QUANTIFYING LONG RUN AGRICULTURAL RISKS AND EVALUATING FARMER RESPONSES TO RISK

Proceedings of a Seminar sponsored by
Southern Regional project S-~~180~~232
"Quantifying Long Run Agricultural Risks and Evaluating
Farmer Responses to Risk"
Sanibel Island, Florida
April 9 - 12, 1989

Agricultural Economics Department
Texas A&M University
College Station, Texas

July 1989

Stochastic Simulation of the Aggregate Impacts of Agricultural Policy and Technological Change[1]

C. Robert Taylor

Riskiness of agricultural production and consumption, which is attributal in large part to variable weather and its effect on crop yields and thus prices of commodities, is a crucial factor in formation of agricultural policy. Numerous theoretical studies have attempted to analytically examine the effects of various policies on risk faced by consumers and producers. Unfortunately, the class of functional forms that can be analytically manipulated to examine such risk is restriced to very simple models, or to linear models with normally distributed random variables. Since the agricultural sector is not appropriately characterized by linear behavioral equations nor by normally distributed random variables (particularly crop yields), theoretical studies give very limited insight into the effects of policies on risk in agriculture. Therefore, numerical models are required to analyze the effects of agricultural policies on risk faced by various market participants.

The purpose of this report is to present estimated effects of (a) the movement to a domestic free market in agriculture; and (b) increasing crop yield variability on risk in agriculture. Results are obtained from a stochastic version of AGSIM, which is an econometric-simulation model of regional crop and national livestock production in the United States. The deterministic version of the model was developed to analyze the

[1]Research reported herein was supported in part by a cooperative agreement with USDA/ERS/RTD, the Alabama Agricultural Experiment Station, and income from an endowment to Auburn University from ALFA/Alabama Farmers Federation. Supercomputer time was provided by the Alabama Supercomputer Center and the National Center for Supercomputer Applications at the University of Illinois. These financial contributions are gratefully acknowledged.

expected or mean aggregate economic impacts of a wide variety of issues facing agriculture, such as technological change, withdrawing pesticides, farm programs, and the conservation reserve. The stochastic version of the model is used to numerically translate a joint nonnormal probability density function (pdf) for national crop yields into probability distributions for economic variables such as net farm income, crop prices, deficiency payments, and stock levels at any point in time. Such information can be used by policy makers to assess the differential risk impacts of policies.

To make informed judgments about validity of probability distributions of economic variables, and to intrepret policy results generated by AGSIM, an understanding of the simulation model and the econometric specification of the hundreds of demand and supply equations that underlie the stochastic version of the model is essential. We now turn to presentation of specification of the econometric equations that form the foundation of the model. This is followed by presentation of the numerically obtained pdfs for net crop income, deficiency payments, and stock levels in the year 2000 that show the effects of technlogical change and movement to a free market in the United States. Finally, assessment of the state-of-the-art for such stochastic simulation is discussed.

The Structure of AGSIM

Specific documentation in this report includes: (a) the structure of the simulation model; (b) specification of the crop supply econometric model; (c) specification of the crop demand econometric model; and (d) the joint probability distribution function for national crop yields. Only the general specification of the model is discussed since presentation of the thousands of parameter estimates is beyond the scope of this paper. Individuals interested in specific parameter estimates should contact the author.

Overview of the Simulation Model

The simulation model ties together econometrically estimated demand and supply equations through maket clearing identities. Computationally, the simulation model solves for the set of crop and livestock prices that simultaneously clear all markets in a given year for given exogenous factors. Due to the dynamics of supply and demand, such market clearing prices must be obtained recursively for each future year simulated.

Figure 1 illustrates the conceptual framework for the simulation model. Consider a simulation for year t. Given prices the previous year, price and return expectations for crops and livestock are computed. Given these expectations, crop and livestock supply are computed from the econometric equations. Then, given the predetermined supply, the set of prices that simultaneously clear all markets is obtained. Due to the nonlinear nature of the demand functions, market clearing prices must be numerically obtained; Newton's procedure, which in this case is a linear approximation of the set of excess demand functions, is iteratively used to find the market clearing prices. Given the market clearing prices for year t, simulation for the next year proceeds in the above manner.

Two simulations occur in parallel (see figure 2); one of these is a benchmark, while the other is for the policy to be evaluated. All estimated economic impacts from implementation of the policy under consideration are based on a comparison of these two sets of simulation results.

Let us now turn to the econometric equations that underlie the simulation model, considering first the crop supply component. Then the crop demand and livestock components of the model are briefly discussed.

Overview of the Crop Supply Model

The crop supply component of AGSIM is based on a set of supply equations for each of the eleven regions shown in Figure 3. Crops included in the model are corn, grain sorghum, barley, oats, wheat, soybeans, cotton and hay, with cultivated summer fallow treated as another land use in semi-arid regions. Acreage idled under government programs is also treated as a competing land use in the model.

Each regional crop supply model is comprised of a set of econometric equations for: (a) the total cropland in the region for crops endogenous to the model, including cultivated summer fallow and land idled under government programs; (b) a set of share equations that give the fraction of the total acreage devoted to individual crops, to summer fallow, or idled under government programs; (c) yield equations for each crop that depends on input and crop prices, time, and (in some instances) the acreage harvested and acreage fallowed the previous year; (d) a machinery power index equation that is a proxy for non-land capital; (e) a set of equations for the participation rate in farm programs for individual crops; and (f) identities for per-acre return expectations. All equations in the model were estimated with data for the 1966-1986 time period. All costs and prices were deflated by the GNP implicit price deflator.

Econometric Specification of the Crop Supply Model

Specification of the acreage component of AGSIM as comprised of a single equation for all land endogenous to the model, and a set of equations that allocate this total to alternative uses of land, departs from the conventional approach of specifying an equation for the absolute acreage of each crop. This new specification is proposed for the following interrelated reasons: (1) It is easier to account for the asymptotic limit on cropland; (2) the competition of non-agricultural interests for cropland can be more easily modeled; (3) it may be better for incorporating long-run dynamics associated with the movement of land into and out of crop production; and (4) it facilitates evaluation of policies that exogenously increase or decrease the amount of land available for crop production (e.g. the conservation reserve). Since this specification is a unique feature of AGSIM and a feature that may explain some of the differences of AGSIM policy evauations with other models, these arguments will be considered in more detail.

First, the specification of a total acreage equation can be used to directly account for the fact that land, irrespective of the crop to which it is planted, is a quasi-fixed factor of production with an asymptotic upper limit. The conventional specification of absolute acreage of individual crops will not necessarily capture the essence of the physical constraint on land, without imposition of a complex set of cross-equation restrictions that create econometric difficulties. With the conventional approach, it is not uncommon to find econometric estimates showing that total acreage will decrease in response to an increase in the returns to a single crop. For example, increasing the returns to corn may increase corn acreage and decrease soybean acreage, but the negative (cross-price) soybean acreage effect would dominate the positive (own-price) corn acreage effect.

Specification of a functional form that will give the appropriate asymptotic upper limit to total acreage is more easily and perhaps better done using the total acreage equation approach than the conventional approach. Although asymptotic functional forms can be used for the absolute acreage of each crop, imposition of such just to get an asymptotic total acreage relationship is not necessarily appropriate.

The total acreage specification is also more amenable to accounting for the competition of non-agricultural interest for agricultural land. With the conventional specification, variables reflecting the non-agricultural demand for land must be incorporated into the equation for each crop rather than into a single equation. We expect the total acreage to be homogeneous of degree zero in all prices (agricultural and non-agricultural), but not homogeneous of degree zero with respect to all agricultural prices holding non-agricultural prices constant. It is also plausible that the set of equations for the fraction of total acreage planted to individual crops are homogeneous of degree zero in agricultural prices. Such homogeneity restrictions are more easily tested or imposed econometrically using the specification proposed here than with the conventional specification.

A third reason for the total acreage is that it is easier to econometrically consider the long-run dynamics involved in expansion and contraction of the cropland base. That is, long-run dynamic considerations are imbedded in a single equation rather than in a set of equations that should have a complex set of static and dynamic cross-equation restrictions. Equations that show the fraction of the total acreage devoted to individual crops can incorporate short-run dynamics arising from factors such as machinery complements that do make it profitable to make short-run changes in cropping patterns.

Finally, the the total acreage specification facilitates evaluation of policies that exogenously change the amount of land in crop production. The change in land in production can be added to (or subtracted from) the total acreage, with the individual acreage (share) equations used to allocate the new total acreage to individual crops based on relative profitability and other factors.

Return Expectations

Acreage and thus supply in AGSIM are driven principally by expected returns and proxies for farm programs. Assuming that land is the major quasi-fixed factor of production, alternative land uses should compete on the basis of expected per-acre returns and not on the basis of per unit price (e.g. the price of corn) per se. An expected return formulation of acreage response has the added advantage for an impact analysis model such as AGSIM in that the estimated acreage equations explicitly show how acreage varies in response to technological change that alters yield, variable costs, or nonland fixed costs (Taylor, Lacewell and Talpaz). Risk response is not explicitly incorporated into the model.

Expected per-acre returns for program crops was defined to be the maximum of lagged regional market price and target price (assuming full deficiency payments) times expected per-acre yield minus variable production costs. Individual crop acreage equations were specified to depend on expected per-acre returns over variable costs for the own-crop and major competing crops in that region, while the total acreage equation was specified to depend on per-acre returns over non-land fixed and variable costs. Fixed costs were considered in the total acreage equation but not in the individual crop acreage equations because they influence long-run acreage expansion or contraction decisions, but should not influence annual decisions about what fraction of an existing cropland base to plant to individual crops.

Because per-acre return expectations play a central role in the econometric equations comprising the crop supply component of AGSIM, it is appropriate to consider the specification of this part of the model before examining acreage response equations. Expectations of returns over variable costs for a crop was postulated to be given by the formula,

(1) $R_{irt} = MAX[P_{ir,t-1}, TP_{irt}] \cdot Y_{irt} - VC_{irt}$

where R_{irt} is expected per-acre returns over variables costs for the i^{th} crop in the r^{th} region in year t; TP_{irt} is the target price for that crop; Y_{irt} is expected yield; and VC_{irt} is the variable cost of producing that crop.

Cost Data

Variable cost data for 1986 by crop, by region and by item were obtained from the 1986 Economic Indicators of the Farm Sector Publication (USDA, 1987a). Time-series variable cost data for use in econometric estimation were constructed by backcasting the 1986 regional data under the assumption that the regional costs were proportional to US average production costs by crop. A time-series of national cost data by crop were obtained from USDA (Gallager and Green).

