat price in 1999. Adding each of the nine residuals (1990–1998) to that expectation, in turn, gives an expected 1999 wheat price distribution comprised of nine possible prices, assumed to be equally likely, whose mean is the computed expected value. Passing the nine possible 1999 prices through the wheat model gives nine expected prices for 2000. When each of the nine residuals (1990–1998) is added, in turn, to the 9 expected prices for 2000, an expected distribution of 81 possible prices results for 2000, and so on. The end result is a year 2005 wheat price distribution that contains 9^7 = 4,782,969 possible values—which centers on the model-determined recursively-generated expected value. Risk in 1999 is measured considering the nine possible outcomes in that year. Risk in 2005 is measured considering the 9^7 possible outcomes in 2005.

Let $x_{i,t}$ represents the value of the *i*th price or yield at time *t,* in an example framework where the first and last forecasted years are 1999 and 2005. The procedure can be described as:

Step 1: Estimate the following regression using historical data on the ith x variable; compute the expected value for the ith variable for 1999; and map the nine estimated residuals for use later:

$$(1)\quad x_{i,t} = \alpha_i + \beta_i x_{i,t-1} + \epsilon_{i,t};$$
$$t = 1990 \ldots 1998;$$
$$\Rightarrow e_{i,1} = \hat{\epsilon}_{i,1990} \ldots e_{i,9} = \hat{\epsilon}_{i,1998};$$
$$\hat{x}_{i,1999} = \hat{\alpha}_i + \hat{\beta}_i x_{i,1998}.$$

Step 2: Compute the 9 possible outcomes for the ith x variable for 1999:

$$(2)\quad x_{i,1999,1} = \hat{x}_{i,1999} + e_{i,1} \ldots x_{i,1999,9} = \hat{x}_{i,1999} + e_{i,9}.$$

Step 3: Compute the 9 alternative expected values for the ith x variable for 2000:

$$(3)\quad \hat{x}_{i,2000,1} = \alpha_i + \beta_i x_{i,1999,1}$$
$$\vdots$$
$$\hat{x}_{i,2000,9} = \alpha_i + \beta_i x_{i,1999,9}.$$

Step 4: Compute the 81 possible outcomes for the ith x variable for 2000:

$$(4)\quad \{x_{i,2000,1,1} = \hat{x}_{i,2000,1} + e_{i,1} \ldots x_{i,2000,1,9} = \hat{x}_{i,2000,1} + e_{i,9}\}$$
$$\vdots$$
$$\{x_{i,2000,9,1} = \hat{x}_{i,2000,9} + e_{i,1} \ldots x_{i,2000,9,9} = \hat{x}_{i,2000,9} + e_{i,9}\}.$$

Step 5: Continue until all 9^7 possible outcomes for the ith x variable in 2005 are generated.
Step 6: Repeat steps 1–5 for each price and yield variable of interest (x_1, x_2, . . . and so on).

As used in this research, each of the *i* subscripts in the model pertains to a different crop's yield or to its price. Yields and prices considered for this Kansas study are for wheat, corn, milo, soybeans, alfalfa, and other hay. For any particular outcome, a crop's revenue is determined by multiplying the price outcome times the yield outcome times the exogenously-determined acres harvested. For example, wheat revenue associated with the 11th outcome in 2000 is determined according to

$$(5)\quad (\text{wheat revenue})_{2000,2,2}$$
$$= (\text{wheat price})_{2000,2,2}(\text{wheat yield})_{2000,2,2}$$
$$\times\ (\text{wheat acres harvested})_{2000}.$$

Similarly, total crop revenue across all crops for the 11th outcome in 2000 is

$$(6)\quad (\text{crop revenue})_{2000,2,2}$$
$$= (\text{wheat revenue})_{2000,2,2}$$
$$+ (\text{corn revenue})_{2000,2,2}$$
$$+ (\text{milo revenue})_{2000,2,2}$$
$$+ (\text{soybean revenue})_{2000,2,2}$$
$$+ (\text{alfalfa revenue})_{2000,2,2}$$
$$+ (\text{other hay revenue})_{2000,2,2}.$$

Equations 5 and 6 make it clear that, for aggregation into revenue, yield and price draws from the set of possibilities in any year must always be from the same point. In short, to appropriately capture historically observed price-yield relationships in predicted distributions, residuals are always pulled from the same year for each model. For example, suppose the 19th possible wheat price in 2000 is $\alpha + \beta(\alpha + \beta W_{1998} + e_3) + e_1$, where α and β are estimates from the wheat price model, W_{1998} is the wheat price in 1998, and e_k is the kth residual from the wheat price model. Then the 19th possible soybean price in 2000 is $\alpha + \beta(\alpha + \beta S_{1998} + e_3) + e_1$, where α and β are now from the soybean price model, S_{1998} is the soybean price in 1998, and e_k is the kth residual from the soybean price model. This ensures, for example, that if yield and price for a crop have historically been negatively correlated, a similar negative correlation will unfold in the future. Also, if corn and milo yields have historically been positively correlated, a similar positive correlation will unfold in the future.

Real-time Use (capturing current information)

Whenever model-based forecasting schemes are used in real time, nonsensical projections occasionally arise—which typically require *ad* *hoc* adjustments. To minimize such difficulties, once a recursive structure in the model is in place, where available, an annual crop yield projection (expectation) is taken from USDA's NASS *Crop Production,* and an annual price projection is determined from current prices of appropriate deferred futures contracts, adjusted by "basis" (historical regression-based monthly cash/futures price relationships), and aggregated to a single annual value through monthly marketings weights. Inclusion of such information serves to keep the projection model's output consistent with known information in real time. For example, if the model were used in late 1999 to make projections for 1999–2005, then futures-based price projections would replace the expected price for 1999 and 2000 given in equations 2 and 4. Yet, to capture uncertainty, the $e_{i1} \ldots e_{i9}$ values would be added to the futures- based expected price series just as they were in the six-step process listed earlier. Similarly, the USDA-projected yield would replace the expected 1999 yield, and the appropriate residuals would be added in turn.

Prices (recursive variables)

In general, models are developed from data generated at the same scale as the projections desired (county, district, or state). When data are unavailable at the desired scale, the next coarsest scale is used where data are available. District and state-level data are always available wherever county data are; state-level data are always available wherever district data are.

