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Estimating Price Variability in Agriculture: Implications for Decision Makers

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ABSTRACT

Using a stochastic version of the POLYSYS modeling framework, an examination of projected variability in agricultural prices, supply, demand, stocks, and incomes is conducted for corn, wheat, soybeans, and cotton during the 1998–2006 period. Increased planting flexibility introduced in the 1996 farm bill results in projections of significantly higher planted acreage variability compared to recent historical levels. Variability of ending stocks and stock-to-use ratios is projected to be higher for corn and soybeans and lower for wheat and cotton compared to the 1986–96 period. Significantly higher variability is projected for corn prices, with wheat and soybean prices also being more variable. No significant change in cotton price variability is projected.

Key Words: POLYSYS model, price variability, stochastic simulation.

The economic well-being of production agriculture and agribusiness is influenced by a number of forces beyond the control of economic agents in agriculture. Producers and analysts can formulate reasonable expectations about the influences of some of these exogenous factors, such as population, per capita incomes, technology, and current government policies and programs, when making production plans. Other exogenous factors cannot be expressly incorporated into the decision-making process, but strongly influence domestic and global agricultural supplies—including random effects of weather, biological phenomena, changes in institutional structures among trading partners, and natural phenomena.

A large portion of the historical variability in agricultural prices, supplies, exports, and returns can be attributed to factors over which individual producers have neither control nor reliable predictive ability. For more than a half century, various government programs specifically designed in part to reduce the variability of agricultural prices, supplies, exports, and farm incomes have affected U.S. agriculture. Since passage of the Federal Agriculture Improvement and Reform (FAIR) Act in 1996, a dismantling of government supply controls and price stabilizing programs has begun, with movement toward freer agricultural production and markets. Now that government supply controls and price stabilizing tools are no longer available, it has become even more critical that producers, policy makers, and other agricultural decision makers are cognizant of the sources and magnitude of variability around agricultural yields and exports, and on

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decision-making variables such as prices and net returns. Also of considerable interest is whether price and net return variability are less or greater in the South than for the U.S. as a whole.

A number of deterministic, large-scale models of the U.S. agricultural sector have proven to be useful tools for projecting prices and incomes with an "average state" of weather, unchanged international institutional structures, and other exogenous conditions.[1] But producers, policy makers, agricultural lenders, agribusinesses, and others are increasingly interested in the range and relative frequencies of prices given the variability associated with yields and exports. Stochastic simulation techniques allow estimation of probability distributions for endogenous variables such as prices and net returns, given probability distributions for uncertain variables in the system. Uncertainty in the agricultural system may be in the form of probability distributions on the random variables, such as yields and exports, or on the disturbance terms for particular equations. Stochastic simulation of such a model results in an estimate of the probability distributions on the endogenous variables, and thus provides an important dimension to the information base for decision makers.

This added dimension of variability around key indicators of agricultural performance will be especially important for examining agricultural sector impacts of the FAIR Act. This paper represents an initial examination of supply, demand, price, and income variability using a stochastic simulation model of the U.S. agricultural sector, based on the Policy Analysis System (POLYSYS) national simulation model (Ray et al. 1997). A 10-year stochastic baseline simulation is performed using the November 1997 Food and Agriculture Policy Research Institute (FAPRI) agriculture baseline. All of the baseline assumptions regarding agricultural policies, domestic and global economic conditions, weather, technological change, and other influences also characterize the stochastic baseline simulation, except that stochastic yield and export shocks are introduced. Examination of the results focuses on crops of primary importance to southern agriculture, including corn, soybeans, cotton, and wheat. For selected commodities, statistics on variability are presented for harvested acreage, yield, supply, feed use, export use, ending stocks, season average price, and net returns per acre. The probability distributions associated with the 10-year simulation are compared to the historical variation of crop prices, supplies, demands, and returns to allow an examination of the change in projected variability in agriculture compared to observed variability in recent years.

Methodology

The POLYSYS national agriculture simulation model is anchored to a national baseline of projections for agriculture. Baseline projections for crop acreages, prices, and expenditures are retailored for 305 production regions corresponding to Agricultural Statistic Districts (ASDs). Changes to the baseline then are introduced exogenously, and the model estimates the impacts of changes to the baseline for regional crop supply, national crop prices and demand, livestock supply and demand, and agricultural income. Endogenous model crops include corn, soybeans, cotton, grain sorghum, barley, oats, wheat, and rice. Seven livestock commodities also are included as a complement to the feed demand component of the crop sector. The calculation of most national variables in POLYSYS is driven by deviations from a baseline and elasticity parameters. POLYSYS incorporates 305 regional linear programming crop supply models and a crop demand and price simultaneous block for the estimation of endogenous crop variables. The regional crop supply models are designed to allocate marginal changes in acreage over the baseline crop acreage within each region, subject to a 15% acreage shift constraint in any simulation year. Thus, a POLYSYS sim-

[1] Examples of large-scale deterministic structural models that are often used for policy analysis include models such as AGMOD (Ferris), COMGEM (Penson and Chen), FAPRI (Devadoss et al.), AGSIM (Taylor 1993), and CARD LP (English et al.).

ulation yields a dynamic performance path for crop and livestock supply, demand, price, and agricultural income variables.