Nonland fixed costs were defined to be the sum of capital replacement, general farm overhead, and taxes and insurance. Fixed costs by region for the 1986 base year were obtained from budgets published in 1986 Economic Indicators of the Farm Sector. Time-series of fixed costs for use in econometric estimation were constructed by backcasting the 1986 costs on the basis of input price and quantity indices. Taxes and insurance fixed costs were based on the prices paid production index for buildings and fencing; overhead fixed costs were based on the prices paid production index for buildings and fencing; capital replacement costs were based on the combined effect of a machinery cost index and the regional (quantity) index of mechanical power and machinery. The mechnaical power and machinery index was used rather than other nonland capital item indices because it appears to be a reasonable proxy for nonland capital and because it was available on a regional basis. No costs associated with land were included in the model because land is viewed as the quasi-fixed factor of production.

Farm Program Variables

Due to frequent changes in government farm program features, there are insufficient degree of freedom to obtain precise econometric estimates of how various programs influence acreage response. In an effort to conserve degrees of freedom, the effect of program participation and set-aside rates were incorporated into acreage equations by a set of crop and region specific proxy variable defined to be the product of participation and set-aside rates. With this specification, the effect on acreage of a one percent change in the set-aside rate is equivalent into a one percent change in the participation rate. Individual acreage equations were specficied to depend on the product of participation and set-aside rates for that crop, while the total acreage equation was specified to depend on a weighted average of these individual crop composite variables. An effective diversion payment rate (Ryan and Abel) was used to model the effects of paid diversion.

Participation rates were specified to depend on expected returns based on market price, expected returns based on an effective support price (Houck and Subotnik) and effective diversion payment rate for each respective commodity program. Thus, participation in government programs in endogenized into the econometric model and thus endogenized in the simulation model.

Total Acreage Equations

Several alternative specification/estimation models of the total acreage equation were considered in developing AGSIM. Models considered include: (1) an OLS model with per-acre returns and the composite participation/set-aside variable as the primary explanatory variables; (2) the same specification estimated along with the share equations using the seemingly unrelated regression technique (SURR); (3) an Almon lag equation that focused on the relationship between acreage and lagged returns, with government program variables (other than program payments) producing only contemporaneous effects; (4) a conventional stochastic difference equation; and (5) a nonstochastic difference equation (Burt).

General specification of the total acreage equation selected after considerable exploratory analysis was,

$$(2) \qquad A_{rt} = AMAX_r \, [1 - EXP\{ - (\alpha_0 + \alpha_1 RENT_{rt} + \alpha_2 PART_{rt} \bullet SA_{rt} + \alpha_3 A_{r,t-1} + \alpha_4 A_{r,t-2})\}]$$

where A_{rt} is total acreage in region r in year t; $AMAX_r$ is the maximum historical acreage including all (program and nonprogram) idle land; $PART_{rt}$ is the weighted average participation rate for program crops; and SA_{rt} is the weighted average set-aside rate for program crops. Functional form (2) gives $AMAX_r$ as the asymptotic upper limit to total acreage.

Four definitions of composite rents, $RENT_{rt}$, in (2) were considered. One definition was the weighted average of return expectations using (1), which lets target price be a floor on the expected price used to compute expected returns. This definition of expected rent is appropriate if changes in total acreage that occur at the margin (i.e. land going out or coming into production) are eligible for deficiency payments and other farm program benefits.

A second definition of composite expected rents used lagged market prices as expected price to compute expected rents. This definition is appropriate if changes in total acreage occur on nonprogram land. A third definition used participation rates to compute an average expected rent for participants and non-participants in farm programs. This definition is appropriate if marginal changes in total acreage occur proportionally on program and nonprogram acres.

The fourth definition of rents used in (2) was lagged actual rents computed from actual prices, yields and government program payments. This definition is appropriate if entry and exit of land for crop production is based on a standard capital budgeting approach using actual rents and program payments.

The composite picture that emerged from estimating the many specifications of total acreage equations (space limitations prevent presentation of the many estimates of these equations) is that the composite program variable, $PART_n*SA_n$, was the most significant single explanatory variable for total acreage. Moreover, this variable has a positive sign, indicating that increased participation in the program or an increase in the set-aside rate would, ceteris paribus, increase total acreage. Given empirical estimates of relevant parameters, an increase in the set-aside rate would not, however, result in a net increase in planted acreage, even though total acreage would increase.

Expected rent based on lagged market price gave better statistical estimates than the other three definitions of rent in 9 of the 11 regions. In the other two regions, the lagged actual returns gave the best statistical results. However, in all cases, the rent variable was either insignificant or marginally significant at usual significance levels. Model selection critieria were not definitive about inclusion of any of the rent variables. Sign of the rent variable was highly sensitive to the set of other explanatory variables. In particular, inclusion or exclusion of a single dummy variable to presumably represent structural change, program difference or a typical year would give an implausible sign to the rent variable. The final set of equations selected had positive signs on the rent variable and the magnitude of the coefficient was subjectively judged to be acceptable.

OLS was used to estimate the final set of equations included in the simulation model. Estimation of the same specification with autoregressive least squares or with a nonstochastic difference equation approach did not give parameter estimates that led to simulation results that differed appreciably from the OLS results.

Mechanical Power and Machinery Equations

Regional indices of mechanical power and machinery were used to backcast the capital replacement component of nonland fixed costs used in computing regional rents. In the simulation model, these indices are also used to compute regional capital replacement costs; this specification of the model implies that machinery is not a limiting factor of production. Given the recent levels of machinery capitalization in agriculture, this does not appear to be unrealistic for simulated policies that do not dramatically change agricultural production.

Nonstochastic difference equations (Burt) were used to model investment because observed investment, as opposed to expected investment, can be subject to random shocks which appear to be better captured in the nonstochastic difference equation. Second-order nonstochastic diffrence equations were found to be significant in all regions. Computed actual rent including government payments was found to be a significant explanatory variable.

The final form of the nonstochastic difference equation for regional mechanical power and machinery indices is,

(3) $M_{rt} = a_0 + a_1E(M_{r,t-1}) + a_2E(M_{r,t-2}) + a_3ARENT_{rt}$

where M_{rt} is the mechnaical power and machinery index, and $ARENT_{rt}$ is actual rent in year t.

Individual Crop Acreage Response

Individual crop acreage response was modeled by a set of equations that allocate the total acreage to individual crops on the basis of expected returns for individual crops, to cultivated summer fallow, or to land idled under government programs. Land allocation is made on the basis of expected returns for individual crops, farm program variables, and other factors. Such a set of equations can be denoted in general form as,

(4) $a_{irt} = f_{ir}(Z_{irt}, \varepsilon_{irt})$

where a_{irt} is the fraction (or share) of the total acreage, A_{rt}, devoted to crop i, to summer fallow, or idled in region r in year t; Z_{irt} is a set of explanatory variables, and ε_{irt} is a random error term.

Because of the zero-one constraint on a_{irt},

(5) $0 \leq a_{irt} \leq 1$ for all i, r, and t

and the adding-up restriction that,

(6) $\sum_{i} a_{irt} = 1$,

the mathematical form of $f_{ir}(.)$ is of crucial importance not only for econometric estimation but for simulation as well.

The final mathematical form selected to model the share equations was the exponential function,

(7) $a_{irt} = 1 - EXP\{\beta_{ir0} + \sum_{j} \beta_{ijrt}R_{jrt} + \gamma_{0ir}\, a_{ir,t-1} + \gamma_{1ir}edp_{irt} + \gamma_{2ir}part_{irt}sa_{irt} + \varepsilon_{irt})\}$

where edp_{irt} is the per-acre effective diversion (not set-aside) payment rate, $part_{irt}$ is the participation rate, and sa_{irt} is the set-aside rate for crop i in region r in year t. Equations for the fraction of the total acreage in cultivated summer fallow and equations for the fraction of the total acreage idled under government programs were specified to have the same form as (7); however, returns and government program variables were weighted averages over all crops rather than individual crop variables. Other functional forms, such as the logistic, were considered but did not perform as well as exponential form (7).

The exponential form of (7) imposes an upper limit of one on the fraction of the acreage devoted to an individual crop, but does not impose a lower limit of zero nor necessarily satisfy the adding-up restriction, (6). However, the form is appealing because the dependent variable can be transformed to result in equations that are linear in parameters if Z is linear. The transformed equation is,

$$(8) \quad w_{krt} = -\log(1 - a_{krt}) = \beta_{kr0} + \sum_{j} \beta_{jkrt} R_{jrt} + \gamma_{0kr} a_{kr,t-1} + \gamma_1 edp_{krt} + \gamma_2 part_{krt} sa_{krt} + \varepsilon_{krt}$$

The set of all equations for all crops, summer fallow, and idled acreage in each region was estimated by SURR to account for plausible correlation of the errors, ε_{krt}.

From a theoretical standpoint, transformed dependent variables for the set of equations in (8) do not have to sum to a particular value to satisfy the adding-up restriction, (6); however, there is a theoretical lower (but no finite upper) limit on w_{krt}. For practical reasons, the theoretical lower limit on the sum of the dependent variables was ignored in econometric estimation. Possible ways to incorporate this restriction into estimation are: (1) specify an error structure for the system of equations and use maximum likelihood estimation; (2) specify a multinomial probit model for the set of share equations; or (3) delete one equation from estimation, as is done when the dependent variables in a system sum to a constant (Theil, pp. 335-6). A complex error structure and maximum likelihood estimation are not practical with so many sets of equations that are repeatedly estimated as the model is updated or improved over time. Likewise, a multinomial probit model applied to share equations is not practical and may be further hampered by the implicit restrictions that would be imposed on cross-crop relationships with such a model.

Deleting the equation for a single crop is feasible with the set of equations given by (8) estimated by SURR. With the set of commodities modeled with AGSIM, hay is a "natural" crop to delete. In this case, the computed share for the deleted crop would be obtained as one minus the sum of the shares for the other crops.

Simulation of the system based on SURR estimates of share equations with hay deleted revealed that simulated hay acreage varied wildly from year-to-year, yet actual hay acreage has been very stable for many years. Deleting any other crops would produce similar simulation results for that crop. Therefore, deletion of a single crop from the system, which is correct in econometric theory, produced implausible simulation results. Consequently, the complete set of share equations was estimated with SURR.

Although econometric estimates of the full set of equations may be slightly biased from an econometric theory viewpoint, they produce more plausible results than the practical alternatives. Nevertheless, shares computed from econometric equations do not necessarily sum exactly to one. To insure that the shares do sum to one in the simulation model, errors in computed shares are proportionally distributed across all crops in the model.

Symmetry and Homogeneity

Microeconomic theory based on the classical static, determinstic profit maximization model shows a symmetry of cross-price (or return) effects in supply equations for competing crops. Although such symmetry may not hold because of uncertainty (Pope), because of dynamic factors (Taylor, 1984b), or because of aggregation, it nevertheless behooves consideration in the context of aggregate acreage response functions.