To determine crop income, all wheat, corn, milo, and soybeans are assumed to be sold at the five-principal-marketing-months marketings-weighted price of the associated marketing year (June–October for wheat and September–January for corn, milo, and soybeans). Alfalfa and other hay prices are based on eight-month (May–December) marketings-weighted prices. Whenever futures-based five-month cash price projections are used, they are built up from monthly cash price projections weighted by historical average (1994–1998) monthly marketings. Also, because most projected monthly-marketings-weighted crop prices are computed from lagged values in the six-step recursive framework, marketing weights for 1999 through 2005 are implicitly assumed to equal the average observed marketing weights over the 1994–1998 period. All crop income is assumed received in the harvest year.

Underlying the crop price projections, district marketing weights are available for wheat, corn, milo, and soybeans, but only state-level marketing weights for alfalfa and other hay. District prices are available for wheat, corn, milo, and soybeans, but only state prices for alfalfa and other hay. Historical state-level marketing weights were taken from *Crops* (Kansas Agricultural Statistics (KAS), USDA) and district marketing weights were acquired directly from KAS. Historical district and state-level crop prices are from *Agricultural Prices* (KAS).

Consistent with the five-month cash price framework, a five-principal-marketing-months national average price (NAP) is projected for each of wheat, corn, milo, and soybeans to determine expected loan deficiency payments (LDPs). As with the more localized cash price projections, futures-based NAP projections are used when futures prices are available. Underlying the NAP projections, historical national marketing weights are taken from *Crop Production* and historical national crop prices are from *Agricultural Prices,* publications of the USDA.

When using futures-based price projections, historical "basis" was determined by regressing 1982–1998 monthly cash prices on monthly nearby futures (a monthly futures price is an average of the Wednesday closes for that month—nearbys do not include expiration months). Deferred futures prices used in this research were observed December 14, 1999. The expected wheat price for 1999 used actual USDA-reported June–October prices in 1999, and for 2000, used Kansas City wheat futures-based projections for June–October in 2000. Corn, milo, and soybean price expectations (which involve September–January) for 1999 and 2000 were similarly constructed, only using appropriate deferred futures prices for corn and soybeans at the Chicago Board of Trade (along with USDA-reported values where appropriate). Alfalfa and other hay prices for 1999 were based on USDA-reported prices from May through November, with December's price assumed to be the same as November's. Expected alfalfa and other hay prices from 2000–2005, and wheat, corn, milo, and soybean prices from 2001–2005, were derived using the recursive process already discussed.

Farm Program Payment Acres, Hay Production, and AMTA Payments (Predetermined Variables)

Projected AMTA (Agricultural Marketing and Transition Act, also referred to as FAIR) payments assume 100-percent program participation, along with the fact that payment acres are 85 percent of base (contract) acres for each of wheat, corn, and milo. Base acreage values are assumed constant over the 1999–2005 projection period and are taken to be the "before CRP reductions" (because, under AMTA, CRP no longer holds base acres) average crop base acres from 1993–1995 reported in the *Enrolled Farm and Producer Report Summaries* for those years and obtained directly from the Kansas Farm Service Agency (KFSA). When payment acres are multiplied by program yields, which the AMTA program treats as fixed since 1986, the result is pay production.

Wheat AMTA payment rates are assumed fixed at 63, 57, 46, and 45 cents per bushel, for 1999, 2000, 2001, and 2002, respectively. Similarly, corn rates are 35, 32, 26, and 25; milo rates are 40, 37, 30, and 29. For 2003 through 2005, annual AMTA payment rates are assumed to equal their 2002 values.

Loan Deficiency Payments (Simulated Variable)

Per-bushel LDP rates for wheat, corn, milo, and soybeans are assumed to be the differences between announced loan rates for 1996 ($2.58, $1.89, $1.80, and $4.97 for wheat, corn, milo, and soybeans, respectively) and simulated NAP prices, whenever the differences are positive. Loan payment rates are multiplied by simulated crop production (through predetermined acres harvested and simulated yields, discussed later). Thus, at each model-generated outcome for a program crop (e.g., nine outcomes in 1999 and 9^7 outcomes in 2005), the simulated NAP price is tested to see whether it is below the loan price, and if so, the relevant loan payment amount is calculated.

CRP (Predetermined Variable)

Changes in CRP acreage over time (due to expiring contracts and to new enrollments) affect income directly through CRP payments and indirectly through changes in acres harvested (discussed later). Information on county-specific historical enrollments (through 1999) and the associated 10-year-later expiration dates (determining projected removals over time for those enrollments), along with annual CRP payment information, was obtained directly from the KFSA.

The KFSA data were used to establish an average 1999 CRP rental (payment) rate, which was the average $/acre paid on all acres currently enrolled in the CRP at that time. Beginning in 2000, annually expiring acres were assumed replaced with new enrollments brought in at contractual annual payment rates equal to the average rate paid on new enrollments over the 1997–1999 period. Those assumptions made it possible to compute an average 2000 CRP rental rate (on all acres currently in the CRP at that time). Similarly, average rental rates were computed for each year, 2001–2005. Annual CRP payments are determined by multiplying average annual rental rates by the number of acres currently in the CRP each year.

Acres Harvested (Predetermined Variables)

In state-level simulations, expected 1999 harvested acreage for each of the six crops is available from the USDA. At the county level, for a given crop the expected 1999 harvested acreage is determined as follows. The 1989–1998 average planted acreage for a given crop is multiplied by the 1989–1998 average of annual harvested-to-planted-acreage ratios for that crop, resulting in a preliminary harvested acreage (PHA) for each crop. All county-level crop-specific PHA values are proportionately adjusted by the same proportion until they sum to the same-crop USDA-reported expected value for the state. Except for annual modifications due to expected changes in the CRP acreage, 2000–2005 annual harvested acreage for each crop is assumed to be the same as it was in 1999. The underlying assumption is that crop mixes only change slowly over time, and not at all during the projection period.

