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

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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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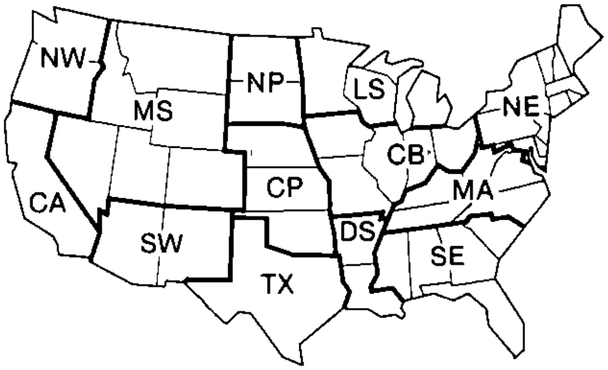
[1] The TECHSIM model and consultative input by its developers are currently made available to the Economic Research Service through Cooperative Research Agreement No 58-319V-2-00349 between the U S Department of Agriculture (USDA) and Montana State University The refinement and application of TECHSIM 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

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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

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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
$YCTl_i$	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
D1	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 Π is regional farm profit, π_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]

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

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

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[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]	$\Pi = \Sigma_i^n \pi_i A_i + \lambda[A_T - \Sigma_i^n A_i]$	$A_i^*(\pi_1, \quad , \pi_n, A_T)$	GL	$\partial A_i^* / \partial \pi_i \geqslant 0$	$\partial A_i^* / \partial \pi_j = \partial A_j^* / \partial \pi_i$
U S processors' supply and demand[3]	$\Pi = \Sigma_i^n r_i Q_i + \lambda F(Q)$	$Q_i^*(r_1, \quad , r_n)$	GL and LOG	$\partial Q_i^* / \partial r_i \geqslant 0$	$\partial Q_i^* / \partial r_j = \partial Q_j^* / \partial r_i$
Livestock					
U S farm supply[4]	$\Pi = \Sigma_i^n \theta_i L_i + \lambda[L_T - \Sigma_i^n L_i]$	$L_i^*(\theta_1, \quad , \theta_n, L_T)$	GL and LOG	$\partial L_i^* / \partial \theta_i \geqslant 0$	$\partial L_i^* / \partial \theta_j = \partial L_j^* / \partial \theta_i$
U S processors' supply and demand[5]	$\Pi = \Sigma_i^n w_i Z_i + \lambda F(Z)$	$Z_i^*(w_1, \quad , w_n)$	LOG	$\partial Z_i^* / \partial w_i \geqslant 0$	$\partial Z_i^* / \partial w_j = \partial Z_j^* / \partial w_i$
U S final demand[6]	$V = U(X) + \lambda[I - \Sigma_i^n P_i X_i]$	$X_i^*(P_1, \quad , P_n, I)$	LOG	$(\partial X_i^* / \partial P_i)\|_{\overline{U}} \leqslant 0$	$\partial X_i^* / \partial P_j + X_j^* \partial X_i^* / \partial I =$ $\partial X_j^* / \partial P_i + X_i^* \partial X_j^* / \partial I$

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[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] Π 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] Π 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 $Q_i \geqslant 0$ and inputs (production of field crops $Q_i = A_i Y_i$) $Q_i \leqslant 0$

[4] Π 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] Π 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 $Z_i \geqslant 0$ and livestock inputs $Z_i \leqslant 0$

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

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

$$\text{Symmetry} \quad \partial A_i^* / \partial \pi_j = \partial A_j^* / \partial \pi_i \quad \text{for all } i \neq j \tag{4}$$

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]

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

where γ_{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.

