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# TECHSIM: A Regional Field Crop and National Livestock Econometric Simulation Model

By Glenn S. Collins and C. Robert Taylor*

## Abstract

TECHSIM, a regional field crop and national livestock econometric simulation model, evaluates impacts of technological change Unlike other econometric models specified and constructed in an *ad hoc* fashion, TECHSIM makes practical use of theory by incorporating *a priori* information regarding the structure of the agricultural sectors modeled during estimation This procedure improves calculation of welfare gains or losses resulting from technological changes to agriculture The model provides policymakers with detailed welfare answers, users need only supply changes in yields and variable production costs.

## Keywords

Field crop sector, livestock sector, econometric model, simulation, welfare impacts

TECHSIM[1] is a relatively simple user-oriented econometric simulation model that can be used to evaluate the shortrun effects of a broad range of technological changes on markets for major field crops and livestock products [2] Unlike other econometric simulation models, which are structured primarily in an *ad hoc* fashion, TECHSIM's structure draws heavily on comparative static relationships and on welfare and microeconomic theory, in particular, homogeneity and symmetry restrictions were imposed on estimates of the model The production component of the model was based on the premise that producers make planting or livestock production decisions by comparing expected net returns of production options. Such a net return specification allows supply shifts resulting from changes in yield and variable production costs to be logically derived, and it provides a recursive link that allows the model to be simulated through time Imposition of theoretical restrictions allows computation of welfare results that are consistent with theoretical results specified by Chavas and Collins (*3*) for technological changes and with those presented by Just and Hueth (*7*) for price distortions [3] Hence, the model provides policymakers with detailed welfare answers, users need only supply changes in yields and variable production costs

## Overview of the Model

Because of the regional heterogeneity of U S. crop production practices, we separated the field crop sector into 13 producing regions (see figure) The field crop commodities included in the model (but not for all regions) are corn, grain sorghum, soybeans, cotton lint, cottonseed, wheat, barley, and oats We aggregated the last three crops into a small grain category The model contains the forward meal and oil products of cottonseed and soybeans The livestock sector is national and includes fed beef, nonfed beef, pork, and sheep

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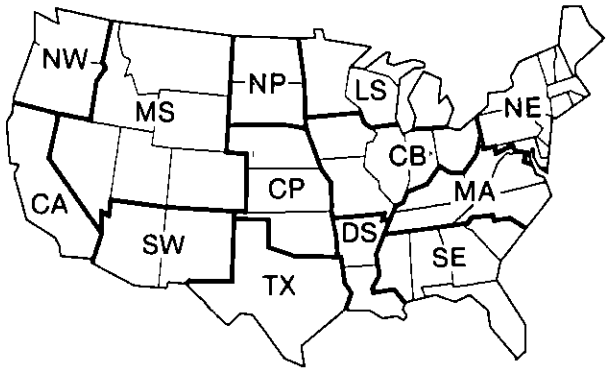
[1]The TECHSIM model and consultative input by its developers are currently made available to the Economic Research Service through Cooperative Research Agreement No 58-319V-2-00349 between the U S Department of Agriculture (USDA) and Montana State University The refinement and application of TECHSIM for evaluation of alternative Federal-State boll weevil/cotton insect management programs was funded through Cooperative Research Agreement No 58-319V-8-2530X between USDA and Texas A&M University and is reported in the second article in this issue An earlier version of the model (AGSIM) was developed under Environmental Protection Agency contract No 68-01-5041

[2]Technological change in this article refers to any change in the technical parameters of the firm's production function as well as any change in institutional constraints

[3]Italicized numbers in parentheses refer to items in the References at the end of this article

## Production Regions Within TECHSIM




CA = California
CB = Corn Belt
CP = Central Plains
DS = Delta States
LS = Lake States
MA = Mountainous Appalachian
MS = Mountain States
NE = Northeast
NP = Northern Plains
NW = Northwest
SE = Southeast
SW = Southwest
TX = Texas

Technological change is introduced by changing one or more of the exogenous variables listed in tables 1 and 2 Technological change may take the form of pesticide withdrawal policies, change in farm size, or introduction of new varieties of field crops and improved livestock breeds For example, one can initiate simulation of a pesticide withdrawal on the field crop sector by changing per-acre yield or variable production costs for a crop either in a specified region or a set of regions Changes in livestock are made by changing liveweight yields or livestock variable production costs at slaughter One can simulate technological changes resulting from institutional changes by changing policy variables such as exports, imports, or loan rates.

The simulation model traces the effects of these changes on production, price, utilization, farm rents, and producer and consumer welfare For the major field crops, the model estimates regional planted acreage, yield, production, producer net returns, and variable production costs It provides aggregate estimates on total supplies, prices, domestic demands,

**Table 1—TECHSIM Endogenous and exogenous variables of the field crop sector**

| Variable | Definition[1] |
|---|---|
| Endogenous | |
| $AC_i$ | Corn harvested acreage, region i, 1,000 acres |
| $AG_i$ | Small grains planted acreage, region i, 1,000 acres |
| $AGS_i$ | Grain sorghum harvested acreage, region i, 1,000 acres |
| $ACT_i$ | Cotton planted acreage, region i, 1,000 acres |
| $AS_i$ | Soybean planted acreage, region i, 1,000 acres |
| $NRC_i$ | Net returns per harvested acre of corn, region i, dollars per acre |
| $NRGS_i$ | Net returns per planted acre of small grains, region i, dollars per acre |
| $NRCT_i$ | Net returns per harvested acre of grain sorghum, region i, dollars per acre |
| $NRS_i$ | Net returns per planted acre of soybeans, region i, dollars per acre |
| AC | Corn harvested acreage, United States, 1,000 acres |
| AG | Small grains planted acreage, United States, 1,000 acres |
| AGS | Grain sorghum harvested acreage, United States, 1,000 acres |
| ACT | Cotton planted acreage, United States, 1,000 acres |
| AS | Soybeans planted acreage, United States, 1,000 acres |
| PC | Price of corn received by farmers, United States, cents per pound |
| CP | Corn production, United States, million pounds |
| CFDD | Corn food demand, United States, million pounds |
| CFD | Corn feed demand, United States, million pounds |
| CSD | Corn seed demand, United States, million pounds |
| CPSD | Corn private stock demand, United States, million pounds |
| CED | Corn net export demand, United States, million pounds |