The county-level six-crop sum of PHA values, divided by the total crop acres reported for the county in the *1992 Agricultural Census,* results in an expected harvested-to-cropland-acreage (HTC) ratio. The HTC ratio is used to prorate annual changes in expected CRP acreage to harvested acreage. However, changes in CRP acreage from last year to this year are assumed to impact expected harvested acreage next year. For a given crop, the 1989–1998 average for that-crop-to-all-six-crops-harvested-acreage ratios is used to prorate to specific crops the changes in harvested acreage due to CRP. Thus, in computing expected acres harvested for a given crop in 2000, changes in CRP acreage from 1998 to 1999 cause a small adjustment (positive or negative) to be added to the 1999 harvested acreage for that crop. Similarly, acres harvested is computed for each crop and each year, 2000–2005.

Crop Yields (Recursive Variables)

Crop yields are in bushels (wheat, corn, milo, and soybeans) or tons (alfalfa and other hay) per harvested acre, and were developed at the county level when the crop was actually produced in that county. Associated recursive models were used for projections covering from 1999 to 2005. Historical yield data were taken from *Kansas Farm Facts* (Kansas Department of Agriculture) or *Crop Production* (USDA). To develop 1999 expected county-level yields that are consistent with USDA state estimates for that year we began with the projections from county recursive models of yield (using 1998 yields as inputs). These 1999 county-level yield projections, when coupled with projected harvested acres discussed earlier, give county-level production estimates which sum to a state-level production estimate for 1999. The ratio between the USDA 1999 state production estimate and this computed state-level production estimate, for a crop, is then multiplied by each county's recursive model prediction for 1999 yield. This ensures that the summed county production estimate for 1999 will equal the USDA 1999 production estimate for Kansas. Expected crop yields for 2000 to 2005 were derived using the recursive process already discussed.

Income (Simulated Variable)

Procedures outlined above allow for simulating income by county, by district, or for the whole state. Each of the 9^k sets of six-yield and six-price recursive model outcomes in year *k,* upon interaction with the predetermined variables discussed, yields a unique gross crop income simulation, which is the sum of crop sales and government payments. Because of LDP payments, which are dynamically determined by price outcomes, the expected gross crop income for year *k* (average across the 9^k outcomes) can easily be substantially different than if LDP payments are computed based on only the expected price in year *k.* Thus, this framework is most suitable for examining expected risk around alternative scenarios.

Selected Model Results

This section contains selected model results for the model described above. Expected crop price and yield paths, expected government program payments, expected gross crop income, and the variability of gross crop income are discussed. Regional effects are discussed after the state-level effects.

Expected Crop Price and Yield Paths

Figure 1 depicts the model-generated expected U.S. national average price (NAP) paths for wheat, corn, soybeans, and milo. Over the pe-

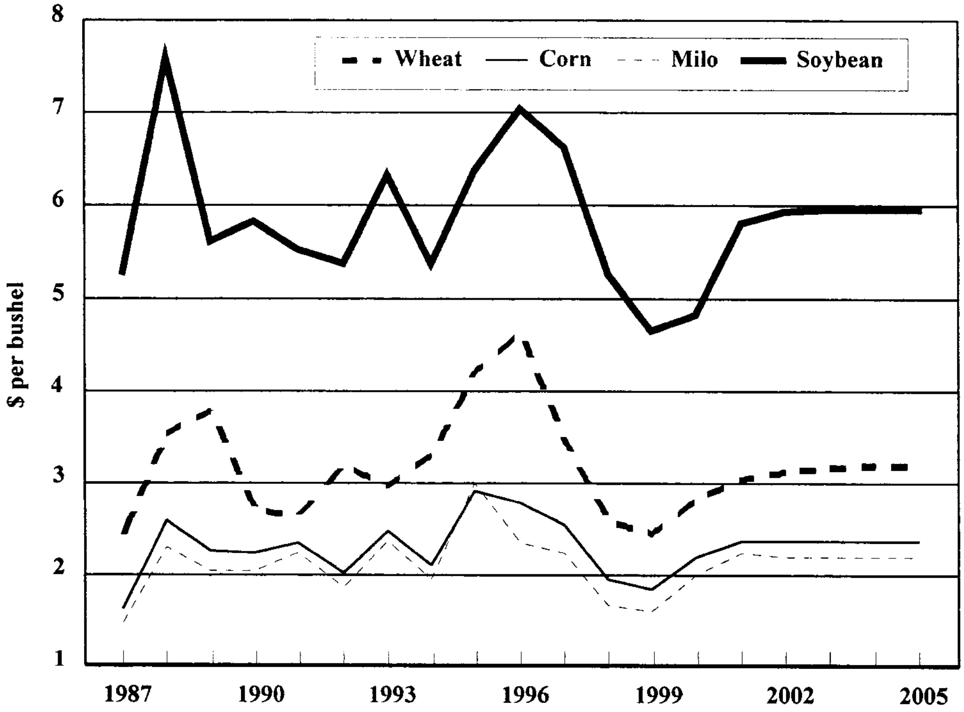

Figure 1. National Average Expected Prices

riod, wheat prices are expected to rise from $2.44 per bushel to between $3.10 to $3.20 per bushel from 2002 through 2005. Similarly, corn (milo) prices are expected to rise from 1999 levels of $1.83 ($1.61) per bushel to between $2.30 ($2.15) and $2.40 ($2.25) from 2001 through 2005. Soybean prices are projected to rise from $4.66 in 1999 to between $5.90 and $6.00 per bushel between 2001 and 2005.

Figure 2 presents the expected Kansas yield paths for wheat, corn, soybeans, and milo over the 2000 to 2005 time frame. Wheat yields are expected to be between 35 and 40 bushels per acre between 2000 and 2005. Corn (milo) yields are expected to range between 135 (65) and 140 (70) bushels per acre during the 2000 to 2005 time period. Soybean yields are expected to range between 30 and 35 bushels per acre during that time period. The fact that yields return to the mean is an artifact of the mean-reverting models. It is important to note that both Figures 1 and 2 represent average values. For example the minimum and maximum value for wheat price in 2002 is $2.10 and $4.55 per bushel, respectively. The minimum and maximum corn yield in 2001 is 118 and 155 bushels per acre, respectively. Corn yields have remained within this range during the last 16 years while wheat prices have remained within that range during all but two (1995 and 1996) of the last 26 years.

Aggregate Crop Income Effects

Government wheat, feed grain, and conservation payments for Kansas are estimated to total $1.55 billion during 1999, up from $530 million during 1997 (Figure 3). The increase is attributable to loan deficiency payments and from the supplemental appropriation that the U.S. Congress approved during the fall of 1999 to deal with low commodity prices. It is expected that these payments will fall back to $560, $415, and $397 million unless additional supplemental appropriations occur during 2000, 2001, and 2002 respectively, at which point the current farm bill expires. The value of program payments from 2002 through 2005 are near the $390 million level assuming continuation of the current set of farm programs.