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

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

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-

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

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

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) (−1.39) (4.78)
	AG	1893.723 − 14.991 B21 + 0.606 AG(−1) (−1.39)
		Weighted R-square of system = 0.84
CA	AC	181.189 − 33.319 B14 + 0.521 AC(−1) (−6.28) (6.67)
	AG	1678.061 − 65.533 B23 + 0.304 AG(−1) (−3.04) (2.60)
	AGS	162.907 − 65.533 B32 + 0.115 AGS(−1) (−3.04) (5.68)
	ACT	118.717 − 33.319 B41 + 0.916 ACT(−1) (−6.28) (4.97)
		Weighted R-square for system = 0.93
MS	AC	938.176 − 666.184 B12 − 40.263 B13 (−4.68) (−0.92)
	AG	13832.550 − 666.184 B21 − 22.935 B23 (−4.68) (−0.34)
	AGS	365.935 − 40.263 B31 − 22.935 B32 (−0.92) (−0.34)
		Weighted R-square for system = 0.82
SW	AC	218.919 − 135.389 B13 (−6.54)
	AG	837.466 − 294.394 B24 + 0.497 AG(−1) (−7.27) (5.33)
	AGS	323.636 − 135.389 B31 + 0.492 AGS(−1) (−6.54) (2.97)
	ACT	491.599 − 294.394 B42 + 0.350 ACT(−1) (−7.27) (2.57)
		Weighted R-square for system = 0.67
CP	AC	1118.161 − 100.407 B14 + 0.844 AC(−1) (−2.00) (13.29)
	AG	3470.443 − 168.793 B23 − 520.051 B25 + 0.890 AG(−1) (−0.32) (−1.68) (11.09)
	AGS	8647.031 − 168.793 B32 − 2165.250 B52 (−0.33) (−4.47)
	ACT	437.985 − 100.407 B41 + 0.365 ACT(−1) (−2.00) (2.21)
	AS	3142.660 − 520.051 B52 − 2165.250 B53 + 0.589 AS(−1) (−1.68) (−4.29) (5.51)
		Weighted R-square for system = 0.94
NP	AC	2458.633 − 164.855 B13 + 0.142 AC(−1) (−3.38) (0.643)
	AG	2247.571 − 172.139 B25 + 0.899 AG(−1) (−1.40) (5.51)
	AGS	302.357 − 164.855 B31 + 0.354 AGS(−1) (−3.38) (2.03)
	AS	324.679 − 172.139 B52 + 0.639 AS(−1) (−1.40) (4.67)
		Weighted R-square for system = 0.56
TX	AC	−84.062 + 2.912 NRC(−1) + 0.959 AC(−1) (5.86) (14.87)
	AG	778.287 − 289.193 B25 + 0.969 AG(−1) (−3.81) (5.55)
	AGS	7594.079 − 897.729 B34 − 7.414 T (−1.78) (−0.22)
	ACT	3468.213 − 897.729 B43 − 0.478 ACT(−1) (−1.78) (3.34)

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Table 4—Regional acreage equations (Continued)