An implicit assumption characterizing results from deterministic simulation models like POLYSYS is that simulation results differ from the baseline only to the extent that changes are introduced to define a simulation. Thus, deterministic models generally are limited to providing point estimates of endogenous variables. It is possible to use a deterministic model to examine the impacts of changes from the baseline for model variables characterized by high levels of uncertainty. For example, the sensitivity of agricultural variables to baseline export projections has been the subject of several POLYSYS simulation analyses (e.g., Ray and Tiller; Ray; Ray et al. 1995). But unless specific changes to the baseline export projections are simulated, the endogenous variables are estimated under the assumption that there is no range of values associated with baseline export projections. While a deterministic model could be used to perform multiple simulations that introduce randomness to desired variables, stochastic techniques provide a statistical framework to perform a series of simulations in an efficient and systematic manner (Taylor 1994; Richardson and Nixon).

A POLYSYS stochastic baseline simulation is developed by introducing variability in (*a*) national crop export projections, and (*b*) yield estimates for each of the 305 regions into the POLYSYS baseline simulation. Stochastic exports for eight crops were simulated from a multivariate empirical (MVE) distribution of deviations from a trend. The MVE distribution for exports was estimated using data for 1982–96. Historical values of crop exports over the 1982–96 period were regressed on a time trend for each of the eight model crops to obtain the error terms (variability) from historical trend expectations.[2] The percentage deviations from the trend for each crop were used to specify empirical probability distributions for crop export deviations. A correlation matrix of crop export deviations for eight crops was calculated and used in conjunction with the historical percentage deviations from trend to simulate correlated random deviates to the annual baseline export values in the stochastic simulation.

A multivariate empirical distribution for crop yields was not used to generate random yields due to the sheer size of the correlation matrix for simulating eight crops in each of 305 regions. The historical variability of regional crop yields, 1972–96, was used to develop empirical distributions for production for each crop in each region. Percentage deviation structures are preserved by year to reflect correlation across crops and regions. Correlated yields were simply simulated by randomly selecting rows from the matrix of annual percentage yield deviations for the 305 regions and eight crops. Once a row in the matrix (year) was selected randomly, the deviations were applied to their respective baseline values to calculate the stochastic yield.[3]

In the first year of a POLYSYS simulation, the model randomly selects a percentage deviation for initial export shocks for each crop and applies it to the baseline value for crop exports in that year. Similarly, a random year is chosen from 1972 through 1996, and the yield percentage deviations for each of eight crops in each of 305 regions for that year are applied to the baseline yield projections. Similar random draws of export shocks and yield percentage deviations are made in each successive year of the simulation. In a 10-year simulation, 10 random annual draws of export shocks and yield percentage deviations are made and applied to their respective baseline values. The model solves the 10-year horizon

[2] Export data are available prior to 1982, but evidence of a structural change in U.S. exports around 1982 exists. An alternative to truncating historical exports at 1982 would be inclusion of additional historical export data with an estimation of structural change included in the regression of historical exports on a time trend.

[3] Historical crop yields were regressed on a time trend to calculate the annual percentage deviations from trend. The regional nature of the crop supply sector of the model requires complete historical yield data at the county level, which were not available electronically prior to 1972. Thus, historical data available for estimation of yield deviations from a trend are limited to 25 years.