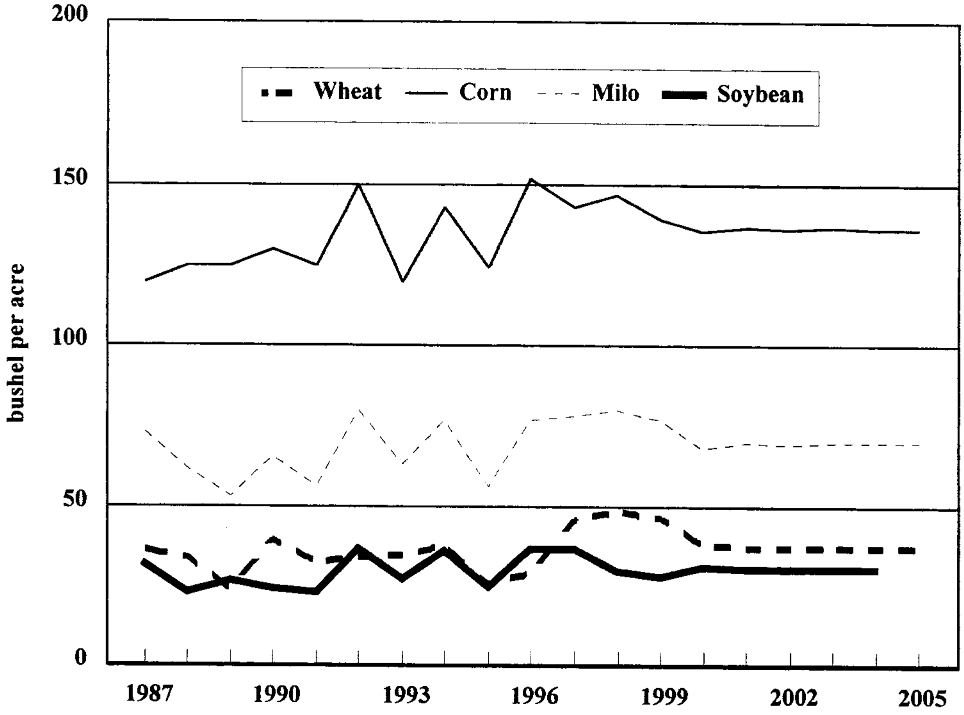

Figure 2. Expected Kansas Crop Yields

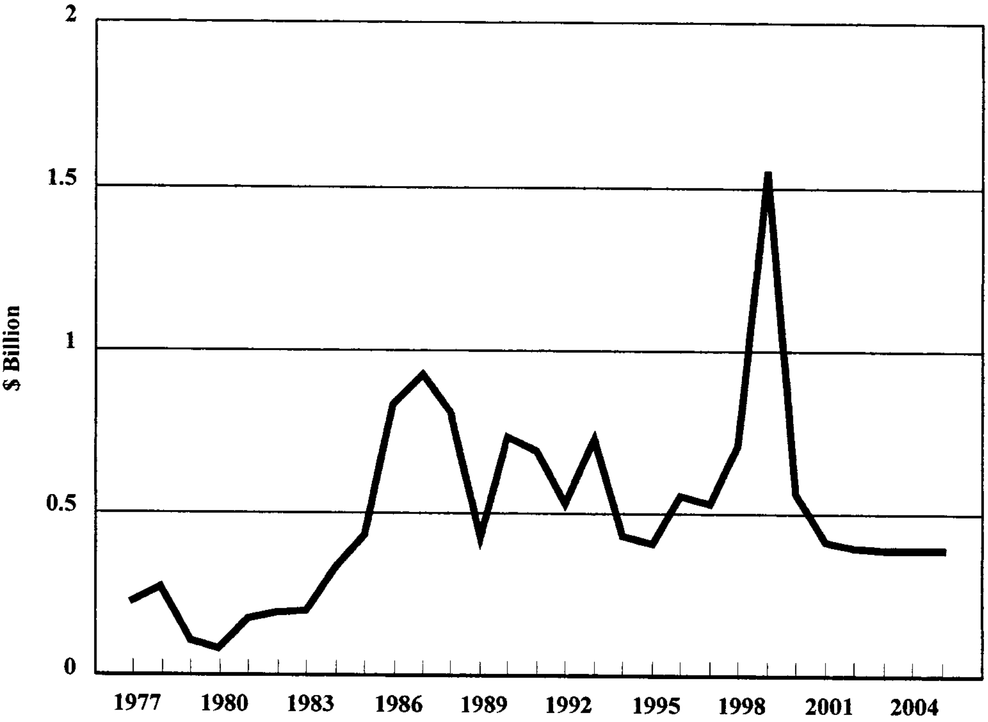

Figure 3. Government Payments for Kansas, 1977–2005 Wheat, Feed Grain, and Conservation and Loan Gains