—Continued

Table 1—TECHSIM Endogenous and exogenous variables of the field crop sector (Continued)

| Variable | Definition[1] |
|---|---|
| Endogenous | |
| PG | Weighted price of small grains, United States, cents per pound |
| GP | Small grains production, United States, million pounds |
| GFDD | Small grains food demand, United States, million pounds |
| GFD | Small grains feed demand, United States, million pounds |
| GSD | Small grains seed demand, United States, million pounds |
| GPS | Small grains private stock demand, United States, million pounds |
| GED | Small grains net export demand, United States, million pounds |
| GSP | Grain sorghum production, United States, million pounds |
| PGS | Price of grain sorghum received by farmers, United States, cents per pound |
| GSFDD | Grain sorghum food demand, United States, million pounds |
| GSFD | Grain sorghum feed demand, United States, million pounds |
| GSSD | Grain sorghum seed demand, United States, million pounds |
| GSPSD | Grain sorghum private stock demand, United States, million pounds |
| GSED | Grain sorghum net export demand, United States, million pounds |
| CTP | Cotton production, United States, million pounds |
| PCTL | Price of cotton lint received by farmers, United States, cents per pound |
| CTLMD | Cotton lint mill demand, United States, million pounds |
| CTLED | Cotton lint net export demand, United States, million pounds |
| CTLPSD | Cotton lint private stock demand, United States, million pounds |
| CTSP | Cottonseed production, United States, million pounds |
| PCTS | Price of cottonseed received by farmers, United States, cents per pound |
| CTSCD | Cottonseed crushing demand, United States, million pounds |
| CTSSD | Cottonseed seed demand, United States, million pounds |
| CTSPSD | Cottonseed private stock demand, United States, million pounds |
| CTSED | Cottonseed net export demand, United States, million pounds |
| SBP | Soybean production, United States, million pounds |
| PSB | Price of soybeans received by farmers, United States, cents per pound |
| SBCD | Soybean crushing demand, United States, million pounds |
| SBSD | Soybean seed demand, United States, million pounds |
| SBPSD | Soybean private stock demand, United States, million pounds |
| SBED | Soybean net export demand, United States, million pounds |
| CTSMP | Cottonseed meal production, United States, million pounds |
| PCTSM | Price of cottonseed meal, 41 percent, Memphis, cents per pound |
| CTSMFD | Cottonseed meal feed demand, United States, million pounds |
| CTSMPSD | Cottonseed meal private stock demand, United States, million pounds |
| CTSMED | Cottonseed meal net export demand, United States, million pounds |
| CTSOP | Cottonseed oil production, United States, million pounds |
| PCTSO | Price of cottonseed oil, f o b Valley Points, cents per pound |
| CTSOFD | Cottonseed oil food demand, United States, million pounds |
| CTSOPSD | Cottonseed oil private stock demand, United States, million pounds |
| CTSOED | Cottonseed oil net export demand, United States, million pounds |
| SBMP | Soybean meal production, United States, million pounds |
| PSBM | Price of soybean meal, 44 percent, Decatur, cents per pound |
| SBMFD | Soybean meal feed demand, United States, million pounds |
| SBMPSD | Soybean meal private stock demand, United States, million pounds |

—Continued

Table 1—TECHSIM Endogenous and exogenous variables of the field crop sector (Continued)

| Variable | Definition[1] |
|---|---|
| Endogenous | |
| SBMED | Soybean meal net export demand, United States, million pounds |
| SBOP | Soybean oil production, United States, million pounds |
| PSBO | Price of soybean oil, crude tanks, Midwestern mills, cents per pound |
| SBOFDD | Soybean oil food demand, United States, million pounds |
| SBOPSD | Soybean oil private stock demand, United States, million pounds |
| SBOED | Soybean oil net export demand, United States, million pounds |
| Exogenous | |
| $VPCC_i$ | Corn variable production costs, region i, dollars per acre |
| $VPCG_i$ | Small grains weighted variable production costs, region i, dollars per acre |
| $VPCGS_i$ | Grain sorghum variable production costs, region i, dollars per acre |
| $VPCCT_i$ | Cotton variable production costs, region i, dollars per acre |
| $VPCS_i$ | Soybean variable production costs, region i, dollars per acre |
| $YC_i$ | Corn yield per harvested acre, region i, pounds per acre |
| $YG_i$ | Small grains weighted yield per planted acre, region i, pounds per acre |
| $YGS_i$ | Grain sorghum yield per harvested acre, region i, pounds per acre |
| $YCTI_i$ | Cotton lint yield per planted acre, region i, pounds per acre |
| $YCTS_i$ | Cottonseed yield per planted acre, region i, pounds per acre |
| $YS_i$ | Soybean yield per planted acre, region i, pounds per acre |
| PPI | Prices paid index for production items, interest, and wage rates (1967=100) |
| CTSMYC | Cottonseed meal crushing yield coefficient, percent |
| CTSOYC | Cottonseed oil crushing yield coefficient, percent |
| SBMYC | Soybean meal crushing yield coefficient, percent |
| SBOYC | Soybean oil crushing yield coefficient, percent |
| T | Time trend, 1961=61, 1962=62, , 1977=77 |
| EXP | Expenditures on nonfood items, United States, million dollars |
| DI | Dummy variable 1974=1, 0 otherwise |
| POLY | Price of rayon polyester, United States, cents per pound |
| PFCT | Price of cotton lint at foreign markets, cents per pound |
| WCTS | World cotton lint supply excluding United States, million pounds |
| CTLR | Cotton loan rate, United States, cents per pound |
| SBGS | Soybean Government stocks, United States, million pounds |
| PFM | Price of fish meal at foreign export markets, Brazil, cents per pound |
| SBOPL | Soybean oil exports P L 480, million pounds |
| CTSOPL | Cottonseed oil exports P L 480, million pounds |
| POP | Population, United States, million |

[1]All value variables were deflated by the producer price index

Table 2—TECHSIM Endogenous and exogenous variables of the livestock sector

| Variable | Definition[1] |
|---|---|
| Endogenous | |
| CPOF | Cattle placed on feed, million head |
| FBPP | Fed beef production, liveweight, million pounds |
| FBP | Fed beef production, carcass weight, million pounds |
| PFFB | Price of fed steers, Omaha, cents per pound |
| PRFB | Price of retail choice cuts of beef, cents per pound |
| NRFB | Fed beef net returns = (PFFB − VPCFB) * ASWFB, cents per head |
| FBDD | Fed beef domestic demand, million pounds |
| RCI | Cattle not placed on feed, million head |
| NFBPP | Nonfed beef production, liveweight, million pounds |
| NFBP | Nonfed beef production, carcass weight, million pounds |
| PFNFB | Price of cull cows at Omaha, cents per pound |
| PRNFB | Price of retail hamburger, cents per pound |
| NRNFB | Nonfed beef net returns = (PFNFB − VPCNFB) * ASWNFB, cents per head |
| NFBI | Nonfed beef imports, million pounds |
| NFBDD | Nonfed beef domestic demand, million pounds |
| NFBSD | Nonfed beef stock demand, million pounds |
| NFBED | Nonfed beef export demand, million pounds |
| SFAR | Sow farrowings, million head |
| POF | Pigs on feed, million head |
| PPP | Pork production, liveweight, million pounds |
| PP | Pork production, carcass weight, million pounds |
| PFP | Price of barrows and gilts, cents per pound |
| PRP | Price of retail pork, cents per pound |
| NRP | Pork net returns = (PFP − VPCP) * ASWP, cents per head |
| PI | Pork imports, million pounds |
| PDD | Pork domestic demand, million pounds |
| PSD | Pork stock demand, million pounds |
| PED | Pork export demand, million pounds |
| SBHI | Sheep breeding herd inventory, million pounds |
| SPOF | Sheep on feed, million head |
| SPP | Sheep production, liveweight, million pounds |
| SP | Sheep production, carcass weight, million pounds |
| PFL | Price of farm lambs, cents per pound |
| PRL | Price of retail mutton, cents per pound |
| NRL | Lamb net returns = (PFL − VPCL) * ASWL, cents per head |
| NSI | Sheep net imports (imports-exports), million pounds |
| SDD | Sheep domestic demand, million pounds |
| SSD | Sheep stock demand, million pounds |
| WPL | Weighted price of livestock by production, cents per pound |
| WPF | Weighted price of feed (grains and meals) by production, cents per pound |
| I | Income spent on fed beef, nonfed beef, pork and sheep, million dollars |