Expressed in terms of per-acre returns, symmetry implies,

$$(9) \quad \frac{\partial a_{it}}{\partial R_{jt}} = \frac{\partial a_{jt}}{\partial R_{it}} \quad \text{for } i \neq j$$

Given functional form (7), symmetry condition (9) can be expressed as,

(10) $(1 - a_{irt})\beta_{irj} = (1 - a_{jrt})\beta_{jri}$ for $i \neq j$

Imposition of restriction (10) with system (8) would lead to nonlinear system estimation because (10) is nonlinear in parameters due to the dependence of the acreage fraction, a_{irt} on the parameter set, β. To avoid nonlinear estimation, (10) was approximated around mean acreages to give the restiction,

(11) $(1 - \bar{a}_{irt})\beta_{irj} = (1 - \bar{a}_{jrt})\beta_{jri}$ for $i \neq j$

where $\bar{a}$ denotes mean acreage over the observation period.

Microeconomic theory also suggests that acreage share equations should be homogeneous of degree zero in returns. Whether the functions should be homogeneous only in terms of nominal returns or real returns as well is a moot issue. Since all value figures in the econometric model are expressed in real terms, the set of equations given by (7) or (8) is automatically homogeneous of degree zero in all **nominal** (agricultural as well as nonagricultural) returns or prices. However, with the particular specification used for AGSIM, combining symmetry, (9), with the adding-up restriction, (6), it can be shown that (7) or (8) should also be homogeneous of degree zero in **real** returns as well. To show this, consider the partial derivative of the adding-up restriction, (6), with respect to the returns, R_{irt}, which gives

(12) $$\sum_j \frac{\partial a_{jrt}}{\partial R_{irt}} = 0$$

Note, however, that substitution of symmetry conditions into (10) gives,

$$(13)\quad \sum_j \frac{\partial a_{jrt}}{\partial R_{jrt}} = \sum_j (1 - a_{irt})\beta_{irj} = (1 - a_{irt})\sum_j \beta_{irj} = 0$$

which implies that $\sum_j \beta_{irj} = 0$ and thus that the acreage share equations should also be homogeneous of degree zero in real returns.

The practical implication of the homogeneity restrictions combined with the symmetry restrictions is that a proportional change in all **real** agricultural returns in (7) or (8) does not change the relative proportions of the individual crops. However, the **total acreage** equation is not required to be homogeneous of degree zero in all prices and returns. Thus, a proportional change in all **agricultural** returns holding other prices in the economy constant will change total acreage and thus the absolute acreage of individual crops.

Approximate symmetry given by (11) and homogeneity given by (13) were tested individually and in groups in each region in an earlier version of the model. The picture that emerged from massive testing is that there is a very high probability that symmetry holds for all regions. Tests of zero degree homogeneity in real returns gave a much more mixed picture but a composite of the many tests suggests that the hypothesis cannot easily be rejected. Thus, approximate symmetry was imposed for cases in the model; homogeneity of degree zero in real returns was also imposed for all share equations except for individual crops in a few regions where econometric analysis did not reveal viable competing crops. Homogeneity of degree zero in nominal returns was imposed throughout the model.

Expected Crop Yield Equations

Expected (as opposed to actual) yield equations were specified to be a function of the ratio of an input price index to the maximum of lagged market price and target price. A chemcial price index was used for cotton and soybeans, and a fertilizer price index was used for the other crops in the model.

The functional form used was,

$$(14) \quad Y_{kt} = a_0 + a_1 t + a_2(PF_t/MAX(P_{k,t-1},TP_{kt}))^2$$

where PF_t is the input price index previously referenced. Functional form (14) is consistent with a quadratic production function, but because of potential aggregation biases the regional yield equations should be intrepreted only as aggregate behavioral relationships.

A linear time trend variable was also included as a proxy for technological change. To allow for the effect of marginal land on average crop yield, the absolute acreage planted of that crop was considered as an explanatory variable; in semi-arid areas, the absolute acreage placed in cultivated summer fallow the previous year was also considered as an explanatory variable to reflect the positive contribution of fallow to average crop yield. Acreage variables had meaningful coefficients only in the two plains regions. Crop and region specific dummy variables were included in (14) to account for years with unusually high or low yields.

Crop Yield Deviates

The set of equations given by (14) are used to compute expected yield that influences acreage response and thus supply. In the stochastic version of AGSIM, actual yield (as opposed to expected yield) in a particular simulation was taken as a deviation about the expected yield equations, (14). Departures from expected yield do not directly influence acreage response in that crop year, but they do influence actual production and thus price and acreage the next crop year.

Crop yield deviates for use in stochastic simulation were obtained from a nonnormal joint probability distribution for national crop yields. Although the supply component of the model is regionalized, compuational considerations dictated use of national rather than regional crop yield deviates. With eight jointly distributed random variables, at least 500 simulations (each for 15 years) are needed to to get a "smooth" characterization of the probability distribution of economic variables. Making regional crop yields stochastic would likely require several thousand simulations to get a meaningful characterization of the probability distribution of economic variables, which is beyond the projects computational budget.

The empirical nonnormal joint pdf for national crop yields was fitted using a normal transformation approach outlined in Taylor (1990). Briefly, the procedure empirically fits marginal distributions using an hyperbolic tangent transformation of a cubic function (Taylor, 1984a). Estimated marginal distributions are then used to transform variates to univariate normality; the transformed variates are assumed to have a multivariate normal distribution.

Data used for empirically fitting the crop yield pdf were constructed by detrending raw yield data to reflect current technlogy. Since the absolute variance of most crop yields has been increasing over time (inspect figure 4), in was also necessary to adjust the varinace of the detrended data for current technology. To correct the yield time-trend deviations for heteroscedasticity, weighted least squares was used, where the weights were computed from regressions of the absolute value of trend line deviations on time.

Empirically fitted marginal distributions are shown in figure 5. Parameter estimates and additional information on estimates of the crop yield pdfs are given in

Taylor, 1987. The manner in which deviates for the simulation model were generated from the fitted nonnormal joint pdf is outlined in Taylor, 1990.

Participation Rate Equations

Regional participation in government farm programs was endogenized into the econometric model and thus the simulation model with a set of equations that show the participation rate as a function of economic and program variables. This set of equations was specified to have the form,

(15) $part_{irt} = 1 - EXP\{ -(c_0 + c_1RM_{irt} + c_2RTP_{irt}(1 - SA_{irt}) + c_3edp_{irt})\}$

where $part_{irt}$ is the participation rate in the program for crop i in region r in year t; RM_{irt} is expected returns based on lagged market price; RTP_{irt} is expected returns based on target price; SA_{irt} is set-aside rate; and edp_{irt} is effective diversion payment rate. Returns based on target price reduced for the set-aside requirement is a parsimonious way of showing the impacts of both target price and set-aside requirements on participation, and as such is conceptually similar to the notion of an effective support price proposed by Houck and Subotnik.

Expected signs are negative for c_1 and positive for c_2 and c_3. No restrictions on individual coefficients were made. Crop specific dummy variables for selected years were included in (15) to account for program features not captured by other explanatory variables. The set of participation equations for all crops in a region were estimated by SURR.

Implied Supply Equation

Short-run partial equilibrium supply equations implied by the above specification of variables and functional forms for the equations that comprise the supply component of

AGSIM are illustrated in Figure 6 for corn in the Corn Belt; shown are: (a) the supply equation with a free market; and (b) the supply equation occuring with a target price of \$3.03/bu. with full deficiency payment and a 15 percent set-aside rate. The program supply curve approaches the free market supply curve because participation in the program decreases as market price increases, as illustrated by the partial-equilibrium corn program participation equation in Figure 7.

At very low market prices, the target price and deficiency payment program keeps land in production; thus, the program supply curve intersects the free market supply curve at low prices (figure 6). Increasing the set-aside rate shifts the program supply curve in figure 6 upward.

Short-run own-prices regional supply elasticities are given in Table 1. Elasticities shown in this Table represent the total of direct and indirect impacts. Direct effects occur through the share equations and the total acreage equations, while indirect effects result from induced participation rate changes and yield effects. Acreage shares for other crops in the region were not held constant; thus, elasticities in Table 1 are based on a general rather than partial equilibrium concept. All elasticities shown in Table 1 were evaluated at 1990 simulated levels of relevant endogenous variables from the baseline scenario discussed in a later section of this report.

General equilibrium long-run and short-run own-price supply elasticities for the U.S. are given in Table 2. Like the regional elasticities in Table 1, these elasticities represent the net of direct and indirect effects. Long-run elasticities were numerically computed by proportionally increasing (by one percent) the price of a single crop in all future periods, then calculating production from the full set of supply equations. Future supply so obtained was subtracted from supply for the same future year in the baseline run of the simulation model to obtain the change in production associated with the price increase. The model was simulated long enough (10 years) for essentially all dynamic adjustments to the higher prices to be reflected in the change in production. This numerical process was repeated for each crop price incremented singly to obtain the estimates in Table 2. Due to the nature of the asymptotic acreage specification used for AGSIM, elasticities decrease as price increses.

Specification of the Crop Demand Model

Commodities included in the crop demand sector are corn, grain sorghum, barley, oats, wheat, soybeans, cotton lint and cottonseed, hay, and cottonseed and soybean meal and oil. Demands were broken up into nine blocks as follows: Cotton lint, hay, grain export, grain stocks, food, feed, oilseed crushings, oilseed exports, and oilseed stocks. All demand functions are in log-linear form, and are homogeneous of degree zero in nominal prices and income. Symmetry of cross-price effects was imposed on the demand functions within a block. Blocks of demand functions were estimated with SURR.

Estimates of short-run and long-run elasticities of net export demand are given in Table 3. Additional details on the crop demand component of the model are given in Eales.

Specification of the Livestock Component

The livestock component of AGSIM is comprised of national level production and inverse demand equations for beef, veal, milk, pork and chickens. Prices at the farm and retail level are endogenized with a system of margin or farm price relationships. Details on the livestock component of AGSIM are given in a report by Frank.

Linkages of Crop and Livestock Models

The livestock component of AGSIM is linked to the crop component of the model because feed costs are explanatory variables in the livestock supply model. Similarly, the crop component of AGSIM is linked to the livestock model because a livestock price index is an explanatory variable in the domestic feed demand equations. In the simulation model, the set of crop and livestock prices that simultaneously clear all crop and all livestock markets is obtained in each year of the simulation period.

Model Selection Criteria

Econometric model building on the basis of aggregate time-series data is an old and murky problem, especially with nonnested hypothesis (Judge, et al., Ch. 21), which is the case here. Analysts are faced with many sets and subsets of explanatory variables, functional forms, and estimation techniques, all of which may be equally plausible a priori. Furthermore, nonnested model selection problems are magnified when working with hundreds of equations, as is the case with AGSIM. Not only is it impractical to compute values for each of the many single equation model selection tests that have been proposed, there is the problem of deciding how to block subsets of equations in order to impose theoretical restrictions such as homogeneity and symmetry, and to obtain parameter estimates with desirable statistical properties such as efficiency and unbiasedness where errors may be correlated or where there may be simultaneity in endogenous variables. Thus, model selection with the large number of equations required in AGSIM can be seen to be far from concrete.