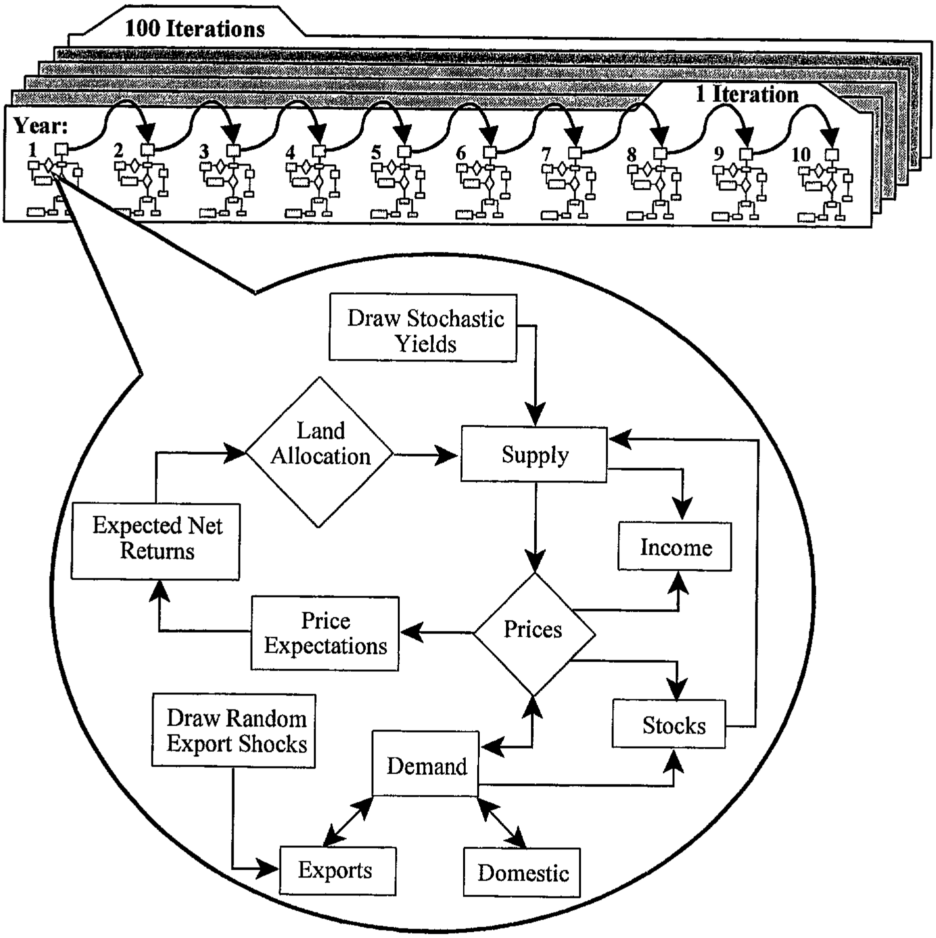

Figure 1. Schematic diagram of stochastic POLYSYS methodology

in a recursive fashion using the random yields and exports as the changes from the baseline that lead to changes in quantities supplied, prices, quantities demanded, ending stocks, and expected prices in the next year that lead to acreage changes.

A 10-year simulation of the model with random annual export shocks and yield deviations comprises one iteration of the model. The 10-year simulation sequence is repeated 100 times to allow estimation of a probability distribution for endogenous model variables for each of the 10 simulation years. Figure 1 illustrates the interaction of variability in exports and yields over the simulation period and across iterations. In the first year of the first iteration, the model draws an export percentage deviation for each crop and applies it to the baseline export value to introduce one realization of a stochastic shock to exports. The model also draws a year and applies the corresponding percentage yield deviations for all eight crops in all 305 regions to introduce one realization of stochastic yields. The stochastic yields directly influence crop supplies, which in turn influence agricultural prices, incomes, stocks, and demands. The random export shocks influence crop demands, which are reflected in total demand, and thus the determination of crop prices. Therefore, the variability of both yields and exports contribute to the determination of agricultural prices.

Effects of the export and yield deviations from the baseline projection are transferred to subsequent simulation years through their initial influence on prices, which are used to form price expectations for future production decisions, and through their influence on crop demands and ending stocks. In the second simulation year, another set of random yield and export deviations is applied to baseline yield and export values, and the simulation is repeated. The same process follows in each of the remaining eight simulation years until a 10-year simulation sequence is completed. This 10-year simulation sequence comprises one iteration of the stochastic model. One hundred iterations are performed, drawing random export and yield percentage deviations in each of the 10 simulation years that comprise one iteration. The resulting stochastic baseline provides 100 estimates of each variable in each simulation year, providing an estimate of the probability distribution for each variable. The stochastic baseline represents a 10-year forecast of supply and demand and income variables, with probability distributions around each endogenous variable.

Results

The simulated summary statistic values for key output variables in POLYSYS—such as planted acres, production, total use, ending stocks, and prices—are summarized in table 1 for crops of major importance to southeastern agriculture, including corn, wheat, soybeans, and cotton. Historical means for the 1986–96 period also are reported. The 11 years of historical data were detrended, and standard deviations from the historical trend are reported in table 1 to avoid overstating the variation in these data. The coefficients of variation for the historical data are calculated using standard deviations based on deviations from trend and the historical means. The first column for each crop in table 1 reports the historical mean, the standard deviation from the trend, and this deviation as a percentage of the historical mean, as a proxy for the coefficient of variation. The second column reports similar descriptions of the data over the 10-year simulation period, 1997–2006, where the means for each variable are means over all 10 simulation years and all 100 ten-year iterations; the standard deviations are the average deviations from the detrended simulation data; and the coefficients of variation are the detrended standard deviations as a percentage of the overall simulation mean. For each crop, the two columns provide one way to compare variable performance in the historical period to variable performance in the simulation period. It should be noted that while these measures provide one method of inter-period comparison (1986–96 compared to 1997–2006), they remain a comparison of one observed path (among the numerous paths that could have occurred during that time) to 100 potential paths of outcomes for the simulation period.

Planted Acreage

The 1996 farm bill provides farmers with nearly complete flexibility in determining their crop mixes, leading to the expectation that planted acreage after 1996 will be more variable than prior to 1996. Planted corn acreage over the 1997–2006 simulation period is projected to be more than 8 million acres greater than the 1986–96 average (table 1). Planting flexibility is projected to increase the relative variability of planted corn acres from 0.053 during 1986–96 to 0.094 for the 1997–2006 period, an increase of 77.4%.

Wheat planted acreage declines slightly from the historical average of 71.5 million acres (table 1). The coefficient of variation for wheat acreage rises from 0.053 during 1986–96 to 0.089 (68% higher) during the 1997–2006 period. For soybeans, 1997–2006 planted acreage projections are 7.7 million acres greater than the historical average. Variability over the simulation period rises 296% from the historical coefficient of variation of 0.023. Cotton planted acreage is projected to increase by 1 million acres during the 1997–2006 period, with average variability over the entire simulation period projected to be 6% lower than over the historical period, as farmers in marginal cotton areas switch to other crops.

Production

Average annual production for the four crops increases throughout the projection period, largely in response to acreage gains and trend-adjusted mean crop yields (table 1).