Region	Variable	Equation[1]
	AS	$-618.208 - 289.193\ B52 + 0.586\ AS(-1) + 13.311\ T$ (−3.66) (4.20) (1.84)
		Weighted R-square for system = 0.96
LS	AC	$3825.292 - 1235.66\ B12 - 1344.27\ B15 + 0.839\ AC(-1)$ (−1.74) (−1.85) (5.68)
	AG	$10704.510 - 1235.66\ B21 - 1456.42\ B25 + 0.167\ AG(-1)$ (−1.74) (−2.39) (0.90)
	AS	$3200.874 - 1344.27\ B51 - 1456.42\ B52 + 0.861\ AS(-1)$ (−1.85) (−2.39) (6.61)
		Weighted R-square for system = 0.60
CB	AC	$25590.870 - 1087.35\ B12 - 14669.80\ B15 + 0.688\ AC(-1)$ (−1.78) (−5.43) (6.07)
	AG	$12460.780 - 1087.35\ B21 - 3517.97\ B25 + 0.457\ AG(-1)$ (−1.78) (−6.08) (9.77)
	AGS	$-39.831 + 5.759\ NRGS(-1) + 0.605\ AGS(-1)$ (1.95) (3.67)
	AS	$18105.870 - 14669.80\ B51 - 3517.97\ B52 + 0.997\ AS(-1)$ (−5.43) (−6.08) (11.90)
		Weighted R-square for system = 0.91
DS	log AC	$0.193 + 0.064 \log NRC(-1) + 0.938 \log AC(-1)$ (1.37) (21.03)
	AG	$987.851 - 262.371\ B23 + 0.303\ AG(-1)$ (−2.87) (2.10)
	AGS	$369.159 - 262.371\ B32 + 0.600\ AGS(-1)$ (−2.87) (4.20)
	ACT	$3624.093 - 1131.01\ B54 + 0.129\ ACT(-1)$ (−3.59) (1.14)
	AS	$3465.740 - 1131.01\ B54 + 0.834\ AS(-1)$ (−3.59) (16.35)
		Weighted R-square for system = 0.93
SE	AC	$3526.471 - 184.825\ B15$ (−4.05)
	AG	$464.003 + 9.846\ NRG(-1) + 0.359\ AG(-1)$ (−1.50) (2.38)
	AGS	$49.511 - 10.481\ B34 + 0.418\ AGS(-1)$ (−4.26) (8.11)
	ACT	$370.777 - 10.481\ B43 + 0.660\ ACT(-1)$ (−4.26) (4.55)
	AS	$486.319 - 184.825\ B51 + 0.967\ AS(-1)$ (−3.82) (12.39)
		Weighted R-square for system = 0.87
MA	AC	$1728.898 - 80.570\ B13 - 417.708\ B15 + 0.702\ AC(-1)$ (−1.84) (−1.76) (6.13)
	AG	$200.835 - 129.432\ B24 + 0.092\ AG(-1)$ (−4.30) (0.66)
	AGS	$280.877 - 80.570\ B31 - 150.814\ B35 + 0.711\ AGS(-1)$ (−1.84) (−3.11) (5.06)
	ACT	$271.224 - 129.432\ B42 + 0.660\ ACT(-1)$ (−4.30) (5.34)
	AS	$-5706.940 - 417.708\ B51 - 150.814\ B53 + 0.565\ AS(-1) + 113.899\ T$ (−1.68) (−2.96) (3.45) (3.22)
		Weighted R-square for system = 0.92
NE	AC	$923.411 - 344.238\ B12 + 0.677\ AC(-1)$ (−4.55) (3.29)
	AG	$1139.900 - 344.238\ B21 + 0.694\ AG(-1)$ (−4.55) (7.93)
	AS	$-22.238 + 2.042 + 0.867\ AS(-1)$ (4.35) (9.48)
		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 + 35.338 T (1.12) (7.36)
	GSD	−98821.800 + 60.990 AG + 50.823 T (4.72) (2.20)
	GSSD	−826.804 + 2.566 AGS + 0.460 T (2.60) (1.35)
	CTSSD	3838.336 + 14.523 ACT − 1.758 T (2.46) (−0.56)
	SBSD	13.911 + 0.825 AS (7.57)
		Weighted R-square for system = 0.85
Food	CFDD	−8240.090 − 3.113 PC − 0.219 EXP + 4.289 T (−1.35) (−6.25) (10.66)
	GFDD	−1246.210 − 2.927 PG − 0.098 EXP + 0.755 T (−3.28) (−3.92) (2.94)
	GSFDD	224.870 − 0.734 PGS − 0.006 EXP − 0.110 T (−1.88) (−1.50) (−1.83)