In converging on the final estimates given in this report, traditional statistical tests were used to the extent possible. However, there are some equations that include statistically insignificant explanatory variables that were left in the model because they appeared to have the correct sign and magnitude, or because their inclusion gave estimates of parameters associated with other critical vaiables that also appeared to have the correct sign and magnitude.

The final step in model selection and verification consisted of simulating the full set of demand and supply equations. This simulation often revealed nonsensical results that were not apparent from inspecting classical statistics, or from inspecting individual regression coefficients, or from inspecting the theoretical properties of certain functional forms. When nonsensical simulation results were found, an effort was made to trace the problem to individual equations or sets of equations. Then reestimated equations based on a different set of explanatory variables, or a different functional form, or a different estimation technique were simulated. Thus, construction of the present version of AGSIM was based on an interative process between simulation and econometric estimation.

Development and validation of a large-scale econometric simulation poses a fundamental problem in resource allocation. Resources for development and validation are restricted, often severely so. At one extreme, the developer can devote all resources to model developement and none to model validation. At the other extrement, the developer can devote most of the resources to validation and few to model development and refinement. The first approach results in a model of qeustionable validity, while the second approach leads to a narrowly defined model for which there are many validation statistics. Thus, development of a large-scale model can be seen to involve singificant compromises between validation and consideration of alternative specifications of the model.

Econometric equations reported in this and companion reports should therefore be viewed as the outcome of a somewhat subjective blend of conventional econometric model selection, a priori beliefs imposed on the model by the developers, and simulation as a means of validation. Even though the computer output from the model is in black and white and may thus appear objective, it should be remembered that the underlying model and thus the model results were influenced by the quasi-subjective process outlined above.

Scenarios Simulated and Critical Assumptions

Effects of four scenarios that were evaluated with the stochastic version of AGSIM are reported: (1) a baseline that assumes continuation of the 1985 Farm Act with target prices held at their real 1990 levels; (2) target prices ten percent above the baseline; (3) elimination of the ARP program ; and (4) current expected crop yields, but variability of crop yields assumed to be that over the 1945-65 period. The latter scenario illustrates the effects of technological change and input changes on risk in agriculture, while holding other variables at their current rather than past levels. Other scenarios show the effects of farm programs on risk. Together the secenarios demonstrate how much risk in agriculture has increased in the last two decades.

Full implementation of a 45 million acre conservation reserve by 1990 was assumed for the baseline and all other scenarios. Total acreage available for production of the endogenous crops (corn, sorghum, barley, oats, wheat, soybeans, cotton and hay) in AGSIM was reduced by 40.8 million acre, with the remaining 4.2 million acres coming from crops exogenous to the model. Acreage reduction program (ARP) regional base acreage of individual crops endogenous to the model was reduced by a total of 27.9 million acres, which is in the same proportions as base reduction in CRP signups 1-5.

Nominal target prices specified in current legislation were used through the 1990 crop year. Real target prices were reduced by four percent to account for inflation through 1990. Real target prices for 1991-2000 were assumed to be at 1990 levels. Full deficiency payments were made to participating producers for all years simulated. Set-aside rates for all program commodities for 1990 and beyond were made a function of beginning stocks; set-aside rates varied from zero with very low stocks to the maximum permitted in current legislation with high stock levels. The relationships between stock levels and set-aside rates were subjectively specified to reflect the intent of current farm legislation.

Trend-line crop yields were assumed for all years, including 1988; however, the variability of crop yields was held constant for the period simulated. Actual data for all endogenous variables through 1986 were used to parameterize and initialize the model; years 1987 through 2000 were simulated.

Simulated effects of the unilateral free trade scenario were based on the assumption that all agricultural programs in the United States would be eliminated, except for the CRP, ethanol tax subsidies and irrigation subsidies. Agricultural programs in all other countries were assumed to remain unchanged.

A disgression on evaluating free trade

Evaluation of the unilateral free trade scenario was based wholly on econometric supply relationships estimated with observations over the 1966-86 time period. Farm program legislation aimed at reducing down-side income risk was in effect throughout this observation period, and farm program payments were significant in most of these years. The question thus arises as to whether farmers would alter their supply behavior when faced with additional down-side risk. If they would, validity of estimates of unilateral free trade based on AGSIM (or any other econometric-simulation model) is in doubt.

Cursory insight into the risk/expectations issue might be gained with the aid of figure 8 which compares total acreage (planted plus land idled under government programs) with per-acre returns including ARP and PIK payments in the United States.

Even though returns have generally declined for over ten years, total acreage in the United States (and in all regions except for the southeast) has continued to rise, yet we expect a positive relationship between acreage and lagged returns.

Of course, econometric theory indicates that such a naive comparison can be misleading because there could be other variables which would explain the paradoxical (or simple correlation) result implied by figure 8. However, consideration of rather long distributed lags and other potential explanatory variables does not shed much light on this paradox.

A plausible explanation of the paradox is that acreage increases during the 1980s could be due in large part to increasing expectations that the government would "bail-out" producers during low income years. Since we do not have direct observations on expectations, or even have indirect observations suitable for definitive analysis with aggregate time-series data, we are unfortunately left to speculate on the supply effects of risk expectations.

If recent increases in acreage are due to reduction of down-side risk under current farm programs as implemented, then we could expect a ceteris paribus gradual decrease in acreage if domestic farm programs were definitively eliminated. This being the case, expected (or average) farm income might increase more under unilateral free trade than indicated by the econometric-simulation results.

Results

Histograms for net crop income in the United States for the year 2000 for the four scenarios are shown in the panels of figure 9. Since most of the lags in adjustments in the agricultural sector have been manifested by the year 2000, the histograms in figure 9 can, for all practical purposes, be viewed as "unconditional" probabilities; that is, the probabilities do not dependon initial conditions specified for the simulation model.

Because of classical identification problems, it is not possible to isolate causes of changes in risk income using histograms constructed from actual time-series data for two different time periods. The stochastic simulation model results, however, allow us to isolate contribution of individual factors to increasing risk. Panel (a) of figure 10 shows income risk with crop yield variation at earlier levels, but all other variables at their current levels. Panel (b) can be loosely viewed as showning income risk with target prices at moderately high levels during the late-1980s, while panel (c) shows a low target price scenario based on actual target prices for 1990 assumed for all future years. Finally, panel (d) shows income risk with unilateral free trade. Moving from panel (a) to panel (b) to panel (c) to panel (d) we can thus loosely trace out the effects of increasing yield variability and the phasing out of farm programs. It is interesting to note that the net income distribution goes from a traditional bell shape (panel a or b) to more of a uniform distribution with a free market (panel d).

Variability of crop prices, which along with acreage changes largely determine the variability of crop income, is illustrated in figure 10 by the corn price historgrams. Price histograms for other major commodities show the same relative effects for the four scenarios; however, soybean price is more variable and wheat price less variable than corn price.

Figure 11 shows ARP payment histograms for the three scenarios that assume such a program. As can be seen, the variability of ARP payments is quite high with current crop yield variability. Furthermore, the probability of various levels of ARP payments approaches uniformity over a fairly wide range. Figures 9, 10, and 11 highlight how farm programs socialize risk (i.e. transfer risk to the government and thus to taxpayers) in agriculture.

Figure 12 shows histograms for the acreage equivalent of stocks, which is defined to the stock beginning stock levels for a crop divided by per-acre yield of that crop, summed over all major crops. The acreage equivalent of stocks is a convenient way to summarize stock levels for all agricultural commodities. Surprisingly, neither farm programs or crop yield variability has much of an effect on the variability of stocks, although by comparing panels (a), (b), and (c) in Figure 12 it can be seen that a movement from moderately high target prices to low target prices to a free market reduces somewhat the mean level of stocks. Levels of individual stocks, however, can fluctuate more under a free market even though total stocks will not. Therefore, a movement to a free market will increase chances of critically low stocks.

Concluding Remarks

Since crop supply is regionalized in AGSIM, regional rather than national crop yields should be ideally treated as stochastic variables in the simulation model. However, regionalizing stochastic crop yields would result in 75 jointly dependent random variables. Adding other important stochastic variables such as exchange rates, interest rates, farm program parameters, or any of the error terms in econometric equations would easily lead to over one hundred jointly distributed random variables in the model. Stochastic simulation with such a large number of random variables would require tens and perhaps hundreds of thousands of simulations to get a reasonably smooth representation of the probability distributions of economic variables of interest. Such simulation would take a several hours of computational time on an existing supercomputer. Because a stochastic simulation model with more random variables would be computationally quite expensive at the present time, usefulness of probability distributions for economic variables as input into the policy making process should be carefully assessed before more complex stochastic simulation models are operationalized.

REFERENCES

Burt, O. R. Nonstochastic Difference Equations, Distribution Lags, and Agricultural Supply, Department of Agricultural Economics, Montana State University, Staff Paper 78-9, 1978.

Eales, James. AGSIM: The Grain and Oilseed Demand Model, University of Illinois, Department of Agricultural Economics, Staff Paper No. 87 E-392, July, 1987.

Frank, M. D. An Econometric Model of the U.S. Livestock Sector, University of Illinois, Department of Agricultural Economics, Staff Paper No. 87 E-395, August, 1987.

Gallagher, P. and R. G. Green. A Cropland Use Model: Theory and Suggestions for Estimating Planted Acreage Response. NED, ERS, USDA. ERS Staff Report No. AGES 840410, November, 1984.

Houck, J. P. and A. Subotnik. "The U.S. Supply of Soybeans: Regional Acreage Functions." Agricultural Economics Research. 21(1969): 99-108.

Judge, C. G., W. E. Griffiths, R. C. Hill, H. Lutkepehl, and T. L. Lee. The Theory and Practice of Econometrics. New York: John Wiley and Sons, 2nd Edition, 1985.

Pope, R. D. "Expected Profit, Price Change, and Risk Aversion." American Journal of Agricultural Economics. 64(1982): 581-4.

Ryan, M. E. and M. E. Abel. "Corn Acreage Response and the Set-Aside Program." Agricultural Economic Research. 24(1972): 102-12.

Taylor, C. R. "A Flexible Method for Empirically Estimating Probability Functions." Western Journal of Agricultural Economics. 9(1984a): 66-76.

Taylor, C. R. AGSIM: U.S. Crop Yield Probability Functions for the Stochastic Simulation Model. University of Illinois, Department of Agricultural Economics, Staff Paper No. 87 E-387, July, 1987b.

Taylor, C. R. "Stochastic Dynamic Duality: Theory and Empirical Applicability." American Journal of Agricultural Economics. 66(1984b): 351-7.

Taylor. C. R. "Two Practical Procedures for Estimating Multivariate Nonnormal Probability Density Functions." American Journal of Agricultural Economics. February, 1990 (forthcoming).