Table 1. Summary Statistics of Historical Average (1986–96) and Simulation Average (1997–2006) Results for Crop Variables

	Corn		Wheat		Soybeans		Cotton[c]	
Item	1986–96[a]	1997–06[b]	1986–96[a]	1997–06[b]	1986–96[a]	1997–06[b]	1986–96[a]	1997–06[b]
Planted Acreage								
Mean (mil. ac.)	74.1	82.3	71.5	69.6	60.3	68.0	12.7	13.7
Std. Dev.	3.9	7.7	3.8	6.2	1.4	6.2	1.0	1.0
Coef. of Variation	0.053	0.094	0.053	0.089	0.023	0.091	0.080	0.075
Production								
Mean (mil. bu., bales)	7,800	10,238	2,220	2,484	2,037	2,692	15	18
Std. Dev.	1,332	1,526	238	271	188	331	1.7	2.4
Coef. of Variation	0.171	0.149	0.107	0.109	0.092	0.123	0.107	0.129
Total Use								
Mean (mil. bu., bales)	8,096	10,211	2,220	2,543	2,077	2,681	16	18.5
Std. Dev.	425	633	134	203	171	204	1.1	1.2
Coef. of Variation	0.053	0.062	0.060	0.080	0.082	0.076	0.068	0.065
Ending Stocks								
Mean (mil. bu., bales.)	1,897	1,271	735	683	265	310	4	4.6
Std. Dev.	877	684	276	192	72	147	1.2	1.3
Coef. of Variation	0.462	0.538	0.375	0.281	0.270	0.473	0.316	0.282
Stocks-to-Total Use Ratio								
Mean (ratio)	0.24	0.12	0.36	0.28	0.13	0.11	0.26	0.25
Std. Dev.	0.11	0.06	0.13	0.09	0.03	0.05	0.10	0.07
Coef. of Variation	0.468	0.508	0.353	0.338	0.231	0.437	0.375	0.288
Season Average Price								
Mean ($/bu., lb.)	2.34	2.65	3.35	3.55	6.06	6.43	0.64	0.69
Std. Dev.	0.31	0.64	0.49	0.71	0.75	1.00	0.06	0.07
Coef. of Variation	0.133	0.242	0.146	0.200	0.124	0.156	0.101	0.102
Net Returns (value of production minus variable expenses)								
Mean ($ mil.)	7,825	11,422	3,533	3,708	7,412	10,182	1,317	1,467
Std. Dev.	1,461	3,427	648	1,620	1,130	1,619	551	380
Coef. of Variation	0.187	0.300	0.183	0.437	0.152	0.159	0.418	0.259

[a] For the 1986–96 historical period, the mean is the historical mean; the standard deviation is the deviation of residuals from detrended historical data; and the coefficient of variation is calculated using that deviation from trend and the historical mean.

[b] For the 1997–2006 simulation period, the mean is the simulation mean; the standard deviation is the deviation of residuals from detrended simulation data; and the coefficient of variation is calculated using that deviation from trend and the overall simulation mean.

[c] For prices and returns, 1986 was removed from the historical period to avoid an extreme price impact resulting from the first year of the cotton marketing loan program in 1986.

The coefficient of variation for corn production actually declines from its respective historical measure by 13%. Some portion of this apparent decline in variability for corn may stem from a significantly higher mean level of production reported for the projected years. If the standard deviations are used to compare variability, then table 1 shows a higher standard deviation (and thus higher nominal variability) for projected corn production during the 1997–2006 simulation period compared to the historical deviation. Variability in wheat production rises by nearly 2% from the historical period, while variability in soybean production rises by more than 33%. Cotton variability is slightly more

Table 2. Probability of Experiencing Selected Corn, Wheat, Soybeans, and Cotton Ending Stock Levels, 1998–2006

Crop/Range	1998	1999	2000	2001	2002	2003	2004	2005	2006
Corn (mil. bu.)									
< 1,000	0.34	0.30	0.36	0.41	0.41	0.38	0.38	0.41	0.41
1,000–2,000	0.46	0.49	0.43	0.47	0.39	0.50	0.44	0.44	0.40
> 2,000	0.20	0.21	0.21	0.12	0.20	0.12	0.18	0.15	0.19
Wheat (mil. bu.)									
< 600	0.21	0.39	0.42	0.45	0.47	0.44	0.46	0.46	0.51
600–1,000	0.66	0.51	0.48	0.48	0.39	0.47	0.46	0.47	0.42
> 1,000	0.13	0.10	0.10	0.07	0.14	0.09	0.08	0.07	0.07
Soybeans (mil. bu.)									
< 200	0.34	0.34	0.32	0.28	0.42	0.32	0.27	0.29	0.38
200–500	0.49	0.39	0.53	0.54	0.45	0.55	0.56	0.53	0.49
> 500	0.17	0.27	0.15	0.18	0.13	0.13	0.17	0.18	0.13
Cotton (mil. bales)									
< 3	0.06	0.09	0.11	0.09	0.11	0.21	0.16	0.13	0.21
3–6	0.73	0.71	0.72	0.77	0.73	0.64	0.71	0.77	0.65
> 6	0.21	0.20	0.17	0.14	0.16	0.15	0.13	0.10	0.14

than 20% above the 1986–96 level (0.107) for the 1997–2006 period.

Total Use

As with production, total use of the four crops is projected to be higher during the simulation period, compared to the historical average (table 1). Corn use, in particular, rises 26.1% during the simulation period from the historical level of 8.1 billion bushels. This increase in corn use is a direct reflection of the FAPRI baseline, which assumes significant increases in grain exports over the simulation period.