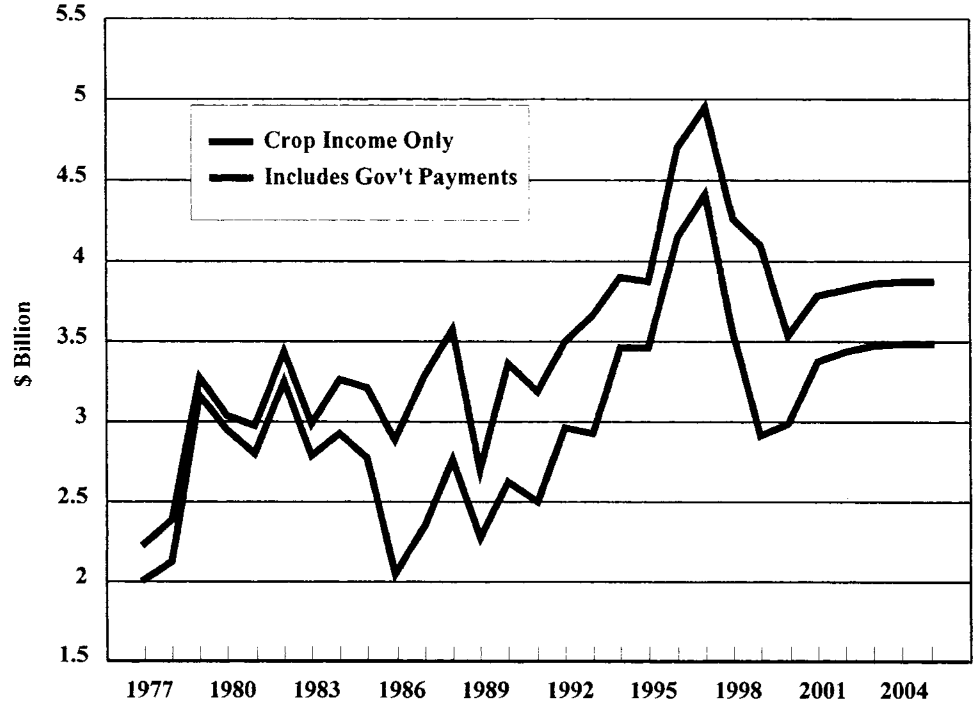

Figure 4. Kansas Crop Income With and Without Government Payments (Includes Loan Gains)

The reduction in production from 1998 levels in each of major crops resulted in a substantial drop in gross crop income in the state (Figure 4). The estimated 1999 gross crop income of $2.91 billion is 23.6 percent below the average of the previous five years and is 18.0 percent below 1998's level. In fact, 1999 crop income is the lowest since 1991. When government payments are added in, total crop-related revenue in 1999 surpassed the $4 billion mark for the fourth time in history at a level of $4.11 billion. Projections for 2000 and 2001 suggest the value of crop production will increase slightly to $2.99 billion in 2000 before recovering to $3.38 in 2001. Including government payments, total crop related revenue is expected to be $3.55 billion during 2000, roughly $560 million below 1999 levels. In the longer term, it is expected that total Kansas crop-related revenues will average nearly $3.9 billion.

Kansas crop income is extremely susceptible to factors which are beyond the farmers' control, such as weather and exports. Figure 5 illustrates the possible variability in Kansas gross crop income which, based upon history, occurs as both production and prices vary. Our estimate for 2000 is for about a 22-percent probability of gross crop income falling below $3.2 billion (the lowest of the previous decade) and a 11-percent probability of gross crop income falling above $4 billion. By 2005, the probability of income below $3.2 billion is 5 percent and the probability of income falling above $4 billion is 40 percent. A substantial probability exists (12 percent) that gross farm income will fall below $3 billion in 2000. The Kansas crop sector is likely facing another lean year in 2000 without additional Federal appropriations.

Regional Impacts of Income and Income Variability

The effects of lower crop income are not felt equally across Kansas because of the relative importance of crops across the state. Given the below average rainfall during the fall, it is

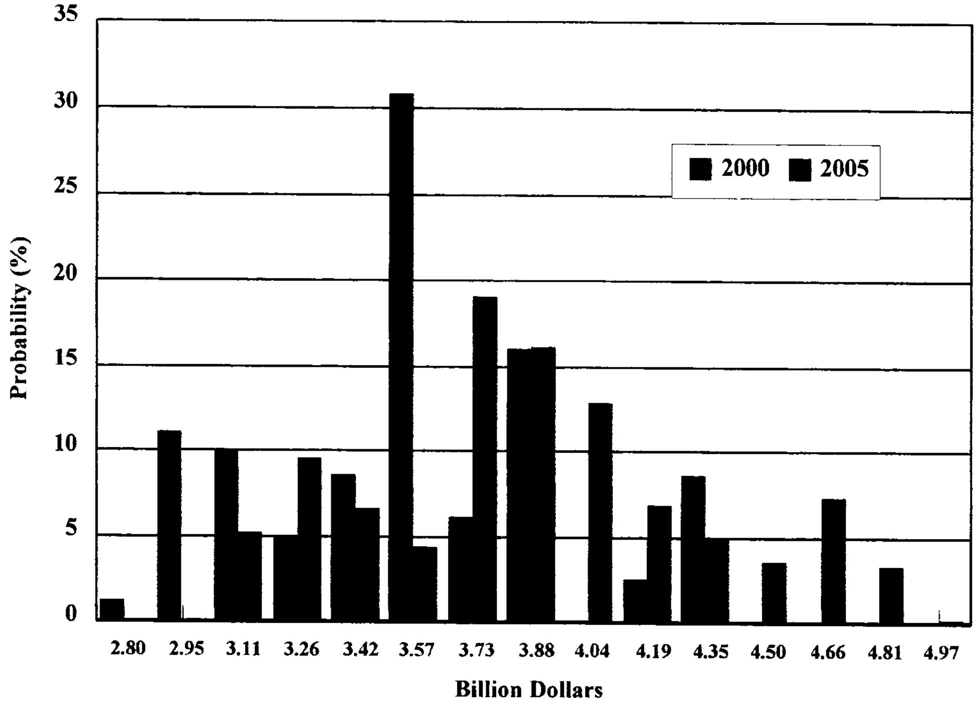

Figure 5. Probability of Gross Crop Income for Kansas, 2000 & 2005

very possible that wheat yields may fall below the 39-bushel yield forecasted by this model. Those areas that are more dependent on wheat could experience a larger cut in incomes than those that are more dependent on soybeans and corn. Figure 6 illustrates the importance of the various crops by region of the state. Typically wheat is the highest value crop in five out of the nine crop districts in Kansas. In the eastern three crop-reporting districts, wheat production typically ranks lower. It is the second most important crop in southeast Kansas, and the fourth most important crop in the northeast and east central parts of the state.

Based on regional income simulations similar to those discussed earlier for Kansas, Figure 7 shows expected government payments (program payments, CRP payments, and loan payments) by region for Kansas. Not surprisingly, because of the reliance of certain regions on program crops relative to soybeans, expected government payments differ substantially by region when measured on a per crop land acre basis. Figure 7 indicates that southwest and south central Kansas are expected to receive the highest annual payments per crop land acre. This is partly due to higher program yields on irrigated acreage (particularly in southwest Kansas) and high program participation (particularly compared to the eastern third of Kansas). Southeast Kansas is least dependent on government program payments, with each crop land acre expected to draw only $10.26 annually. The expected payment in 2000 is $13.09 and the expected payment in 2005 is $7.76 per acre. Over the entire state, each crop land acre averages $15.57 of government payments per acre.