Taylor, C. R., R. D. Lacewell, and H. Talpaz. "Use of Extraneous Information with the Econometric Model to Evaluate Impacts of Pesticide Withdrawals." Western Journal of Agricultural Economics. 4(1979): 1-8.

Theil, H. Principles of Econometrics, John-Wiley and Sons, Inc., 1971.

USDA, Economic Indicators of the Farm Sector: Costs of Production, 1986. Washington, D.C.; U. S. Government Printing Office, 1987a.

USDA, Economic Indicators of the Farm Sector: Production and Efficiency Statistics, 1986. Washington, D.C.; U. S. Government Printing Office, 1987b.

Table 1. Short-Run Own-Price Regional Supply Elasticities Evaluated at 1990 Simulated Levels of Endogenous Variables

	REGION										
Crop	Alabama	Corn Belt	Lake States	Northern Plains	Southern Plains	Delta	Mountain	Pacific States	North-east	Appalachian	South-east
Corn	1.56	0.20	0.46	0.77	0.30	0.10	0.65	0.01	0.06	0.12	0.47
Grain	0.24	0.68	0.00	0.55	0.55	0.27	0.00	2.57	0.00	0.97	0.17
Barley	0.00	0.00	0.13	0.17	0.00	0.00	0.48	0.02	0.19	4.87	0.30
Oats	0.15	0.46	0.61	0.04	0.03	0.00	0.30	0.01	0.15	0.00	0.37
Wheat	0.85	0.41	0.29	0.11	0.28	0.61	0.13	0.07	0.64	0.19	0.44
Soybeans	0.79	0.14	0.38	0.07	0.40	0.41	0.00	0.00	0.28	0.50	0.71
Cotton	2.02	1.47	0.00	0.00	0.82	2.42	0.47	0.09	0.00	0.71	0.38
All hay	0.13	0.07	0.06	0.13	0.12	0.15	0.15	0.05	0.07	0.04	0.13

Table 2. U. S. Crop Supply Elasticities

Crop	General equilibrium own-price supply elasticities	
	Short-run	Long-run
Corn	0.35	0.40
Sorghum	0.56	0.88
Barley	0.24	0.39
Oats	0.31	0.49
Wheat	0.20	0.33
Soybeans	0.22	0.47
Cotton	0.84	1.61
All hay	0.09	0.18

Table 3. Elasticities of Net Export Demand in AGSIM

Commodity	Short-run own-price elasticity	Long-run own-price elasticity
Cotton lint	-1.3392	-1.3392
Corn	-1.0376	-1.2038
Sorghum	-1.5628	-1.8646
Barley	-0.5627	-0.7106
Oats	-0.4750	-3.9256
Wheat	-0.2473	-0.4042
Soybeans	-0.6143	-2.4964