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Table 2—TECHSIM. Endogenous and exogenous variables of the livestock sector (Continued)

| Variable | Definition[1] |
|---|---|
| Exogenous | |
| ASWFB | Fed beef average liveweight at slaughter, pounds |
| ASWNFB | Nonfed beef average liveweight at slaughter, pounds |
| ASWP | Pork average liveweight at slaughter, pounds |
| ASWL | Lamb average liveweight at slaughter, pounds |
| VPCFB | Fed beef variable production costs at slaughter, cents per pound |
| VPCNFB | Nonfed beef variable production costs at slaughter, cents per pound |
| VPCP | Pork variable production costs at slaughter, cents per pound |
| VPCL | Lamb variable production costs at slaughter, cents per pound |
| PPLIT | Pigs per litter, head |
| FLPI | Personal consumption expenditures in importing countries, million dollars |

[1]All value variables were deflated by the producer price index

exports, ending stocks, producer net returns, and welfare measures for all field crops. For livestock, the model provides aggregate estimates on inventories, the number of animals on feed or placed on feed, slaughter (liveweight and carcass), imports, total supplies, domestic demands, exports, ending stocks, farm prices, retail prices, price margins, and welfare measures for each livestock group These results are obtained by simultaneously solving all markets for the equilibrium price vector

## Structure of the Production and Consumption Sectors

In both the field crop and livestock production sectors, we use expected net returns as the principal explanatory variables rather than commodity prices For both production sectors, this implies that producers who maximize farm income allocate production between enterprises based on expected net returns, rather than simply on output and input prices

Table 3 shows the general structure of the production and consumption sectors in TECHSIM It depicts the assumed objective function, the resulting behavioral choice equations, the comparative static results, and the functional form of the estimated equations for each production and consumption component For example, one can obtain regional planted acreage equations by maximizing

$$\Pi = \Sigma_i^n \pi_i A_i + \lambda[A_T - \Sigma_i^n A_i] \qquad (1)$$

where $\Pi$ is regional farm profit, $\pi_i$ is expected regional net returns for field crops grown in the region, $A_i$ is planted acreage, and $A_T$ is the total cropland which can be allocated among crop alternatives Maximization of equation (1) gives behavioral choice equations for field crop producers as follows.[4]

$$A_i = A_i^*(\pi_1, \quad , \pi_n, A_T) \quad \text{for all } i \qquad (2)$$

We obtained comparative static results on the theoretical implications of equation (1) by minimizing the difference between the indirect and direct profit functions [5]

$$L^* = \Pi^* - \Pi \qquad (3)$$

where $\Pi^*$ and $\Pi$ are the indirect and direct profit functions, respectively Minimization of equation (3) results in the following theoretical implications (see appendix)

[4]From equation (2), the firm is assumed to allocate acreage based on the relative expected per acre net returns of the firm's crop alternatives This assumption appears reasonable as planted acreage is fixed after planting decisions have been made However, one would expect that both yields and inputs could be altered if harvested acreage equations were desired, as the firm could adjust input usage during the production period preceding harvest In this case, harvested acreage equations would be a function of output and input prices rather than of net returns

[5]The direct and indirect profit functions have conventional meanings where the indirect profit function contains parameters only as arguments (that is, optimal quantities of $A_i^*$ are inserted into the direct profit function)

Table 3—General structure of the production and consumption sectors in TECHSIM

| Sector | Objective function | Behavioral function | Functional form[1] | Theoretical implications | |
|---|---|---|---|---|---|
| | | | | Own effect | Symmetry |
| Field crop | | | | | |
| Regional farm acreage[2] | $\Pi = \Sigma_i^n \pi_i A_i + \lambda[A_T - \Sigma_i^n A_i]$ | $A_i^*(\pi_1, \ldots, \pi_n, A_T)$ | GL | $\partial A_i^*/\partial \pi_i \geq 0$ | $\partial A_i^*/\partial \pi_j = \partial A_j^*/\partial \pi_i$ |
| U S processors' supply and demand[3] | $\Pi = \Sigma_i^n r_i Q_i + \lambda F(Q)$ | $Q_i^*(r_1, \ldots, r_n)$ | GL and LOG | $\partial Q_i^*/\partial r_i \geq 0$ | $\partial Q_i^*/\partial r_j = \partial Q_j^*/\partial r_i$ |
| Livestock | | | | | |
| U S farm supply[4] | $\Pi = \Sigma_i^n \theta_i L_i + \lambda[L_T - \Sigma_i^n L_i]$ | $L_i^*(\theta_1, \ldots, \theta_n, L_T)$ | GL and LOG | $\partial L_i^*/\partial \theta_i \geq 0$ | $\partial L_i^*/\partial \theta_j = \partial L_j^*/\partial \theta_i$ |
| U S processors' supply and demand[5] | $\Pi = \Sigma_i^n w_i Z_i + \lambda F(Z)$ | $Z_i^*(w_1, \ldots, w_n)$ | LOG | $\partial Z_i^*/\partial w_i \geq 0$ | $\partial Z_i^*/\partial w_j = \partial Z_j^*/\partial w_i$ |
| U S final demand[6] | $V = U(X) + \lambda[I - \Sigma_i^n P_i X_i]$ | $X_i^*(P_1, \ldots, P_n, I)$ | LOG | $(\partial X_i^*/\partial P_i)\|_{\bar{U}} \leq 0$ | $\partial X_i^*/\partial P_j + X_j^* \partial X_j^*/\partial I = \partial X_j^*/\partial P_i + X_i^* \partial X_j^*/\partial I$ |

[1]The generalized Leontief (GL) is a flexible functional form and provides a local second-order approximation to any arbitrary functional form (4) L and LOG denote a linear and log function, respectively

[2]$\Pi$ is regional field crop producers' profit, $A_i$ is acreage planted, $\pi_i = r_i Y_i - VPCC_i$ is regional profit per acre where $r_i$ is field crop output price, $Y_i$ is field crop yield per planted acre, $VPCC_i$ is variable field crop production cost, and $A_T$ is total crop land available for planting

[3]$\Pi$ is U S field crop processors' profit, r is a vector of output prices and input (field crop output) prices, and Q is a vector of outputs $Q_i \geq 0$ and inputs (production of field crops $Q_i = A_i Y_i$) $Q_i \leq 0$

[4]$\Pi$ is U S livestock producers' profit, $L_i$ is livestock slaughter (liveweight) supply, $\theta_i = w_i ASW_i - VPCL_i$ is profit per animal where $w_i$ is livestock output price, $ASW_i$ is average liveweight at slaughter, and $VPCL_i$ is variable livestock production costs, and $L_T$ is the total number of available animals which can be allocated between livestock enterprises

[5]$\Pi$ is U S livestock processors' profit, w is a vector of output prices and input (livestock producers' output) prices, and Z is a vector of livestock carcass outputs $Z_i \geq 0$ and livestock inputs $Z_i \leq 0$