	CTSOFDD	20.017 − 0.084 PCTSO − 0.031 EXP (−0.76) (−4.28)
	SBOFDD	−1822.450 − 0.042 PSBO + 0.026 EXP + 0.934 T (−0.41) (1.63) (4.92)
		Weighted R-square for system = 0.93
Export	CED	−578684.000 − 18689.100 PC + 54797.350 D1 + 329.766 T (−3.09) (7.54) (0.45)
	GED	26588.800 − 1095.320 PG + 39565.980 D1 (−0.45) (11.59)
	GSED	−92888.800 + 11960.020 PC − 14669.800 PGS + 4333.833 D1 (2.21) (−2.26) (1.45)
Stock	CPSD	512270.300 − 21101.700 PC − 216.227 T (−5.69) (−0.61)
	GPSD	−3064436.00 − 15616.100 PG + 1597.586 T (−5.02) (3.26)
	GSPSD	−93163.90 − 3028.210 PGS + 52.424 T (−2.09) (0.44)
		Weighted R-square for system = 0.81
Cotton	CTLMD	10.450 − 0.300 PCTL + 0.021 EXP + 0.127 POLY (−2.40) (0.58) (2.70)
	CTLED	168455.600 − 71.947 PCTL + 148.116 PFCT − 34.803 WCTS − 85.400 T (−1.65) (1.97) (−0.50) (−0.95)
	CTLPSD	49617.700 − 48.208 PCTL + 185.543 WCTS + 219.888 CTLR − 255.650 T (−0.41) (0.94) (1.52) (−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 (−10 40) (4 80) (5 81) (18 34)
	SBPSD	−1154555 0 − 689 595 PSB − 0 124 SBGS + 0 184 SBPSD(−1) + 590 254 T (−0 76) (−1 15) (0 92) (2 45)
	SBED	−3456061 0 − 1534.45 PSB + 27 276 PFM + 1767 681 T (−2 54) (4.42) (11 47)
	SBMED	−1001169 0 − 318 354 PSBM + 12.848 PFM + 511 646 T (−0 57) (1 10) (8.11)
	SBOPSD	−73858 2 − 45 709 PSBO + 38 116 T (−3 04) (2 65)
	SBOED	−38850 0 − 2 640 PSBO − 0 124 SBOPL + 20 417 T (−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 (−1 71) (3 26) (36 46) (−5.64)
	CTSPSD	−134558 0 + 0 114 CTSP + 68 041 T (3 93) (4 86)
	CTSED	−9021 92 − 1 195 PCTS + 0 051 PFM + 4 606 T (−0 11) (0 36) (2 09)
	CTSMPSD	448 388 − 47 78 PCTSM (−1 49)
	CTSMED	−3892 89 − 57 807 PCTSM + 0 916 PFM + 2 044 T (−1 13) (1 55) (0 34)
	CTSOPSD	53321 89 − 7 749 PCTSO + 14 086 PSBO − 26 981 T (−3 43) (2 29) (3 84)
	CTSOED	−81185 4 − 45 299 PCTSO + 53 019 PSBO + 2.143 CTSOPL + 41 384 T (−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 (1 23) (4 34) (1 93) +3764 42 B15 + 17314 25 B16 + 2963 23 T (0 46) (0.96) (3 28)
	GFD	1216868 0 + 20046 4 B21 − 3162 01 B23 + 7762 688 B24 − 7235 78 B25 (1 23) (0 41) (2 94) (−2 01) + 9068 263 B26 − 618 38 T
	GSFD	(1 68) (−2 40)
	GSFD	−124649.0 + 74962 29 B31 − 3162 01 B32 − 18870 1 B34 (4 34) (0 41) (−2 81) + 4907 73 B35 + 17407 81 B36 + 590 35 T (1 08) (3 83) (2 47)
Meals	CTSMFD	−9401 66 + 12389 48 B41 + 7762 69 B42 − 18870 1 B43 (2 04) (3 10) (−2 96) + 9517 17 B45 + 380 62 B46 (3 08) (0 35)
	SBMFD	−1399818 0 + 3764 42 B51 − 7235 78 B52 + 4907 73 B53 (0 46) (−2.01) (1 08) + 9517 17 B54 + 2427 71 B56 + 715 51 T (2 92) (0 79) (6 71) Weighted R-square for system = 0 84