To compare the income variability effects of net farm income across regions, Figures 8, 9, and 10 display years 2000 and 2005 net income frequencies for west central, central, and east central Kansas. Expected crop income in 2000 is projected to be less than 2005 by $4.22, $4.07, and $11.49, for west central, central, and east central Kansas, respectively. Focusing on various negative outcomes, Figure 8 (west central) shows that the probability of acquiring net income less than −$2.50 per acre is 68 percent in 2000 against the substantially lesser probability of 30 percent for 2005. Each negative income category has a larger

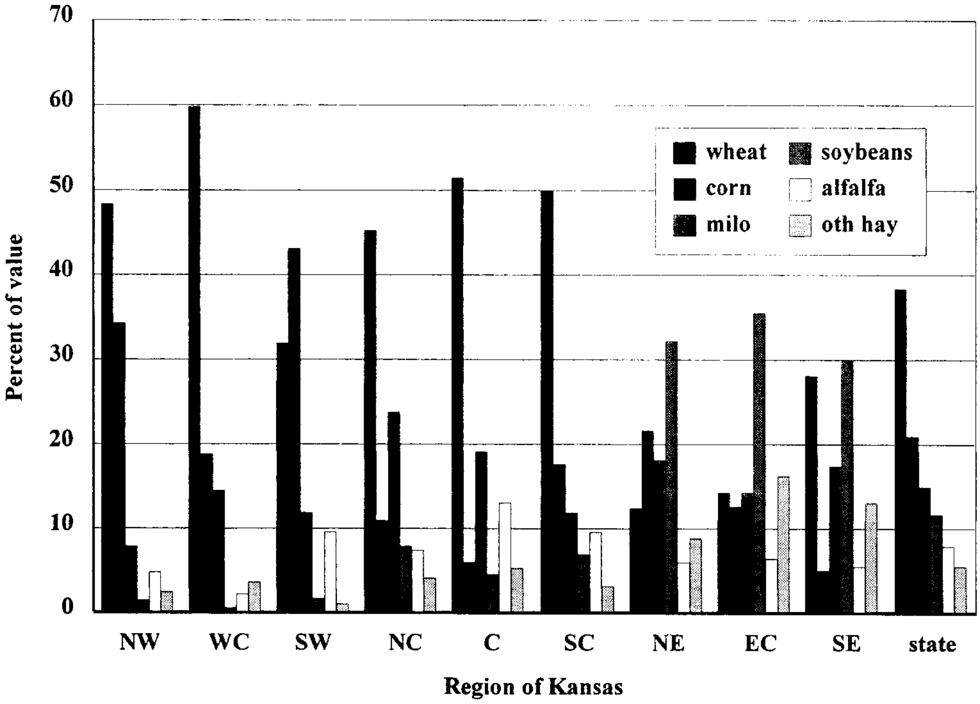

Figure 6. Relative Importance of Crop Value: 1989–1998 average

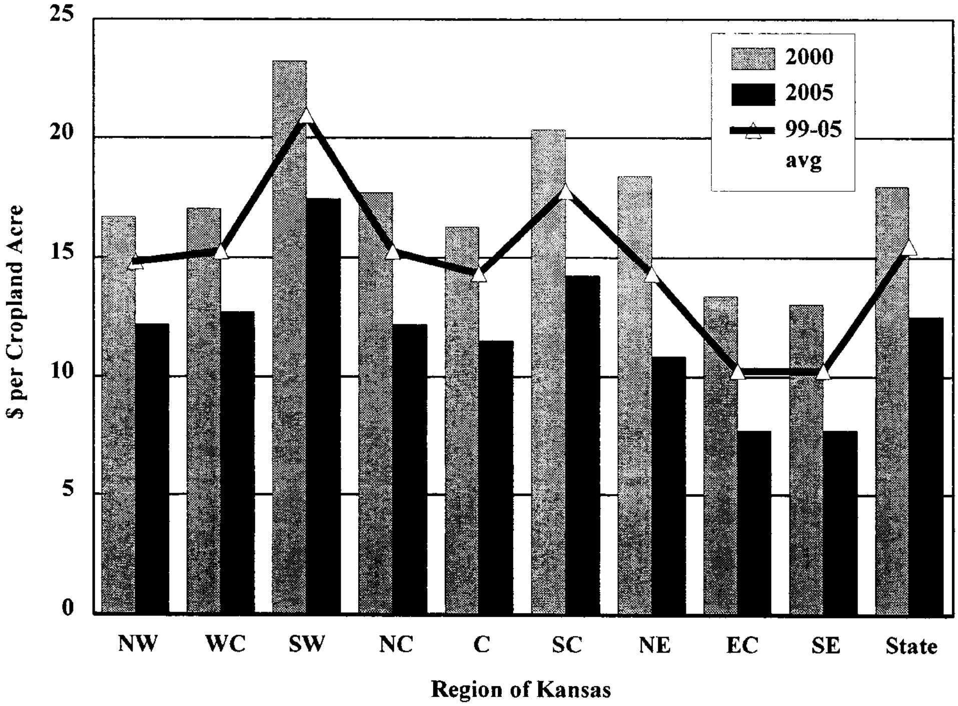

Figure 7. Expected Government Payments for Kansas 2000, 2005, and 1999–2005 Average