Variability in total use for the projection years is greater than the historical variability for corn and wheat, but lower for soybeans and cotton. Wheat total use shows the greatest increase in variability, while soybeans total use shows the greatest decrease in variability. Wheat variability is 33.3% above the historical coefficient of 0.060 in the simulation, while corn variability is 17% higher. Soybean total use variability declines by 7.3% during the simulation period, compared to the historical period. Cotton total use experiences similar variability results, with lower variability over the 1997–2006 period.

Stocks

Average ending stock levels generally are projected to decrease in absolute terms for corn and wheat and as a percentage of total use for all four crops over the 1997–2006 period (table 1). The coefficients of variation for corn and soybean ending stocks and stocks-to-use ratios increase during the simulation period compared to the historical period, while they decrease for wheat and cotton. Variability in soybean stocks, a reflection of the variability in soybean acreage, increases by more than 75% in the simulation compared to the historical period, as it becomes the preferred flex crop under the 1996 farm bill. Variability in cotton stocks as measured by the simulation coefficient of variation 0.282 is lower than the historical coefficient of variation 0.316.

The probability of experiencing various levels of ending stocks is summarized in table 2. Averaged over the entire projection period, there is a 38% chance that corn ending stocks will be below 1 billion bushels, a 45% chance that stocks will fall between 1–2 billion bushels, and an 18% chance that corn stocks will be above 2 billion bushels. Table 2 also shows that, averaged over 1998–2006, there is a 42%

Table 3. Summary Statistics and Probability Distributions of Season Average Prices for Corn, Wheat, Soybeans, and Cotton, 1998–2006

Crop Season Avg. Price	1998	1999	2000	2001	2002	2003	2004	2005	2006
Corn ($/bu.)									
Mean ($)	2.48	2.42	2.48	2.59	2.65	2.71	2.65	2.92	2.86
Std. Dev.	0.65	0.57	0.66	0.58	0.70	0.66	0.66	0.80	0.82
Coef. of Variation	0.261	0.236	0.265	0.222	0.266	0.243	0.249	0.273	0.287
Min. Observ. ($)	1.35	1.29	1.46	1.38	1.46	1.49	1.51	1.67	1.61
Max. Observ. ($)	3.99	4.26	4.76	4.07	4.47	4.42	4.50	5.08	5.52
Probability ≤ ($)									
10%	1.79	1.76	1.68	1.92	1.86	1.94	1.85	2.01	2.00
25%	1.96	1.99	1.97	2.14	2.08	2.25	2.13	2.38	2.19
33%	2.05	2.14	2.10	2.18	2.13	2.34	2.21	2.52	2.27
50%	2.30	2.29	2.32	2.45	2.52	2.59	2.55	2.72	2.67
66%	2.59	2.54	2.70	2.84	2.89	2.85	2.90	3.01	3.02
75%	2.95	2.76	2.93	2.98	3.18	3.18	3.06	3.30	3.37
90%	3.38	3.11	3.30	3.30	3.47	3.64	3.49	4.13	4.06
Wheat ($/bu.)									
Mean ($)	3.05	3.41	3.52	3.60	3.71	3.57	3.72	3.65	3.67
Std. Dev.	0.65	0.76	0.81	0.76	0.95	0.83	0.88	0.82	0.84
Coef. of Variation	0.214	0.224	0.230	0.211	0.258	0.234	0.235	0.225	0.229
Min. Observ. ($)	1.52	1.91	1.61	2.04	1.62	1.61	1.56	1.96	2.03
Max. Observ. ($)	5.15	5.19	5.83	5.72	6.06	5.79	6.12	5.95	5.91
Probability ≤ ($)									
10%	2.27	2.39	2.51	2.63	2.49	2.58	2.52	2.61	2.55
25%	2.68	2.92	2.95	3.04	3.01	3.04	3.19	3.13	2.99
33%	2.76	3.03	3.12	3.18	3.32	3.15	3.35	3.33	3.28
50%	2.90	3.33	3.47	3.57	3.67	3.54	3.60	3.60	3.71
66%	3.22	3.65	3.74	3.89	4.01	3.82	4.02	3.85	4.02
75%	3.36	3.89	4.07	4.07	4.29	4.02	4.20	4.02	4.14
90%	3.79	4.42	4.41	4.43	4.93	4.62	4.77	4.63	4.40
Soybeans ($/bu.)									
Mean ($)	6.30	6.04	6.18	6.20	6.48	6.47	6.45	6.61	6.92
Std. Dev.	1.22	1.21	1.11	1.15	1.11	1.06	1.19	1.10	1.23
Coef. of Variation	0.193	0.200	0.179	0.185	0.172	0.163	0.184	0.166	0.178
Min. Observ. ($)	4.18	4.27	3.88	4.21	4.24	4.31	4.49	4.26	4.77
Max. Observ. ($)	9.98	9.25	9.82	9.41	9.87	9.42	10.52	10.74	10.43
Probability ≤ ($)									
10%	4.86	4.76	4.91	4.90	5.11	5.21	5.19	5.33	5.40
25%	5.37	5.03	5.39	5.34	5.77	5.64	5.59	5.75	6.03
33%	5.65	5.29	5.58	5.56	5.89	5.85	5.84	5.97	6.25
50%	6.16	5.63	6.02	6.03	6.38	6.35	6.11	6.54	6.73
66%	6.63	6.50	6.44	6.51	6.82	6.87	6.64	6.91	7.29
75%	6.95	6.75	6.84	6.86	7.03	7.22	6.94	7.28	7.54
90%	7.82	7.80	7.38	7.66	7.92	7.78	7.88	7.73	8.44