[6]U(X) is utility of final consumers, I is consumer income, and $X_i$ is livestock final consumer demands

Own effect $\partial A_i^* / \partial \pi_i \geq 0$ for all i

Symmetry $\partial A_i^* / \partial \pi_j = \partial A_j^* / \partial \pi_i$ for all $i \neq j$ (4)

These restrictions were imposed as *a priori* information for each regional acreage equation. They imply that planted acreage for each crop increases with respect to its own per-acre net returns (own effect) and that the change in acreage of crop i with respect to net returns of crop j equals the change in acreage of crop j with respect to net returns of crop i

As shown in table 3, we estimated most of the production equations in the model using a generalized Leontief functional form (*4*) This form is one of the so-called flexible functional forms because it provides a local second-order approximation to any arbitrary functional form For the acreage equations in (2) it implies [6]

$$A_i^* (\pi_1, . \quad , \pi_n) = \Sigma_j^n \gamma_{ij} (\pi_j/\pi_i)^{1/2} + \omega_i A_T$$

where $\gamma_{ij}$ are estimated parameters We estimated these equations with the restrictions in equations (4) for each region using restricted generalized least squares The restrictions for regional acreage equations imply that.

Own effect $\partial A_i^* / \partial \pi_i = \Sigma_j^n - \gamma_{ij}/2\pi_j^{1/2} \pi^{-3/2} \geq 0$

Symmetry $\partial A_i^* / \partial \pi_j = \partial A_j^* / \partial \pi_i = \gamma_{ij} = \gamma_{ji}$

Using the same methodology, we specified and estimated equations to represent the other sectors according to the structure in table 3 The model in its presented version contains over 170 equations and was estimated with data for the 1961-77 period

## Estimated Regional Acreage Equations

We estimated the regional acreage and yield equations in 13 separate blocks using restricted generalized least squares (*10*) This estimation technique allows for correlation between error terms in a set of estimated equations and for the introduction of *a priori* information Error terms for acreage within a region are likely to be correlated because of a fixed land base, whereas deviations of yields are likely to be correlated as a result of weather Furthermore, yield and acreage are likely related because of the heterogeneous quality of land in a region

The generalized Leontief form was used to estimate acreage response functions for each region Initially, we obtained preliminary estimates for each region by imposing all *a priori* restrictions depicted in table 3 and by using the previous year's lagged crop acreage as a proxy for quasi-fixed production factors However, the final choice of the estimated structure was based upon statistical properties and expected theoretical signs [7] Table 4 illustrates the estimated acreage equations comprising the field crop production sector

Each acreage equation has the expected economic sign with respect to own and cross net returns. Most of these signs are statistically significant at the 5-percent level Only three equations were found that did not compete with other field crops Hence, these equations were estimated as a function solely of their own net return These equations are for corn in the TX and DS regions and for grain sorghum in the CB region

## Estimated Field Crop Demands

The estimated field crop demands are illustrated in tables 5, 6, and 7 Each table describes a set of equations that was estimated by separate blocks. The first block in table 5 represents the demand for seed use for each field crop All the equations in this block have expected signs, only corn acreage was insignificant at the 5-percent level

The food demand equations were estimated as per capita demands All the expected signs for these equations are negative However, only the own-price effects for grain sorghum and small grains were significant at the 10-percent level Expenditure signs on all nonfood items were negative and were signif-

[6] The generalized Leontief form for the indirect profit function can be written as

$$\Pi^* (\pi_1, \quad , \pi_n, A_T) = \Sigma_i^n \Sigma_j^n \gamma_{ij} \pi_i^{1/2} \pi_j^{1/2} + \Sigma_i^n \omega_i \pi_i A_T$$

and one can obtain by use of the envelope theorem the following behavioral choice equation

$$\partial \Pi^* / \partial \pi_i = A_i^* = \Sigma_j^n \gamma_{ij} (\pi_j/\pi_i)^{1/2} + \omega_i A_T$$

[7] Some inconsistencies between theory and results were expected Hence, lagged acreages were omitted and time was included in some of the regions

Table 4—Regional acreage equations

| Region | Variable | Equation[1] |
|---|---|---|
| NW | AC | 31 811 — 14 991 B12 + 0 634 AC(−1)<br>(−1 39) (4.78) |
| | AG | 1893 723 — 14.991 B21 + 0.606 AG(−1)<br>(−1 39) |
| | | Weighted R-square of system = 0 84 |
| CA | AC | 181 189 — 33 319 B14 + 0 521 AC(−1)<br>(−6 28) (6 67) |
| | AG | 1678 061 — 65 533 B23 + 0 304 AG(−1)<br>(−3 04) (2 60) |
| | AGS | 162.907 — 65.533 B32 + 0 115 AGS(−1)<br>(−3 04) (5 68) |
| | ACT | 118 717 — 33 319 B41 + 0 916 ACT(−1)<br>(−6 28) (4 97) |
| | | Weighted R-square for system = 0 93 |
| MS | AC | 938 176 — 666 184 B12 — 40 263 B13<br>(−4 68) (−0 92) |
| | AG | 13832 550 — 666 184 B21 — 22 935 B23<br>(−4.68) (−0 34) |
| | AGS | 365 935 — 40 263 B31 — 22 935 B32<br>(−0 92) (−0.34) |
| | | Weighted R-square for system = 0 82 |
| SW | AC | 218 919 — 135 389 B13<br>(−6 54) |
| | AG | 837 466 — 294 394 B24 + 0 497 AG(−1)<br>(−7 27) (5 33) |
| | AGS | 323 636 — 135 389 B31 + 0 492 AGS(−1)<br>(−6 54) (2.97) |
| | ACT | 491 599 — 294 394 B42 + 0 350 ACT(−1)<br>(−7 27) (2.57) |
| | | Weighted R-square for system = 0.67 |
| CP | AC | 1118.161 — 100 407 B14 + 0 844 AC(−1)<br>(−2 00) (13 29) |
| | AG | 3470 443 — 168 793 B23 — 520 051 B25 + 0 890 AG(−1)<br>(−0 32) (−1.68) (11 09) |
| | AGS | 8647.031 — 168 793 B32 — 2165.250 B52<br>(−0.33) (−4 47) |
| | ACT | 437 985 — 100.407 B41 + 0 365 ACT(−1)<br>(−2 00) (2 21) |
| | AS | 3142 660 — 520 051 B52 — 2165 250 B53 + 0 589 AS(−1)<br>(−1 68) (−4 29) (5 51) |
| | | Weighted R-square for system = 0 94 |
| NP | AC | 2458 633 — 164 855 B13 + 0 142 AC(−1)<br>(−3 38) (0 643) |
| | AG | 2247 571 — 172 139 B25 + 0 899 AG(−1)<br>(−1 40) (5 51) |
| | AGS | 302 357 — 164 855 B31 + 0 354 AGS(−1)<br>(−3 38) (2.03) |
| | AS | 324 679 — 172 139 B52 + 0 639 AS(−1)<br>(−1 40) (4 67) |
| | | Weighted R-square for system = 0 56 |
| TX | AC | −84 062 + 2 912 NRC(−1) + 0 959 AC(−1)<br>(5 86) (14.87) |
| | AG | 778 287 — 289 193 B25 + 0.969 AG(−1)<br>(−3 81) (5 55) |
| | AGS | 7594 079 — 897 729 B34 — 7 414 T<br>(−1.78) (−0.22) |
| | ACT | 3468.213 — 897 729 B43 — 0 478 ACT(−1)<br>(−1 78) (3 34) |