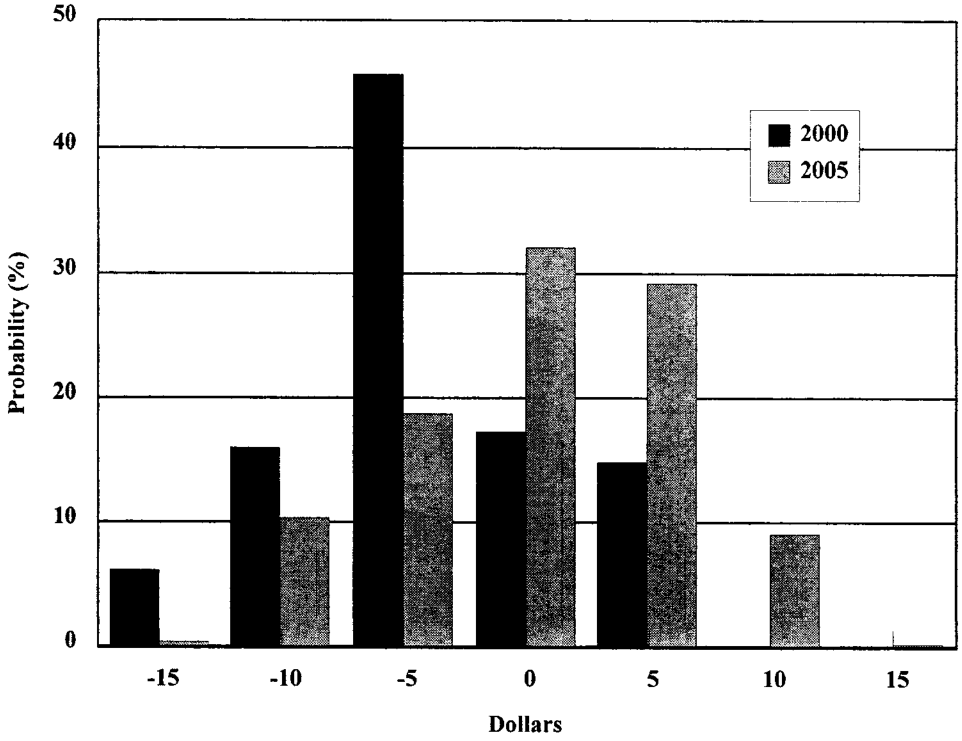

Figure 8. Probability of Net Crop Income per Cropland Acre West-Central Kansas, 2000 and 2005

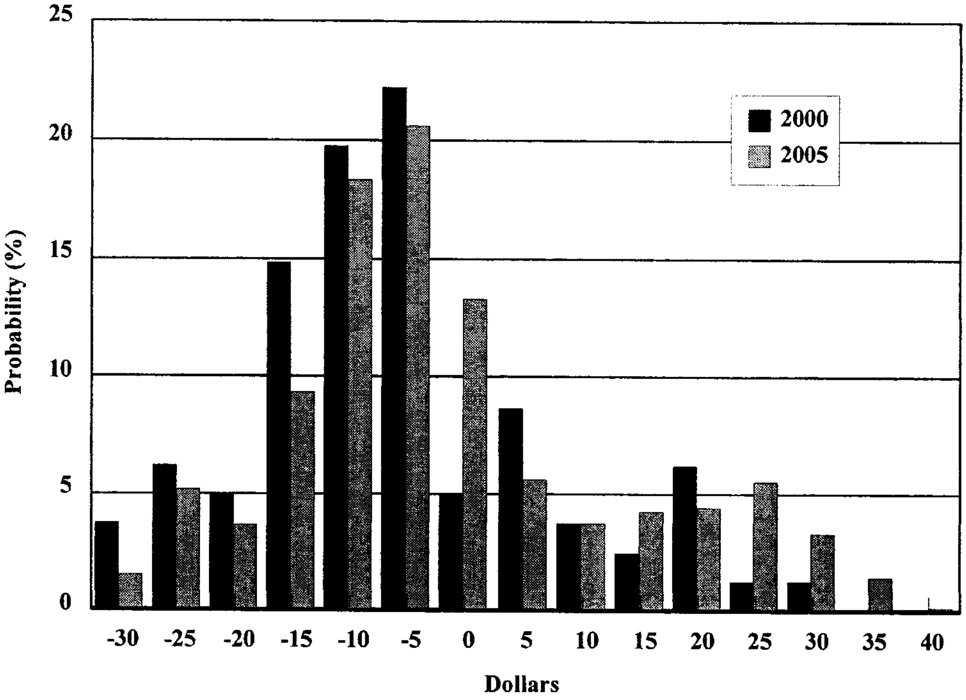

Figure 9. Probability of Net Crop Income per Cropland Acre Central Kansas, 2000 and 2005

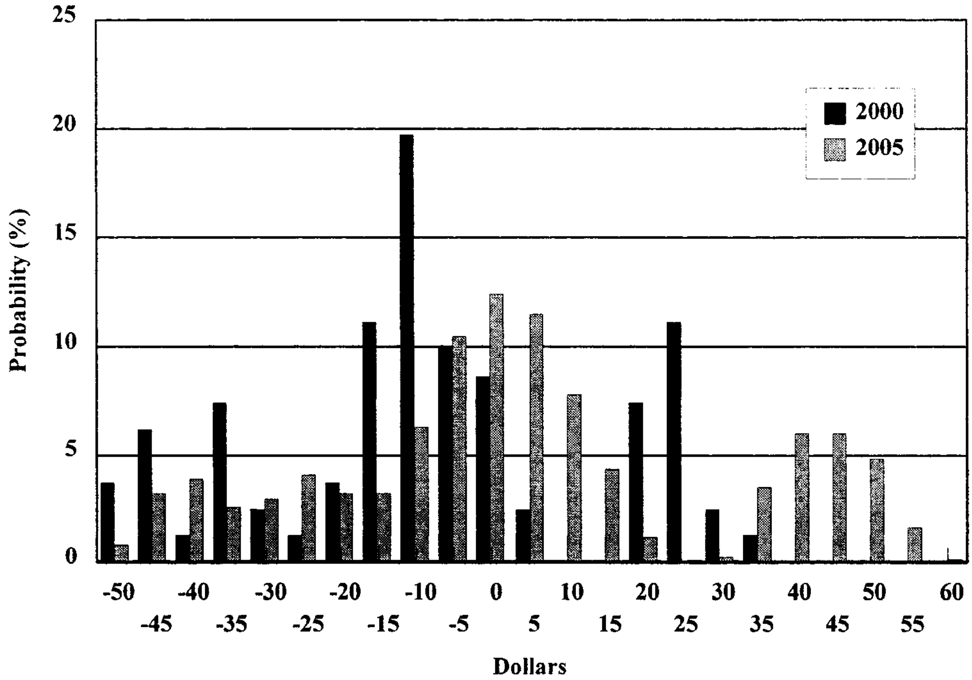

Figure 10. Probability of Net Crop Income per Cropland Acre East-Central Kansas, 2000 and 2005

probability of occurring in 2000 than in 2005. Figure 9 (central) shows that the probability of acquiring net income less than −$12.50 per acre is 30 percent in 2000 but only 20 percent in 2005. Figure 10 (east central) depicts a probability of acquiring net income less than −$7.50 per acre of 57 percent in 2000 and 30 percent in 2005. The figures indicate that lower income levels are much more likely in 2000 than in 2005 for each of the three districts.