Table 3. (Continued)

Crop Season Avg. Price	1998	1999	2000	2001	2002	2003	2004	2005	2006
Cotton ($/lb.)									
Mean ($)	0.67	0.67	0.68	0.70	0.69	0.71	0.70	0.70	0.71
Std. Dev.	0.07	0.08	0.08	0.08	0.08	0.09	0.07	0.08	0.09
Coef. of Variation	0.108	0.121	0.117	0.108	0.119	0.129	0.106	0.118	0.133
Min. Observ. ($)	0.47	0.50	0.53	0.48	0.51	0.56	0.54	0.53	0.51
Max. Observ. ($)	0.83	0.89	0.94	0.91	0.97	0.99	0.88	1.04	1.02
Probability ≤ ($)									
10%	0.58	0.58	0.57	0.60	0.58	0.60	0.60	0.61	0.60
25%	0.62	0.61	0.62	0.65	0.64	0.63	0.64	0.65	0.65
33%	0.64	0.63	0.64	0.67	0.66	0.66	0.66	0.67	0.66
50%	0.67	0.66	0.66	0.70	0.70	0.70	0.71	0.70	0.69
66%	0.70	0.70	0.70	0.73	0.72	0.75	0.74	0.74	0.75
75%	0.72	0.72	0.72	0.74	0.74	0.76	0.76	0.75	0.76
90%	0.76	0.78	0.78	0.78	0.78	0.82	0.79	0.79	0.83

chance that wheat ending stocks will fall below 600 million bushels, a 33% chance that soybean ending stocks will fall below 200 million bushels, and a 13% chance that cotton ending stocks will fall below 3 million bales. The probability of achieving very high stock levels averaged over the simulation period is 17% for soybeans (stocks over 500 million bushels), 16% for cotton (stocks greater than 6 million bales), and 9.4% for wheat (stocks over 1 billion bushels). In looking at intertemporal changes in ending stocks, the probability of experiencing very low stocks increases considerably over the simulation period for wheat, cotton, and corn, with the probability distribution for soybean ending stocks remaining relatively constant over time.

Season Average Price

Season average annual prices during the 1997–2006 period are projected to increase over the historical period for all four crops (table 1). Corn prices are projected to average $2.65 per bushel over the 1997–2006 period with a coefficient of variation of 0.242, indicating that season average corn prices are projected to be 82% more variable over the 10-year study horizon than during the historical period. The coefficient of variation for wheat prices over the 1997–2006 period indicates that wheat prices will be 40% more variable than during the 1986–96 period. Soybean prices are projected to have 25.8% more relative variability than during the historical period. By contrast, cotton prices have the lowest average comparative increase in variability (1%) during the simulation period versus the 1986–96 period.

Annual summary statistics and probabilities for crop prices are provided in table 3. There is a 10% chance that the 1998 corn price will be less than $1.79 per bushel, and a 25% chance that the 1998 price will be below $1.96 per bushel. On the other end of the distribution, the 1998 corn price has only a 10% chance of exceeding $3.38 per bushel. Generally, the distribution of crop prices within each simulation year is skewed leftward, as indicated by an annual mean price greater than the median price ("50% probability ≤" in table 3). Thus, producers have a higher probability of experiencing prices below the expected value of price and are less likely to experience prices at or above the expected value of price.

Histograms of crop price coefficients of variation averaged over the 10-year simulation period show the probabilities of experiencing alternative levels of price variability during the simulation period, as presented in figure