Figure 1: AGSIM: Conceptual Framework for the Simulation Model

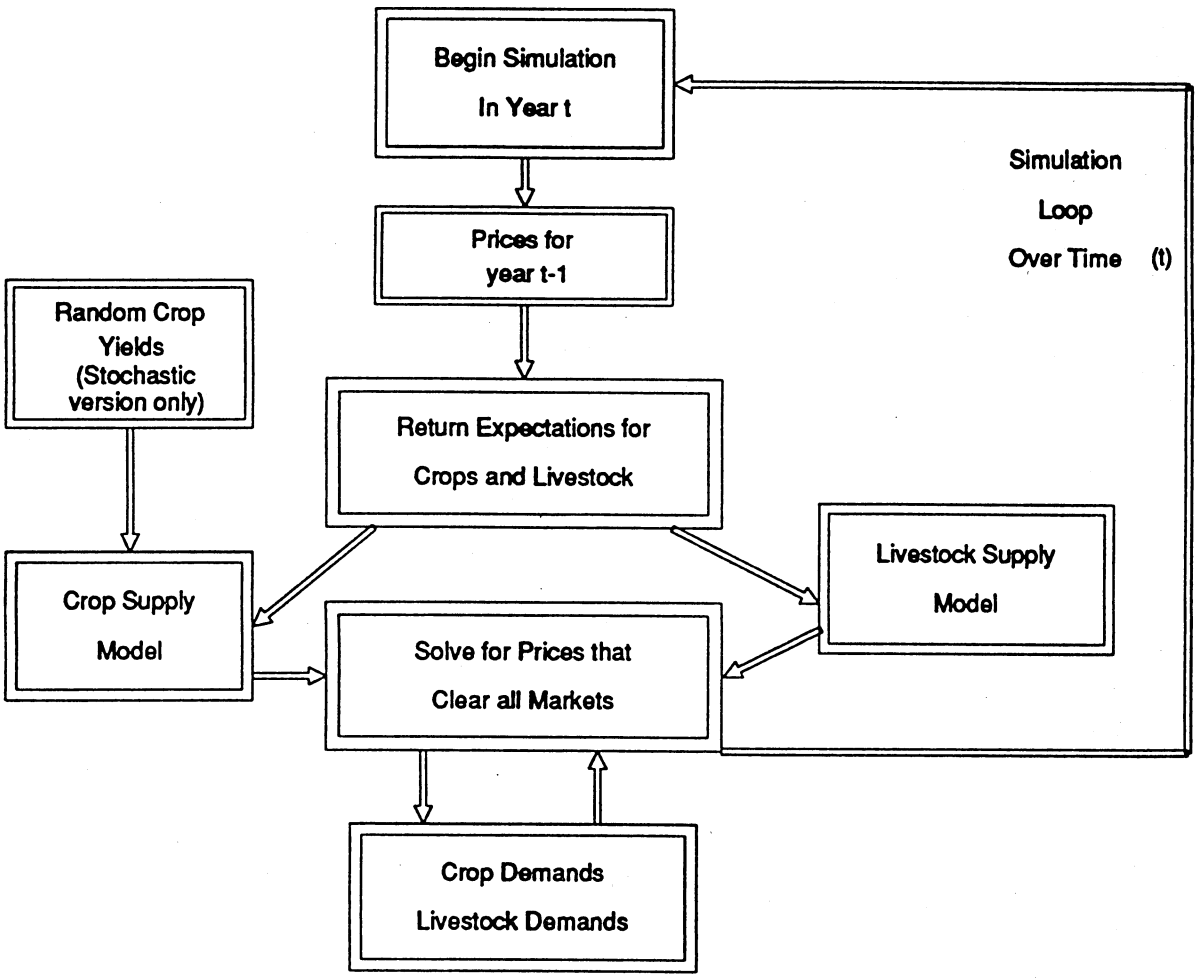


Figure 2: Framework for Economic Impact Estimates

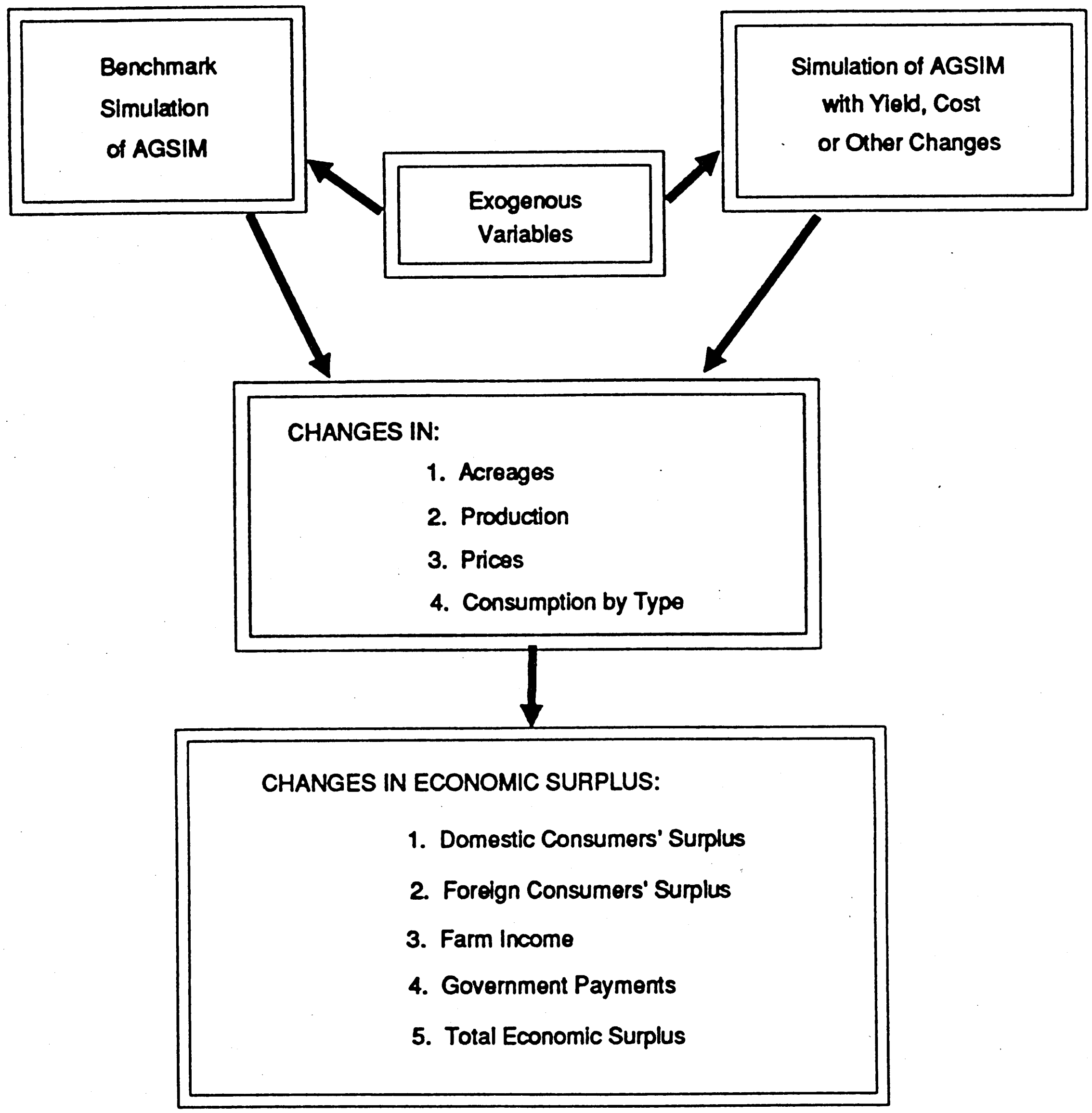


Figure 3. Regional Delineation for the Crop Supply Component of AGSIM

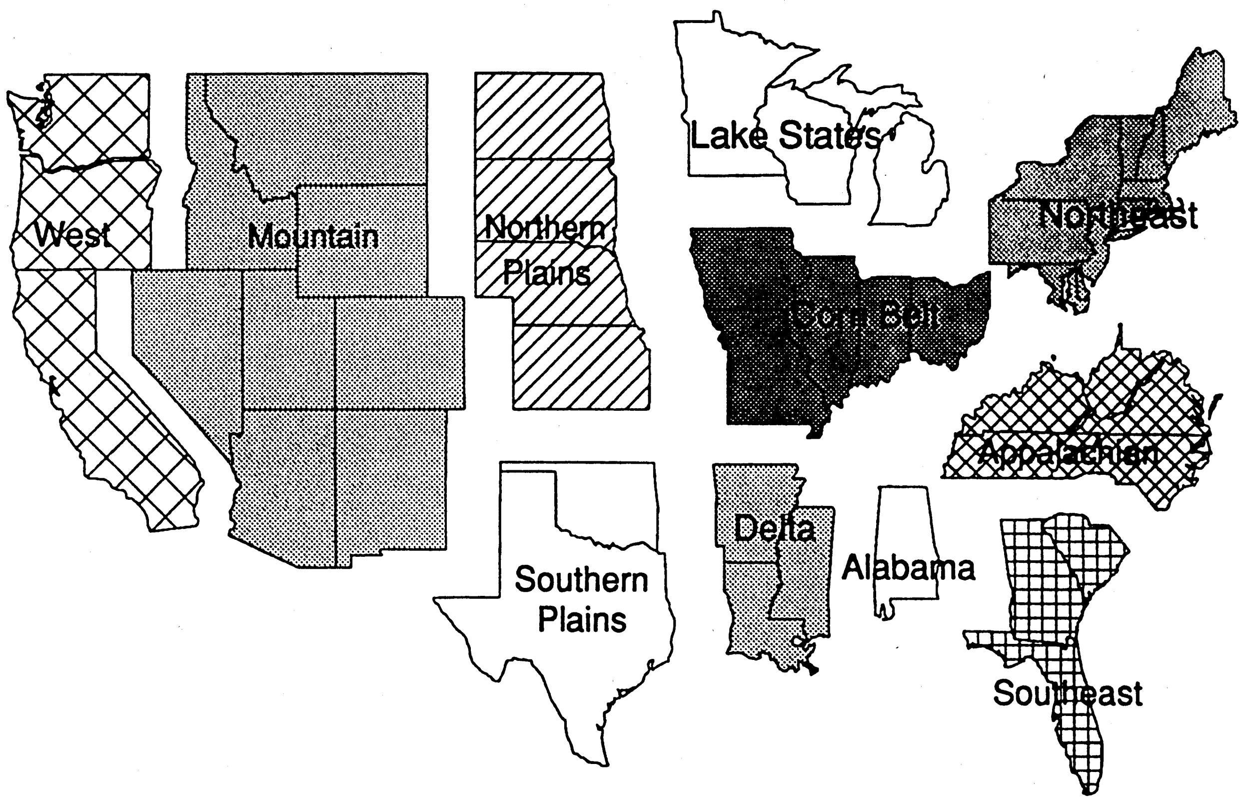


Figure 4. United States Crop Yields, 1930-88.

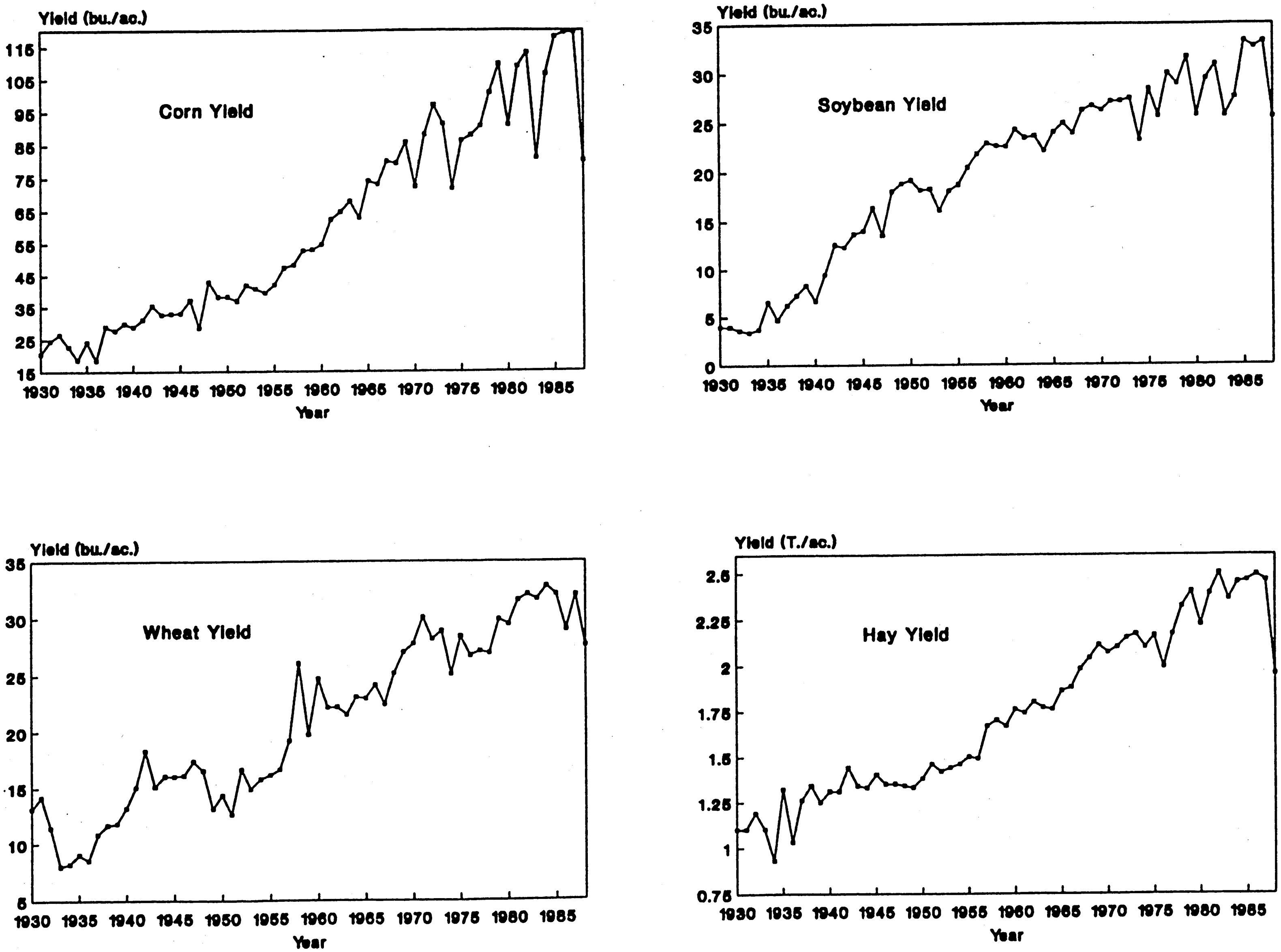


Figure 5. Marginal Probability Density Functions for Yield.

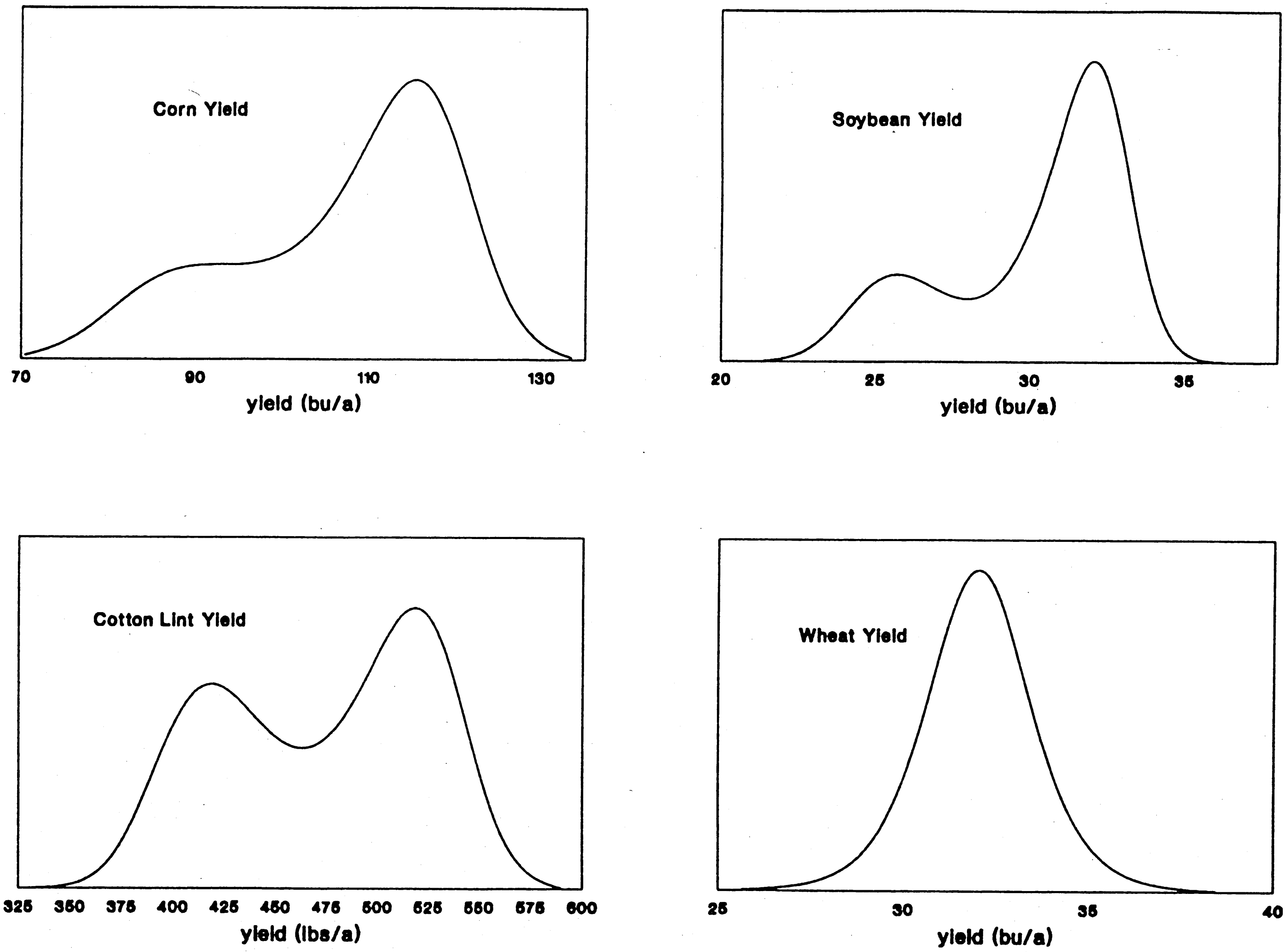


Figure 5. (continued)