Summary and Implications

Parametric, semi-parametric, and non-parametric approaches are used extensively to model random variables necessary for risk analysis. This paper has examined the use of semi-parametric and non-parametric modeling approaches for simulating price and yield distributions with an application to Kansas agriculture. The model discussed has been used for agricultural outlook, to examine the effect of farm policy on the Kansas agricultural economy, and to examine the effect of government program payments on tax revenue.

Results from the model indicate that 2000 will be another difficult year for Kansas farmers, although crop income will increase slightly from 1999. However, unless another supplemental infusion of government payments occurs, crop income is expected to be the lowest since 1992. In addition, there is a 22-percent chance that crop income will fall below the previous low of $3.2 billion recorded during the last 10 years. We also found that the variability and the expected income varied by region in the state with the Eastern region in the statement being more susceptible to financial hardship than the Western region.

Future enhancements to the model will be to add a livestock component to address the interactions between crop and livestock sectors. In addition, gross revenue figures will be converted to net income figures to further investigate the impact on tax revenues. Finally, additional work will be completed to examine the use of trend models (Richardson, Klose, and Gray) compared to mean reverting models to project crop yield.

References

Berends, P., A.M. Featherstone, and T.L. Kastens. "Technology Restrictions on Cost Functions: An Application of Genetic Algorithms." abstract in *Journal of Agricultural and Applied Economics* 31(1999):401.

Eakin, B.K., D. P. McMillen, and M.J. Bruno. "Constructing Confidence Intervals using the Bootstrap: An Application to a Multi-Product Cost Function." *Review of Economics and Statistics* 72(1990):339–44.

Efron, B. "Better Bootstrap Confidence Intervals." *Journal of the American Statistical Association* 82(1987):171–85.

Farm Services Agency, Kansas Office, *Enrolled Farm and Producer Report Summaries for 1993, 1994, and 1995.*

Featherstone, A.M., C.B. Moss, T.G. Baker, and P.V. Preckel. "The Theoretical Effects of Farm Policies on Optimal Leverage and the Probability of Equity Losses." *American Journal of Agricultural Economics* 70(1988):572–79.

Featherstone, A.M., G.A. Moghnieh, and B.K. Goodwin. "Farm-Level Nonparametric Analysis of Cost-Minimization and Profit-Maximization Behavior." *Agricultural Economics* 13(November 1995):111–20.

Featherstone, A.M., J. Mintert, and T.L. Kastens. "Kansas Agricultural Outlook." *Kansas Business Review* 22(Winter 1998–99):10–16.

Featherstone, A.M., P.V. Preckel, and T.G. Baker. "Modeling Farm Financial Decisions in a Dynamic and Stochastic Environment." *Agricultural Finance Review* 50(1990):80–99.

Griffiths, W.E., R.C. Hill, and G.G. Judge. *Learning and Practicing Econometrics.* New York: John Wiley & Sons, 1993.

Hannan, E.J. "Regression for Time Series." in M. Rosenblatt, (ed.), *Time Series Analysis,* John Wiley, New York, New York, 1963.

Hogg, R.V. and A.T. Craig. *Introduction to Mathematical Statistics,* Macmillan Publishing Company, Inc. New York, New York, 1978.

Kansas Department of Agriculture, USDA. *Kansas Farm Facts.* Several issues.

Kansas Department of Agriculture, USDA, *Crops.* Several issues.

Kansas Department of Agriculture, USDA, *Agricultural Prices.* Several issues.

Kastens, T.L. and A.M. Featherstone. "The Federal Agricultural Improvement and Reform Act of 1996: A Kansas Perspective." *Review of Agricultural Economics* 19(Fall-Winter 1997):326–49.

Kastens, T.L. and A.M. Featherstone. "Impact of Additional Federal Farm Subsidies on Kansas Tax Revenue." Presentation to the Consensus Revenue Estimating Outlook Meeting, Topeka, Kansas, October 25, 1999.

Miller, A.C. and T.R. Rice. "Discrete Approximations of Probability Distributions." *Management Science* 29(1983): 352–362.

Newey, W.K. "Semiparametric Efficiency Bounds." *Journal of Applied Econometrics* 5(1990):99–135.

Preckel, P.V. and E. DeVuyst. "Efficient Handling of Probability Information for Decision Analysis Under Risk." *American Journal of Agricultural Economics* 74,3(Aug. 1992): 655–662.

Ramirez, O.A. "Multivariate Transformations to Parametrically Model and Simulate Joint Price-Yield Distributions under Non-Normality, Autocorrelation and Heteroscedasticity: A Tool for Assessing Risk in Agriculture," *Journal of Agricultural and Applied Economics,* Forthcoming 2000.

Richardson, J.W., S.L. Klose, and A.W. Gray. "An Applied Procedure for Estimating and Simulating Multivariate Empirical (MVE) Probability Distributions in Farm Level Risk Assessment and Policy Analysis," *Journal of Agricultural and Applied Economics,* Forthcoming 2000.

Tauer, L. "Do New York Dairy Farmers Maximize Profits or Minimize Costs?" *American Journal of Agricultural Economics* 77(1995):421–29.

The Rainbow Book, Summary of the FAPRI Baseline. Food and Agricultural Policy Research Institute. Columbia, Missouri. December 1996.

U.S. Department of Agriculture. *1996 Farm Bill Press Release.* April 26, 1996.

U.S. Department of Agriculture, *Agricultural Prices.* Several issues.

U.S. Department of Agriculture. *Crop Production.* National Agricultural Statistics. Several issues.

U.S. Department of Agriculture. *Economic Indicators of the Farm Sector, State Financial Summary.* Rural Economy Division, Economic Research Service. Several issues.

U.S. Department of Agriculture. *Historical State Farm Income Indicators by State.* Economic Research Service and National Agricultural Statistics Services. Computer database at Cornell University.

U.S. Department of Commerce. *1992 Census of Agriculture, Kansas State and County Data.* Economics and Statistics Administration, Bureau of the Census.

Varian, H.R. *Microeconomic Analysis.* W.W. Norton & Company. 1978.