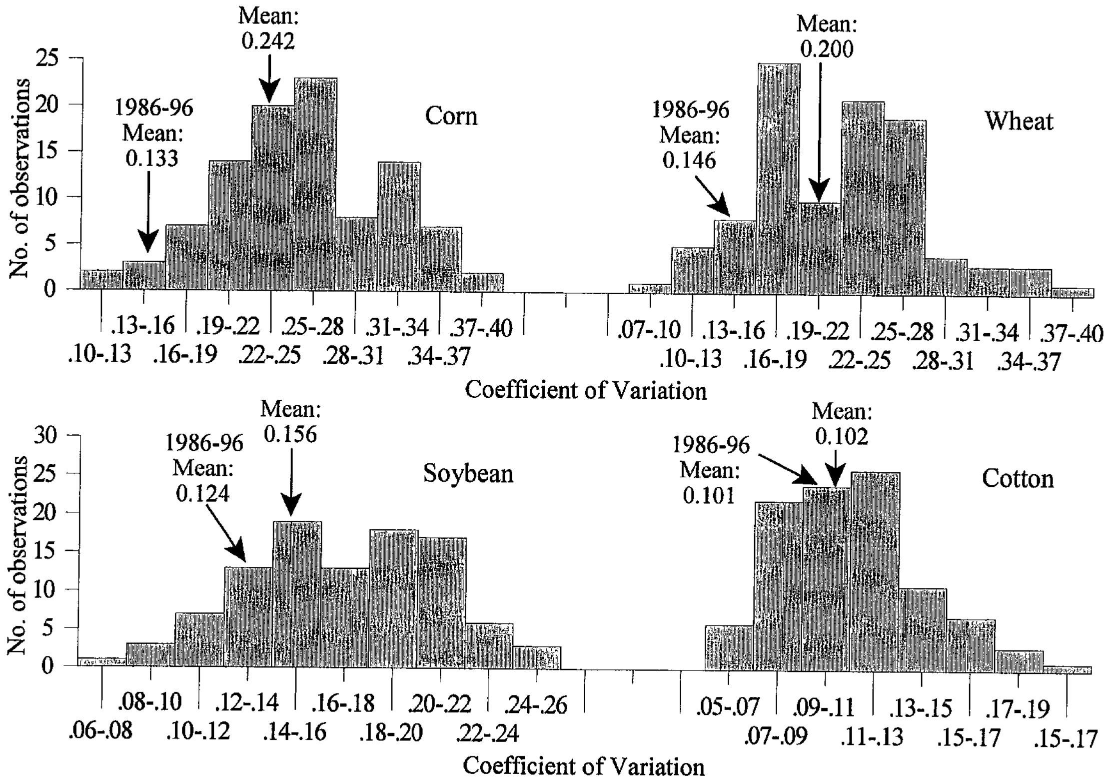

Figure 2. Histograms of simulation period price coefficients of variation

2.[4] Comparing the historical period to the simulation period, figure 2 shows that corn price experiences the most dramatic increase in variability during 1997–2006. The probability of achieving a level of variability greater than the historical level (mean historical coefficient of variation of 0.133) is greater than 95%. Simulation period corn prices were less variable than historical period prices in fewer than five of the 100 iterations. Soybean prices were more variable in the simulation period in more than 76% of the iterations, and wheat prices were more variable in more than 86% of the iterations. Average cotton price variability during the simulation period was approximately equal to variability during the historical period.

A statistical test was performed to test the hypothesis that the mean of the simulation coefficient of variation for price is greater than or equal to the coefficient of variation of actual prices experienced from 1986–96. The simulation mean coefficient of variation for corn price (0.242) was significantly different from the coefficient of variation for corn price over 1986–96 (0.133) (figure 2) at the 0.01 significance level (t = 18.8). The simulation mean coefficients of variation for wheat price (0.20) and soybean price (0.156) were also significantly different from the historical coefficients of variation (0.146 and 0.124, respectively) at the 0.01 significance level (t = 9.0 for wheat, and t = 8.65 for soybeans). The simulation mean coefficient of variation for cotton (0.102) was not significantly different from the historical coefficient of variation (0.101). The result for cotton can be partially

[4] Note that the coefficients of variation presented in figure 2 are calculated as the percentage of the residuals from trend to the period expected value, an analogous calculation to the coefficients of variation presented in table 1. The annual coefficients of variation presented in table 3, however, are the sample standard deviation as a percentage of the mean.

Table 4. Summary Statistics for the 1986–96 Historical Period and 1998–2006 Projections for Net Returns to the Eight Major Crops

	Net Returns (Value of Production minus Variable Expenses)									
	1986–96[a]	1998	1999	2000	2001	2002	2003	2004	2005	2006
Mean ($ mil.)	21,235	24,745	24,993	25,725	27,874	29,211	30,337	30,812	33,096	33,983
Std. Dev.	2,848	4,866	4,860	5,741	5,074	6,057	5,590	6,170	6,330	6,587
Coef. of Var.	0.134	0.197	0.195	0.223	0.182	0.207	0.184	0.200	0.191	0.194

[a] For the 1986–96 historical period, the mean is the historical mean; the standard deviation is the deviation of residuals from detrended historical data; and the coefficient of variation is calculated using that deviation from trend and the historical mean.

explained by the dependence of cotton producers on the marketing loan over the historical period.

Income Measures

Average net returns (value of production less variable expenses) over the simulation period for all four of the crops are greater than their respective 1986–96 averages (table 1). Net returns are more variable for wheat, corn, and soybeans, while cotton net returns experience a marked decline in variability. Variability in cotton returns falls by 38% during the 10-year simulation period compared to the 11-year historical period.

Wheat returns experience the greatest increase in variability, rising 138.8% in the simulation from their historical coefficient of 0.183. Variability of corn net returns is about 60% higher than the historical coefficient, and the soybeans net returns coefficient is nearly 5% higher than the historical coefficient of variation, 0.152.

Historical and projected net returns (value of production less variable expenses) to the eight major crops (corn, grain sorghum, oats, barley, wheat, soybeans, cotton, and rice) are provided in table 4. Mean returns rise significantly over the projection period—from $24.7 billion in 1998 to $34 billion in 2006. Compared to the historical variability (coefficient of 0.134), the relative coefficient of variation for this income measure ranges between 25.6% and 52.1% greater during the simulation period.

Summary and Conclusions

This research used a stochastic version of the POLYSYS national agriculture simulation model to compare the variability of agricultural variables projected for the 1997–2006 period to variability observed prior to 1996. As expected, increased planting flexibility introduced in the 1996 farm bill results in significant increases in planted acreage variability compared to historical levels of variability for major southern crops. The coefficients of variation for corn, wheat, and soybean planted acreage are more than 68% higher over the 1997–2006 period compared to the 1986–96 period. Variability in cotton planted acreage declines during the simulation period as producers in marginal cotton areas switch to other crops. Increases are experienced in the absolute level of total use for all four crops over the projection years compared to historical levels, while total use variability increases for corn and wheat, but decreases for soybeans and cotton. Average ending stocks decline for corn and wheat, while stocks-to-use ratios decline for all crops during the simulation period. Ending stocks and stocks-to-use variability for corn and soybeans are projected to increase over their historical levels, while variability for wheat and cotton are projected to decrease over their historical levels.