—Continued

Table 4—Regional acreage equations (Continued)

| Region | Variable | Equation[1] |
|---|---|---|
| | AS | −618.208 − 289 193 B52 + 0 586 AS(−1) + 13 311 T<br>(−3 66) (4 20) (1 84)<br>Weighted R-square for system = 0 96 |
| LS | AC | 3825 292 − 1235.66 B12 − 1344 27 B15 + 0 839 AC(−1)<br>(−1 74) (−1 85) (5.68) |
| | AG | 10704 510 − 1235 66 B21 − 1456 42 B25 + 0 167 AG(−1)<br>(−1 74) (−2.39) (0 90) |
| | AS | 3200 874 − 1344 27 B51 − 1456 42 B52 + 0 861 AS(−1)<br>(−1 85) (−2 39) (6 61)<br>Weighted R-square for system = 0 60 |
| CB | AC | 25590 870 − 1087 35 B12 − 14669 80 B15 + 0 688 AC(−1)<br>(−1 78) (−5 43) (6 07) |
| | AG | 12460 780 − 1087 35 B21 − 3517 97 B25 + 0 457 AG(−1)<br>(−1.78) (−6 08) (9 77) |
| | AGS | −39 831 + 5 759 NRGS(−1) + 0 605 AGS(−1)<br>(1 95) (3 67) |
| | AS | 18105 870 − 14669 80 B51 − 3517 97 B52 + 0 997 AS(−1)<br>(−5 43) (−6 08) (11 90)<br>Weighted R-square for system = 0.91 |
| DS | log AC | 0 193 + 0.064 log NRC(−1) + 0 938 log AC(−1)<br>(1 37) (21 03) |
| | AG | 987 851 − 262 371 B23 + 0 303 AG(−1)<br>(−2 87) (2 10) |
| | AGS | 369 159 − 262.371 B32 + 0 600 AGS(−1)<br>(−2 87) (4 20) |
| | ACT | 3624 093 − 1131 01 B54 + 0 129 ACT(−1)<br>(−3.59) (1 14) |
| | AS | 3465 740 − 1131 01 B54 + 0 834 AS(−1)<br>(−3 59) (16 35)<br>Weighted R-square for system = 0 93 |
| SE | AC | 3526 471 − 184 825 B15<br>(−4 05) |
| | AG | 464 003 + 9 846 NRG(−1) + 0 359 AG(−1)<br>(−1 50) (2 38) |
| | AGS | 49 511 − 10 481 B34 + 0 418 AGS(−1)<br>(−4 26) (8 11) |
| | ACT | 370 777 − 10 481 B43 + 0 660 ACT(−1)<br>(−4 26) (4 55) |
| | AS | 486 319 − 184 825 B51 + 0.967 AS(−1)<br>(−3 82) (12 39)<br>Weighted R-square for system = 0 87 |
| MA | AC | 1728 898 − 80 570 B13 − 417 708 B15 + 0 702 AC(−1)<br>(−1 84) (−1 76) (6 13) |
| | AG | 200 835 − 129 432 B24 + 0 092 AG(−1)<br>(−4 30) (0 66) |
| | AGS | 280 877 − 80 570 B31 − 150 814 B35 + 0 711 AGS(−1)<br>(−1 84) (−3 11) (5 06) |
| | ACT | 271 224 − 129 432 B42 + 0 660 ACT(−1)<br>(−4 30) (5 34) |
| | AS | −5706 940 − 417 708 B51 − 150 814 B53 + 0 565 AS(−1) + 113 899 T<br>(−1 68) (−2 96) (3 45) (3 22)<br>Weighted R-square for system = 0 92 |
| NE | AC | 923 411 − 344 238 B12 + 0 677 AC(−1)<br>(−4 55) (3 29) |
| | AG | 1139 900 − 344 238 B21 + 0 694 AG(−1)<br>(−4 55) (7 93) |
| | AS | −22 238 + 2 042 + 0 867 AS(−1)<br>(4 35) (9 48)<br>Weighted R-square for system = 0 84 |

[1] Values in parentheses are t values, and $B_{ij} = (NR_j/NR_i)^{1/2}$ where NR is lagged 1 year and i,j = 1 (corn), 2 (small grains), 3 (grain sorghum), 4 (cotton), and 5 (soybeans)

Table 5--Field crop demand equations

| Block | Variable | Equation[1] |
|---|---|---|
| Seed | CSD | −68993 500 + 4 038 AC (1 12) + 35 338 T (7 36) |
| | GSD | −98821 800 + 60 990 AG (4 72) + 50 823 T (2 20) |
| | GSSD | −826 804 + 2 566 AGS (2 60) + 0 460 T (1 35) |
| | CTSSD | 3838 336 + 14 523 ACT (2 46) − 1 758 T (−0 56) |
| | SBSD | 13 911 + 0 825 AS (7 57) |
| | | Weighted R-square for system = 0 85 |
| Food | CFDD | −8240 090 − 3 113 PC (−1 35) − 0 219 EXP (−6 25) + 4.289 T (10 66) |
| | GFDD | −1246.210 − 2 927 PG (−3 28) − 0 098 EXP (−3 92) + 0.755 T (2.94) |
| | GSFDD | 224 870 − 0 734 PGS (−1.88) − 0 006 EXP (−1 50) − 0 110 T (−1 83) |
| | CTSOFDD | 20 017 − 0.084 PCTSO (−0 76) − 0 031 EXP (−4.28) |
| | SBOFDD | −1822 450 − 0.042 PSBO (−0 41) + 0.026 EXP (1 63) + 0.934 T (4.92) |
| | | Weighted R-square for system = 0 93 |
| Export | CED | −578684 000 − 18689 100 PC (−3 09) + 54797 350 D1 (7 54) + 329 766 T (0.45) |
| | GED | 26588 800 − 1095 320 PG (−0 45) + 39565 980 D1 (11.59) |
| | GSED | −92888 800 + 11960 020 PC (2 21) − 14669.800 PGS (−2 26) + 4333 833 D1 (1 45) |
| Stock | CPSD | 512270 300 − 21101 700 PC (−5 69) − 216 227 T (−0 61) |
| | GPSD | −3064436 00 − 15616 100 PG (−5 02) + 1597 586 T (3 26) |
| | GSPSD | −93163.90 − 3028 210 PGS (−2 09) + 52 424 T (0 44) |
| | | Weighted R-square for system = 0 81 |
| Cotton | CTLMD | 10 450 − 0 300 PCTL (−2.40) + 0 021 EXP (0 58) + 0 127 POLY (2 70) |
| | CTLED | 168455 600 − 71 947 PCTL (−1.65) + 148 116 PFCT (1 97) − 34 803 WCTS (−0 50) − 85 400 T (−0 95) |
| | CTLPSD | 49617.700 − 48.208 PCTL (−0 41) + 185 543 WCTS (0 94) + 219.888 CTLR (1.52) − 255.650 T (−1 46) |
| | | Weighted R-square for system = 0 69 |