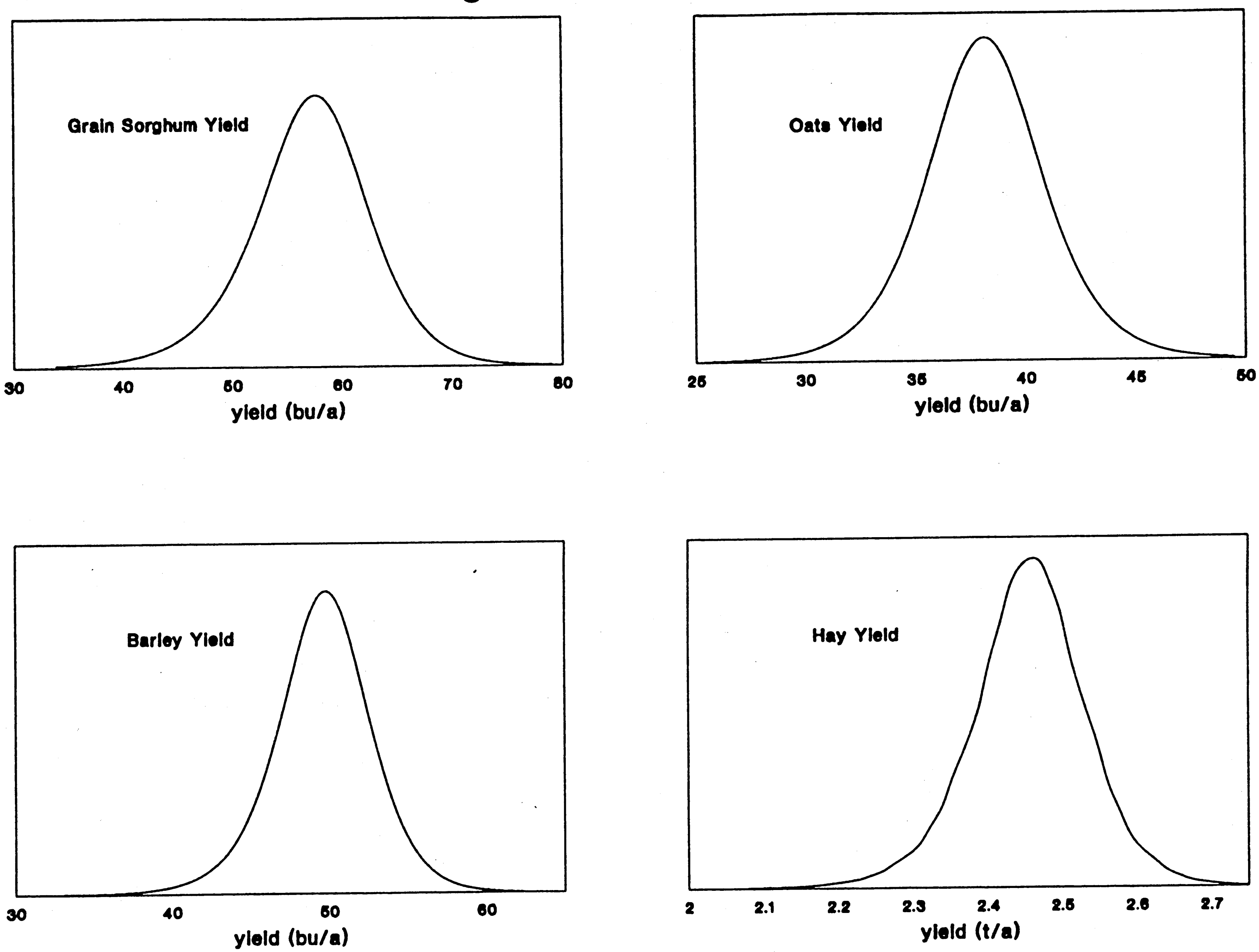
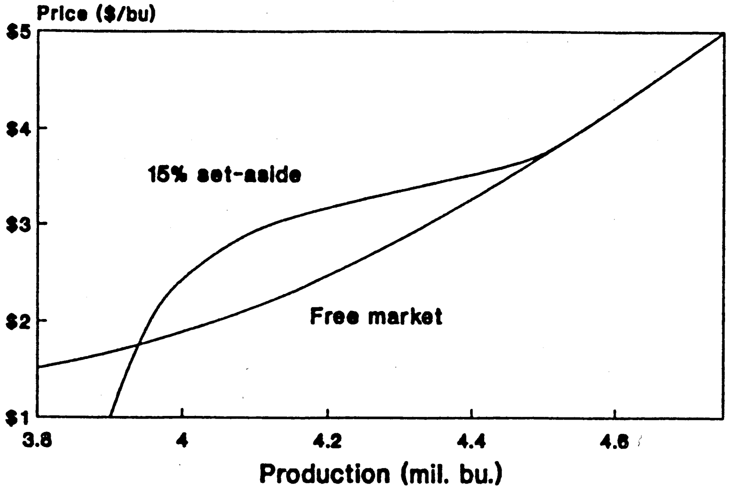
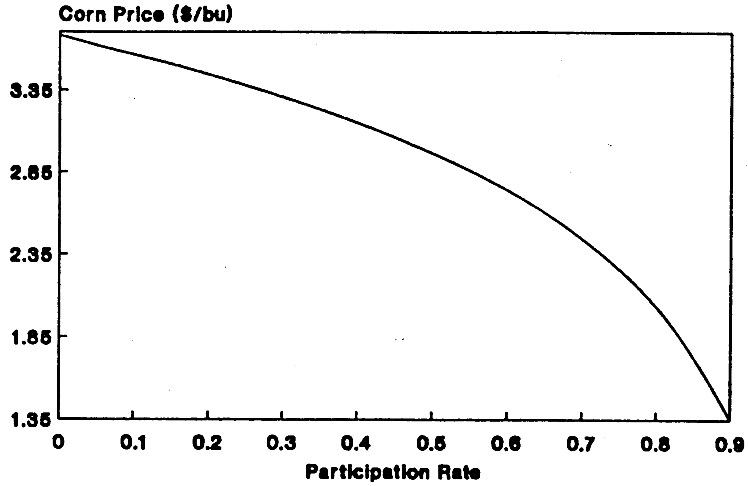


Figure 6: Corn Belt Corn Supply Curve
Free market vs 15% set-aside rate



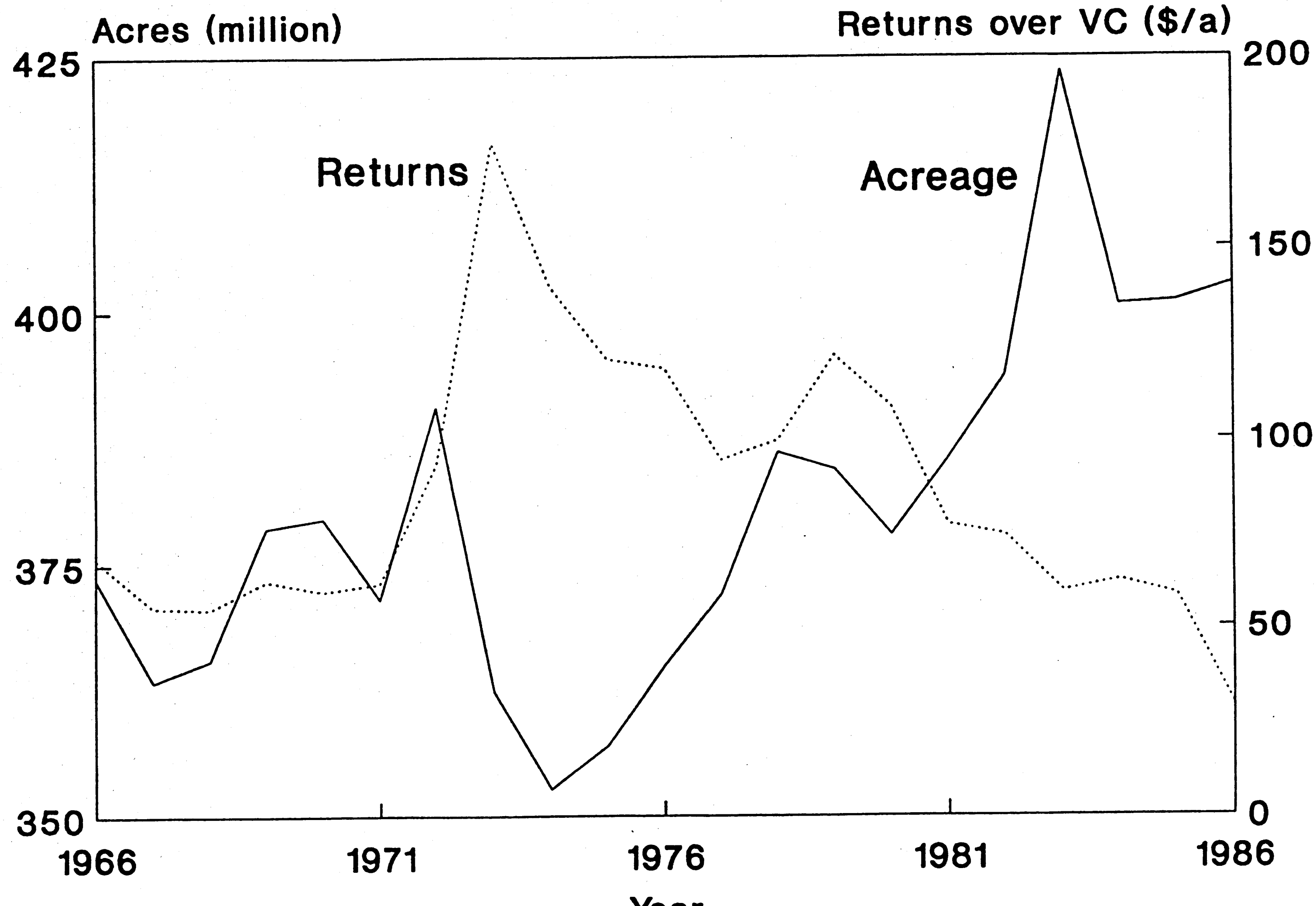
TP is $3.03 with full deficiency payment

Figure 7: Participation Rate in the corn program as related to price



TP is $3.03 and set-aside rate is 15%

Figure 8. Total Acreage Compared to Per-Acre Returns



Returns include farm program payments

Figure 9. Net Crop Income Histograms for the year 2000.