The levels and variability of supply, demand, and stock variables for each crop are reflected in projections of season average prices. Steady increases are projected for all crop prices over the period, with the exception of an early downturn in wheat price followed by recovery and gains. Comparing the average coefficient of variation for the historical period to that for the simulation period (calculated as deviations from a trend as a percentage of the period expected value), corn prices average 82% more variable during the 1997–2006 period than during the historical period. Variability of wheat and soybean prices is 40% and 25.8% higher, respectively, than variability observed during the 1986–96 period. In contrast, cotton prices are only 1% more variable during the simulation period. The increases in price variability and production variability are also transmitted to increases in the variability associated with net returns to each crop.

While price variability is clearly projected to increase over the period, it is not possible to use the data presented to determine precisely what portion of increased price variability may be attributed to government program and policy changes instituted in the 1996 farm bill. Average stocks tended to be relatively low at the outset of the 1996 farm bill period and are projected to remain low. Definitive statements regarding price variability since the 1996 farm bill should be tempered with recognition that low stocks are generally manifest in greater price variability, irrespective of policy settings. For example, had corn stocks not been above 4 billion bushels in 1988, when average corn yield fell from 120 bushels per acre to 85 bushels per acre, a very different corn price path may have been observed during the historical period. Further assessment of price variability attributable to the 1996 farm bill will await times of higher stock-to-use ratios.

Among the crops considered, cotton is most unique to the South and experiences the least variability during the simulation period, with price variability very near recent historical levels and a decrease in variability of net returns compared to the 1986–96 period. In the case of soybeans, another important crop in the South, while mean simulation price and net returns variability are greater than historical variability, soybeans exhibit substantially less variability than corn and wheat. Hence, price and net return variability for midwestern corn and Great Plains wheat may be larger than for southern cotton.

References

Devadoss, S., P. Westhoff, M. Helmar, E. Grundmeier, K.E. Skold, W.H. Meyers, and S.R. Johnson. "The FAPRI Modeling System: A Documentation Summary." In *Agricultural Sector Models for the United States: Description and Selected Policy Applications,* eds., C.R. Taylor, S.R. Johnson, and K.H. Reichelderfer, Chap. 7. Ames IA: Iowa State University Press, 1993.

English, B.C., E.G. Smith, J.D. Atwood, S.R. Johnson, and G.E. Oamek. "The CARD LP Model: A Documentation Summary." In *Agricultural Sector Models for the United States: Description and Selected Policy Applications,* eds., C.R. Taylor, S.R. Johnson, and K.H. Reichelderfer, Chap. 5. Ames IA: Iowa State University Press, 1993.

Ferris, J.N. "AGMOD: An Econometric Model of U.S. and World Agriculture." In *Agricultural Sector Models for the United States: Description and Selected Policy Applications,* eds., C.R. Taylor, S.R. Johnson, and K.H. Reichelderfer, Chap. 4. Ames IA: Iowa State University Press, 1993.

Food and Agricultural Policy Research Institute (FAPRI). *November 1997 U.S. Agricultural Outlook.* FAPRI, University of Missouri, Columbia, December 1997.

Penson, J.B., and D.T. Chen. "General Design of COMGEM: A Macroeconomic Model Emphasizing Agriculture." In *Agricultural Sector Models for the United States: Description and Selected Policy Applications,* eds., C.R. Taylor, S.R. Johnson, and K.H. Reichelderfer, Chap. 8. Ames IA: Iowa State University Press, 1993.

Ray, D.E. "The 1996 Farm Bill: Implications for Farmers, Families, Consumers, and Rural Communities." Paper presented at the National Public Policy Education Conference, Providence RI, September 1996.

Ray, D.E., D.G. De La Torre Ugarte, M.R. Dicks, and K.H. Tiller. "The POLYSYS Modeling Framework: A Documentation." Work. Pap., Agricultural Policy Analysis Center, University of Tennessee, Knoxville, November 1997.

Ray, D.E., D.G. De La Torre Ugarte, M.R. Dicks, and R.L. White. *Farm Bill Series.* Agricultural Policy Analysis Center, University of Tennessee, Knoxville. Various selections, Issue Nos. 1–8, 1995.

Ray, D.E., and K.H. Tiller. "U.S. Agricultural Exports: Projected Changes Under FAIR and Potential Unanticipated Changes." Paper presented at the Western Agricultural Economics Association Annual Meetings, Reno NV, July 1997.

Richardson, J.W., and C.J. Nixon. "Description of FLIPSIM V: A General Firm-Level Policy Simulation Model." Bull. No. B-1528, Texas Agr. Exp. Sta., College Station, 1986.

Taylor, C.R. "AGSIM: An Econometric-Simulation Model of Regional Crop and National Livestock Production in the United States." In *Agricultural Sector Models for the United States: Description and Selected Policy Applications*, eds., C.R. Taylor, S.R. Johnson, and K.H. Reichelderfer, Chap. 3. Ames IA: Iowa State University Press, 1993.

———. "Deterministic versus Stochastic Evaluation of the Aggregate Economic Effects of Price Support Programs." *Agr. Systems* 44(1994): 461–73.