[1]Values in parentheses are t-values and food demands are per capita

Table 6—Soybean and cottonseed Respective meal and oil supply identities and demand equations

| Block | Variable | Equation[1] |
|---|---|---|
| Soybean | SBMP | SBCD * SBMYC |
| | SBOP | SBCD * SBOYC |
| | SBCD | −3809087 0 − 6345 890 PSB + 959 881 PSBM + 923 867 PSBO + 1962.221 T<br>(−10 40) (4 80) (5 81) (18 34) |
| | SBPSD | −1154555 0 − 689 595 PSB − 0 124 SBGS + 0 184 SBPSD(−1) + 590 254 T<br>(−0 76) (−1 15) (0 92) (2 45) |
| | SBED | −3456061 0 − 1534.45 PSB + 27 276 PFM + 1767 681 T<br>(−2 54) (4.42) (11 47) |
| | SBMED | −1001169 0 − 318 354 PSBM + 12.848 PFM + 511 646 T<br>(−0 57) (1 10) (8.11) |
| | SBOPSD | −73858 2 − 45 709 PSBO + 38 116 T<br>(−3 04) (2 65) |
| | SBOED | −38850 0 − 2 640 PSBO − 0 124 SBOPL + 20 417 T.<br>(−0 15) (−1 28) (1 16) |
| | | Weighted R-square for system = 0 97 |
| Cottonseed | CTSMP | CTSCD * CTSMYC |
| | CTSOP | CTSCD * CTSOYC |
| | CTSCD | 157266 5 − 245 177 PCTS + 98 759 PCTSO + 0 875 CTSP − 79 904 T<br>(−1 71) (3 26) (36 46) (−5.64) |
| | CTSPSD | −134558 0 + 0 114 CTSP + 68 041 T<br>(3 93) (4 86) |
| | CTSED | −9021 92 − 1 195 PCTS + 0 051 PFM + 4 606 T<br>(−0 11) (0 36) (2 09) |
| | CTSMPSD | 448 388 − 47 78 PCTSM<br>(−1 49) |
| | CTSMED | −3892 89 − 57 807 PCTSM + 0 916 PFM + 2 044 T<br>(−1 13) (1 55) (0 34) |
| | CTSOPSD | 53321 89 − 7 749 PCTSO + 14 086 PSBO − 26 981 T<br>(−3 43) (2 29) (3 84) |
| | CTSOED | −81185 4 − 45 299 PCTSO + 53 019 PSBO + 2.143 CTSOPL + 41 384 T<br>(−3 32) (4.65) (8 93) (7 01) |
| | | Weighted R-square for system = 0 98 |

[1]Values in parentheses are t values

Table 7—Feed-grain and feed meal demand equations

| Block | Variable | Equation[1] |
|---|---|---|
| Grains | CFD | −5805774 0 + 20046 4 B12 + 74962 29 B13 + 12389 45 B14<br>(1 23) (4 34) (1 93)<br>+3764 42 B15 + 17314 25 B16 + 2963 23 T<br>(0 46) (0.96) (3 28) |
| | GFD | 1216868 0 + 20046 4 B21 − 3162 01 B23 + 7762 688 B24 − 7235 78 B25<br>(1 23) (0 41) (2 94) (−2 01)<br>+ 9068 263 B26 − 618 38 T<br>(1 68) (−2 40) |
| | GSFD | −124649.0 + 74962 29 B31 − 3162 01 B32 − 18870 1 B34<br>(4 34) (0 41) (−2 81)<br>+ 4907 73 B35 + 17407 81 B36 + 590 35 T<br>(1 08) (3 83) (2 47) |
| Meals | CTSMFD | −9401 66 + 12389 48 B41 + 7762 69 B42 − 18870 1 B43<br>(2 04) (3 10) (−2 96)<br>+ 9517 17 B45 + 380 62 B46<br>(3 08) (0 35) |
| | SBMFD | −1399818 0 + 3764 42 B51 − 7235 78 B52 + 4907 73 B53<br>(0 46) (−2.01) (1 08)<br>+ 9517 17 B54 + 2427 71 B56 + 715 51 T<br>(2 92) (0 79) (6 71) |
| | | Weighted R-square for system = 0 84 |

[1]Values in parentheses are t-values, and $B_{ij} = (P_j/P_1)^{1/2}$ for i=1 (corn), 2 (small grains), 3 (grain sorghum), 4 (cottonseed meal), and 6 (weighted price of livestock, WPL)

icant at the 5-percent level, except those for soybean oil

Export and stock demands were grouped, and their estimated parameters are shown in the succeeding block All own-price effects have the expected economic sign and are significant, except the small grains export demand equation Dummy variables accounting for export shifts were significant for corn and small grains

The final set of estimated equations in table 5 represents the residual cotton lint demands Each own-price coefficient in these three equations is negative The price of polyester for cotton lint fiber demand was positive and significant, implying that increases (decreases) in polyester prices decrease (increase) the mill demand of cotton lint The last two equations, cotton lint export and stock demands, reflect the general statistical problems for stock and export equations Even though we included many explanatory variables to describe behavior, insignificant coefficients were obtained

Table 6 presents the estimated demands for soybean and cottonseed meal and oil equations The first two equations in each block are supply identities for soybean and cottonseed meal and oil production The yield coefficients are exogenous, as they changed little during the estimation period

The first equation, soybean crushing demand, depicts significant coefficients for each explanatory variable Prices of soybean meal and oil (the outputs of soybeans after crushing) have positive signs Several difficulties were encountered with the equation for soybean private stocks A different assortment of explanatory variables was initially included in this equation However, except for the illustrated specified form, they each gave a positive own-price effect All coefficients for the soybean export equation were significant The price of foreign fish meal had a significant and positive sign, indicating substitute products The last four equations in this block represent the export and stock demands for soybean meal and oil. All own-prices have the expected signs

The cottonseed block depicts demands for cottonseed, cottonseed oil, and cottonseed meal The first equation in the block CTSCD gave poor statistical results except when cottonseed production was included We estimated cottonseed private stocks using cottonseed production and time as the only variables Although the price of cottonseed was initially specified in the equation, its estimated coefficient was positive and insignificant We also encountered incorrect signs and insignificant coefficients in the cottonseed export demand equation However, the illustrated specified form gave expected signs even though some coefficients were insignificant The remaining equations show the estimated coefficients for cottonseed meal and oil stock and export demands The own-price effects have the expected sign and are significant for the last two equations

We estimated the feed demand equations (table 7) with symmetry imposed on feed prices All the own-price effects are negative and significant, indicating downward-sloping functions Examining cross signs reveals that corn is a substitute for all feeds Other substitutes are soybean meal and grain sorghum, small grains, and cottonseed meal and soybean meal

## Livestock Supply Equations

Table 8 shows the livestock supply equations In the beef block, the number of cattle placed on feed (CPOF) or not placed on feed (RCI) is determined by expected net returns for each alternative After determining placements, we explained fed beef production (FBPP) by lagged cattle placed on feed and by the relative prices of farm fed beef and the weighted feed-grain price index A similar result is used to explain nonfed beef production (NFBPP) An interesting result of the shortrun production response is that fed beef production shows a positive response to its own price and a negative response to a weighted feed grain price, whereas nonfed beef production shows the converse Hence, a rise in feed-grain prices decreases fed beef production and an increases nonfed beef production [8]