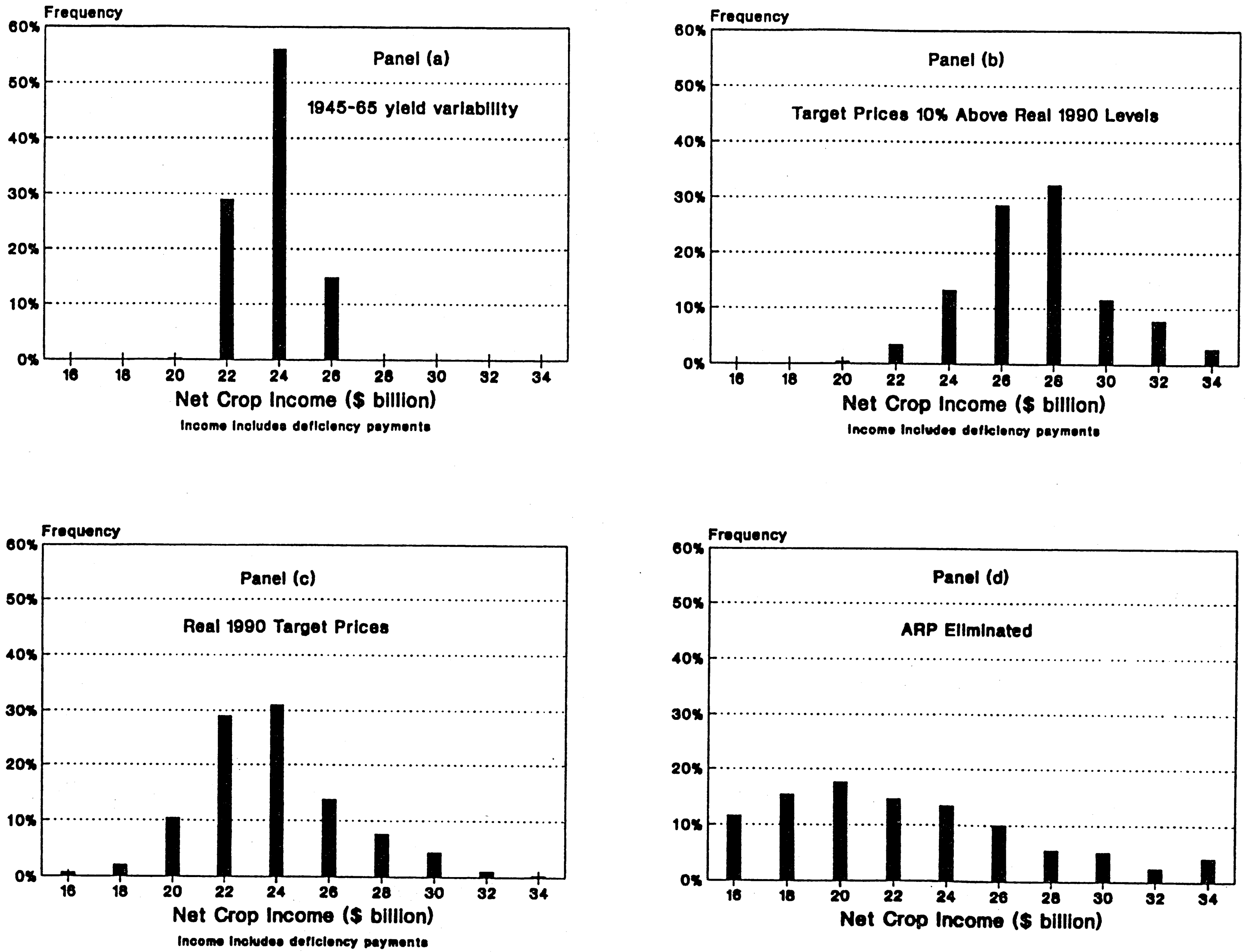


Figure 10. Corn Price Histograms in the Year 2000.

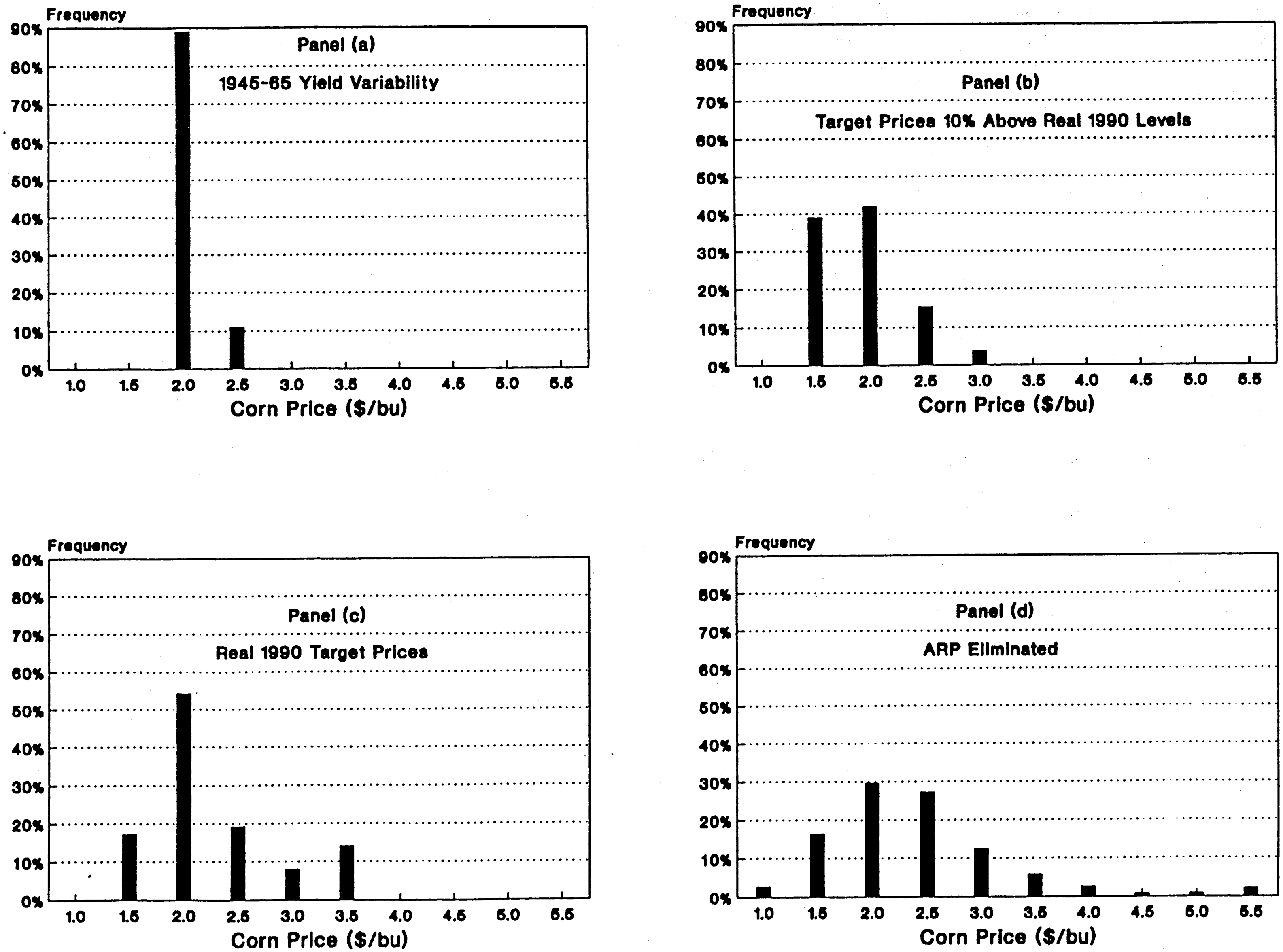


Figure 11. ARP Payment Histograms for the Year 2000.

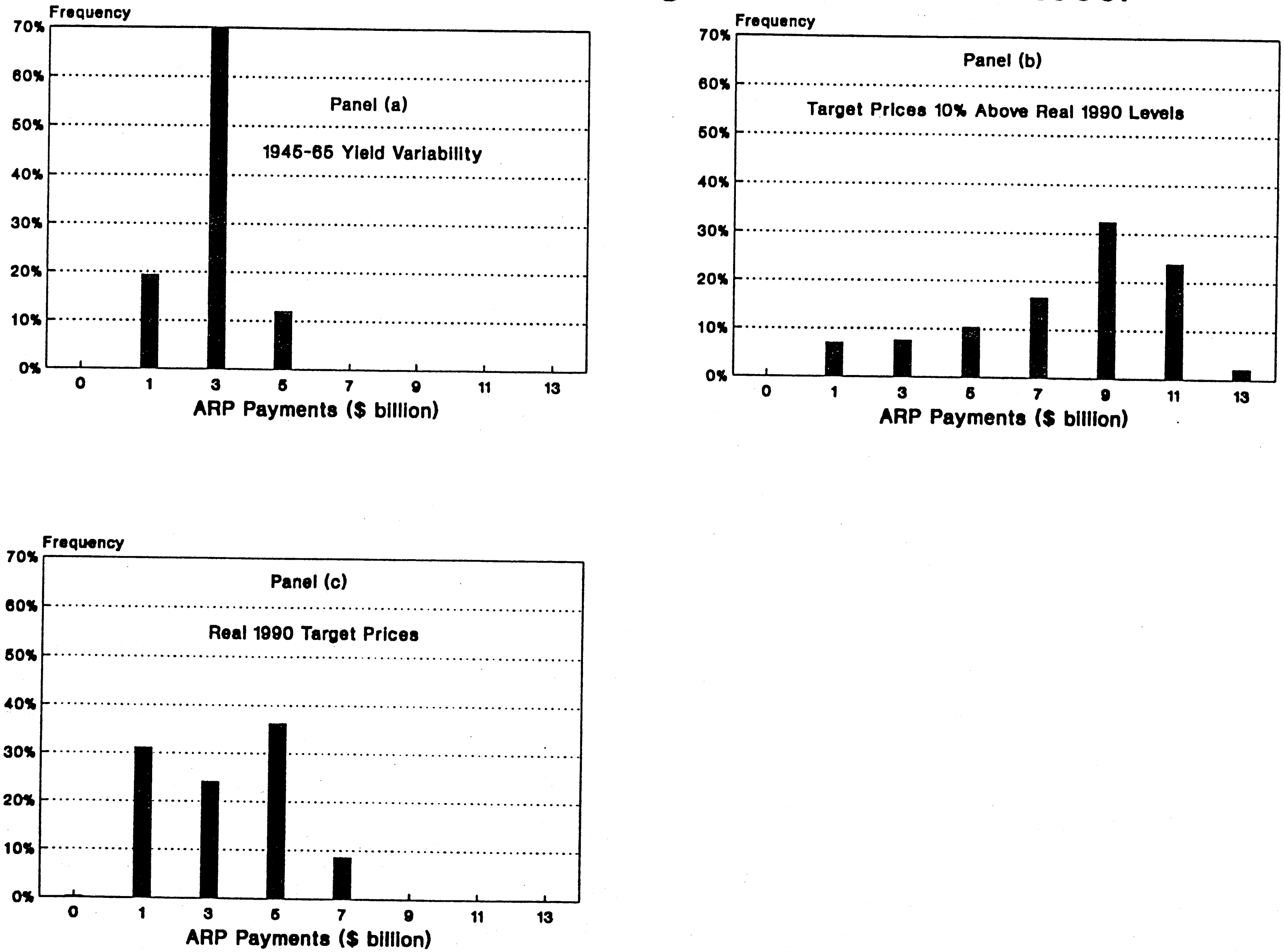


Figure 12. Acreage Equivalent of Stocks in the Year 2000.