The next block explains pork supplies The number of sows farrowing is explained by net returns of barrows and gilts, the number of pigs per litter, and the previous year's sow farrowings The number of pigs on feed is then explained by sow farrowings and the previous year's pigs on feed The shortrun

[8]These results are similar to those of Jarvis (*6*)

Table 8—Livestock supply equations

| Block | Variable | Equation[1] |
|---|---|---|
| Beef | FBPP[2] | 6024 356 − 13997 40 COFB + 1025.044 CPOF(−1)<br>(2 40) (28 34) |
| | FBP | 0 5858 FBPP<br>(28.34) |
| | PFFB | 0 3004 PRFB<br>(96 82) |
| | NFBPP[2] | 10108 640 CONFB + 683 459 RCI(−1)<br>(5 20) (11 19) |
| | NFBP | 0 5834 NFBPP<br>(450 07) |
| | PFNFB | 0 3073 PRNFB<br>(42 43) |
| | CPOF[3] | 38 986 − 37 408 R12 + 0.878 CPOF(−1)<br>(−4 74) (20 58) |
| | RCI[3] | 42 023 − 37 408 R21 + 0 754 RCI(−1)<br>(−4 74) (14 05) |
| | | Weighted R-square for system = 0 99 |
| Pork | PPP[2] | −11209 5 COP + 311 803 POF(−1) + 4 217 T<br>(9.57) (4 50) |
| | PP | 0 638 PPP<br>(74 81) |
| | POF | 3.799 SFAR + 0 051 POF(−1)<br>(15 65) (0 84) |
| | SFAR | 0 022 NRBG(−1) + 0 466 SFAR(−1) + 0 591 PPLIT<br>(1 82) (2 71) (1 31) |
| | PFP | 0.314 PRP<br>(38 36) |
| | | Weighted R-square for system = 0 99 |
| Sheep | SPP[2] | 96 625 − 1018 62 COS + 437 79 SPOF(−1)<br>(−2.23) (19 21) |
| | SP | 0 488 SPP<br>(742 83) |
| | SPOF | 0 153 SBHI(−1)<br>(64.11) |
| | PLF | 0 256 PRL<br>(72 69) |
| | log SBHI | 891 856 + 0 922 log NRL(−1) − 117 76 T<br>(2.82) (43 55) |
| | | Weighted R-square for system = 0 99 |
| Imports | log NFBI | 0 201 log PRNFB(−1) + 0.895 log NFBI(−1)<br>(1 10) (8 86) |
| | log PI | 0 155 log PRP(−1) + 0 897 log PI(−1)<br>(1.93) (15 56) |
| | log NSI | 0 058 log PRL(−1) + 0 916 log NSI(−1)<br>(0.43) (6 65) |
| | | Weighted R-square for system = 0 99 |

[1]Values in parenthese are t values
[2]$CO_i = (WPF/PF_i)^{1/2}$ where i = FB (fed beef), NFB (nonfed beef), P (pork), and L (lamb)
[3]$R_{ij} = (NR_i/NR_j)^{1/2}$ where NR is lagged 1 year, and i,j = 1 (fed beef), and 2 (nonfed beef)

pork production equation is positively sloped with respect to the farm price of barrows and gilts

The sheep and lamb production block is structurally similar to the other livestock production blocks The net returns for lambs positively influences the sheep breeding-herd inventory, and the number of sheep placed on feed is explained by lagged breeding-herd inventories Sheep production is positively sloped with respect to the farm price of lambs and negatively related to weighted feed-grain price The last three equations explain livestock imports of each livestock group.

## Livestock Demand Equations

Table 9 shows the livestock demands For domestic retail demands, we imposed the theoretical restrictions for final consumer demands Although each own price is highly significant, only pork demand is inelastic. The estimated income elasticities (2 07, -0 64, 0 37, 0 95) indicate that fed beef is a superior good whereas nonfed beef is an inferior good Arzac and Wilkinson (2) obtained similar results The last set of equations explains stock and export demands for the livestock sector of the model Each equation gives expected negative own-price effects

## Total Welfare Estimation by TECHSIM

Welfare measures in competitive markets have received considerable attention in recent years Mishan (8) demonstrated that in a partial equilibrium setting, producer surplus is a measure of industry quasi-rents (shortrun net returns) to fixed production factors of the industry In contrast to this partial equilibrium approach, Anderson (1) and, more recently, Just and Hueth derived welfare measures from both partial and general equilibrium (that is, all prices and quantities in the economy are allowed to vary) These studies considered only the case where the distortion results from direct

Weighted R-square for system = 0 99

Table 9—Livestock demand equations

| Block | Variable | Equation[1] |
|---|---|---|
| Domestic | log FBDD | −6 98 − 1 980 log PRFB + 0 501 log PRNFB − 0 381 log PRP<br>(−15 39) (4 57) (5 89)<br>+ 0 009 log PRL + 2 076 log I<br>(0 32) (26 53) |
| | log NFBDD | 9 412 + 2 105 log PRFB − 2 806 log PRNFB + 0 463 log PRP<br>(9 15) (−9 79) (3 64)<br>+ 0 048 log PRL − 0 644 log I<br>(1 13) (−2.47) |
| | log PDD | 1 731 + 0 241 log PRFB + 0 115 log PRNFB − 0 670 log PRP<br>(2 67) (1 46) (−10 23)<br>+ 0 038 log PRL + 0 371 log I<br>(1 82) (6 16) |
| | log SDD | 0 634 + 0 826 log PRFB + 0 513 log PRNFB + 0 700 log PRP<br>(1 00) (0 55) (1 50)<br>−3 829 log PRL + 0 952 log I<br>(−4 07) (0 99) |
| Stocks | log NFBSD | −0 829 log PRNFB + 1 198 log T<br>(−1 22) (3.31) |
| | log PSD | −178 72 − 0 457 log PRP + 0 635 log PRP(−1) + 24 1924 log T<br>(−0 60) (0 94) (1 25) |
| | log SSD | −1 263 log PRL + 1 877 log PRL(−1)<br>(−1 46) (2.16) |
| Exports | log NFBED | 4878.3 − 3.085 log PRNFB + 8 627 log FLPI − 641 189 log T<br>(−1 98) (3 25) (8 23) |
| | log PED | −683 95 − 1.766 log PRP + 91 842 T<br>(−1 74) (3 68) |

[1]Values in parentheses are t values

price alterations However, a number of policy questions do not pertain to direct price distortions, but rather to nonprice or technological changes that may result from changes in technology or Government regulations [9] Thus, Chavas and Collins derived welfare measures of a technological change in general equilibrium for related multiproduct and multifactor industries They found that an exact change in total welfare from a technological change in a general equilibrium framework for a multi-industry economy is given by

$$\Delta W = \Sigma_i^m \Delta T_{1i}^+ - \Sigma_i^n \Delta T_{1i}^- + \Delta I \qquad (5)$$

where $\Delta W$ is the exact change in total welfare, $\Delta T_{1i}^+$ is the change in technical rents of m outputs of industry 1, $\Delta T_{1i}^-$ is the change in technical rents of n inputs of industry 1, and $\Delta I$ is the change in consumer income

The results in equation (5) show that changes in total welfare can be derived from changes in consumer income and technical rents (defined as the area under the supply or demand curves) in the industry distorted, where all measurements are made in a general equilibrium setting For an econometric simulation model, equation (5) implies that if the general equilibrium equations are linear, then the technical rents measuring the change in total welfare are provided by [10]

$$\Delta W = \Sigma_i^m .5[y_{1i}(a_1) - y_{1i}(a_0)]\ [P_{1i}(a_1) + P_{1i}(a_0)] - \Sigma_i^n\ 5[x_{1i}(a_0)]\ [r_{1i}(a_1) + r_{1i}(a_0)] + I(a_1) - I(a_0) \qquad (6)$$

where $y_{1i}$, $x_{1i}$, $P_{1i}$, $r_{1i}$, and I are the respective output supply (m outputs), input demand (n inputs), output prices, input prices, and consumer income before and after the technical change in the parameter $a$

Thus, to evaluate the change in total welfare in the economy, we need information only on the general equilibrium prices and quantities in the distorted industry before and after the technological change and the change in consumer income If the consumer income effect is small or if it is neglected, then equation (6) is similar to the previous results of Harberger (5)

In the case of TECHSIM, technological changes within the firm can be reflected by changes in either yields or variable production costs of both field crop and livestock sectors [11] For TECHSIM, equation (5) implies that one can show the change in total welfare when the field crop sector is distorted in the following manner

$$\Delta W = \Sigma_j^{13} \Sigma_i^6\ 5[Q_{ij}(a_1) - Q_{ij}(a_0)]\ [P_i(a_1) + P_i(a_0)] - [A_{ij}(a_1) - A_{ij}(a_0)]\ [C_{ij}(a_1) + C_{ij}(a_0)] + I(a_1) - I(a_0) \qquad (7)$$

where $Q_{ij}$, $A_{ij}$, $C_{ij}$, $P_i$, and I are production, acreage planted, variable production cost of the ith crop in the jth region, field crop output prices, and consumer income respectively [12]

## Distribution of Welfare

Although equation (7) shows the total welfare impact, the distribution of rents is also computed. For example, the change in crop rent by region is simply the difference in net returns before and after the technological change We computed the change in industry rents for other agricultural sectors using the results of Just and Hueth for price distortions because prices will indirectly change following technological changes in the field crop sector [13] This implies that one can obtain the change in industry rents for soybean meal and the oil industry by taking first differ-

[9] A nonprice, or technological, distortion implies that the source of the distortion is not an exogenous price alteration In this context, all prices are assumed to be affected only indirectly, assuming profit maximization and perfect competition

[10] If the general equilibrium functions are nonlinear, then equation (5) provides only an approximation

[11] Note that the source of the change is directly attributed to nonprice distortions even though all prices will change indirectly

[12] The six field crops are i = 1 (corn), i = 2 (small grains), i = 3 (grain sorghum), i = 4 (cotton), i = 5 (cottonseed), and i = 6 (soybeans), respectively The 13 regions are depicted in the figure

[13] Just and Hueth show that one can obtain the kth industry rent by taking the difference between the consumer surplus of the kth industry and the consumer surplus of the k-1 industry or

$$\Delta\Pi_k = -\Delta CS_k + \Delta CS_{k-1}$$

where $\Delta CS$ is the change in consumer surplus for the respective markets

ences between consumer surpluses of soybean meal and oil and soybean crushings A similar procedure is used to compute cottonseed meal and oil industry rent. The remaining distribution of field crop sector rents is given by the change in consumer surpluses for field crops. We use these consumer surplus measures to calculate the sum of rents and final consumer surpluses beyond the farm gate for those industries using these crops as intermediate inputs and for those consumers ultimately consuming them

The distribution of rents to the livestock sector is given by the rents to each livestock group (fed beef, nonfed beef, pork, and sheep) One determines livestock wholesale and retail producer rents by taking first differences between the appropriate consumer surpluses. The last welfare measure is the sum of final consumer surpluses for livestock consumers

## Summary

Unlike most econometric models, the welfare measures for TECHSIM reflect both distribution of rents throughout the agricultural sector and the total welfare impact This model improves the basis for determining which group(s) within a sector gain(s) or lose(s) as a result of technological change The model also makes practical use of theory by incorporating *a priori* information on the structure of the agricultural sectors modeled during estimation [14] The next article applies the model to assess the welfare implications for boll weevil/cotton insect management

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## Appendix

Consider minimization of the following primal-dual problem

$$L^* = \Pi^* - \Pi$$

where $\Pi^*$ and $\Pi$ are the respective indirect and direct profit functions. From Silberberg (*9*), $L^*$ must

[14] The livestock sector has limited applications to policies affecting dairy and poultry because these sectors were not explicitly modeled

be positive semidefinite This implies that the following matrix must be semidefinite

$$\partial^2 L^*/\partial\pi_i\partial\pi_j = \begin{bmatrix} \partial^2 L^*/\partial\pi_1\partial\pi_1 & \partial^2 L^*/\partial\pi_1\partial\pi_n \\ \partial^2 L^*/\partial\pi_n\partial\pi_1 & \partial^2 L^*/\partial\pi_n\partial\pi_n \end{bmatrix} \quad \text{(A1)}$$

Hence, all principal minors of matrix (A1) must be nonnegative, these consist of the following typical elements

$$\partial^2 L^*/\partial\pi_i\partial\pi_j = \partial^2 \Pi^*/\partial\pi_i\partial\pi_j - \partial^2 \Pi/\partial\pi_i\partial\pi_j \quad \text{(A2)}$$

Silberberg has shown that equation (A2) is equivalent to

$$\partial^2 L^*/\partial\pi_i\partial\pi_j = \Sigma_k^n \, (\partial^2 \Pi/\partial\pi_i\partial A_k)\,(\partial A_k^*/\partial\pi_j) \quad \text{(A3)}$$

Equation (A3) involves the partial derivatives of the behavioral choice functions in equation (2) The conditions on the bordered Hessian determinants of the terms in (A1) place restrictions on the size and sign and also represent the known implications of the producer objective function in equation (1) Applying equation (A3), one obtains the following elements of matrix (A1)

$$\partial^2 L^*/\partial\pi_i\partial\pi_j = \begin{bmatrix} \partial A_1^*/\partial\pi_1 & \partial A_1^*/\partial\pi_n \\ \partial A_n^*/\partial\pi_1 & \partial A_n^*/\partial\pi_n \end{bmatrix} \quad \text{(A4)}$$

Positive semidefiniteness of matrix (A4) implies that the diagonal elements are nonnegative

$$\text{Own effect} \quad \partial A_i^*/\partial\pi_i \geqslant 0 \ \text{ for all } i \quad \text{(A5)}$$

Furthermore, because matrix (A4) is symmetric, one can add the following additional restrictions

$$\text{Symmetry} \quad \partial A_i^*/\partial\pi_j = \partial A_j^*/\partial\pi_i \ \text{ for all } i \neq j \quad \text{(A6)}$$