[1] Values in parentheses are t-values, and $B_{ij} = (P_j/P_i)^{1/2}$ 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

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[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) (2 40) (28 34)
	FBP	0 5858 FBPP (28.34)
	PFFB	0 3004 PRFB (96 82)
	NFBPP[2]	10108 640 CONFB + 683 459 RCI(–1) (5 20) (11 19)
	NFBP	0 5834 NFBPP (450 07)
	PFNFB	0 3073 PRNFB (42 43)
	CPOF[3]	38 986 – 37 408 R12 + 0.878 CPOF(–1) (–4 74) (20 58)
	RCI[3]	42 023 – 37 408 R21 + 0 754 RCI(–1) (–4 74) (14 05) Weighted R-square for system = 0 99
Pork	PPP[2]	–11209 5 COP + 311 803 POF(–1) + 4 217 T (9.57) (4 50)
	PP	0 638 PPP (74 81)
	POF	3.799 SFAR + 0 051 POF(–1) (15 65) (0 84)
	SFAR	0 022 NRBG(–1) + 0 466 SFAR(–1) + 0 591 PPLIT (1 82) (2 71) (1 31)
	PFP	0.314 PRP (38 36) Weighted R-square for system = 0 99
Sheep	SPP[2]	96 625 – 1018 62 COS + 437 79 SPOF(–1) (–2.23) (19 21)
	SP	0 488 SPP (742 83)
	SPOF	0 153 SBHI(–1) (64.11)
	PLF	0 256 PRL (72 69)
	log SBHI	891 856 + 0 922 log NRL(–1) – 117 76 T (2.82) (43 55) Weighted R-square for system = 0 99
Imports	log NFBI	0 201 log PRNFB(–1) + 0.895 log NFBI(–1) (1 10) (8 86)
	log PI	0 155 log PRP(–1) + 0 897 log PI(–1) (1.93) (15 56)
	log NSI	0 058 log PRL(–1) + 0 916 log NSI(–1) (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 (−15 39) (4 57) (5 89) + 0 009 log PRL + 2 076 log I (0 32) (26 53)
	log NFBDD	9 412 + 2 105 log PRFB − 2 806 log PRNFB + 0 463 log PRP (9 15) (−9 79) (3 64) + 0 048 log PRL − 0 644 log I (1 13) (−2.47)
	log PDD	1 731 + 0 241 log PRFB + 0 115 log PRNFB − 0 670 log PRP (2 67) (1 46) (−10 23) + 0 038 log PRL + 0 371 log I (1 82) (6 16)
	log SDD	0 634 + 0 826 log PRFB + 0 513 log PRNFB + 0 700 log PRP (1 00) (0 55) (1 50) −3 829 log PRL + 0 952 log I (−4 07) (0 99)
Stocks	log NFBSD	−0 829 log PRNFB + 1 198 log T (−1 22) (3.31)
	log PSD	−178 72 − 0 457 log PRP + 0 635 log PRP(−1) + 24 1924 log T (−0 60) (0 94) (1 25)
	log SSD	−1 263 log PRL + 1 877 log PRL(−1) (−1 46) (2.16)
Exports	log NFBED	4878.3 − 3.085 log PRNFB + 8 627 log FLPI − 641 189 log T (−1 98) (3 25) (8 23)
	log PED	−683 95 − 1.766 log PRP + 91 842 T (−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

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

where ΔW is the exact change in total welfare, ΔT_{li}^+ is the change in technical rents of m outputs of industry l, ΔT_{li}^- is the change in technical rents of n inputs of industry l, and ΔI 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]

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

where y_{li}, x_{li}, P_{li}, r_{li}, 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

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

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-

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[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 ΔCS 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

References

(1) Anderson, J E "A Note on Welfare Supluses and Gains from Trade in General Equilibrium," *American Economic Review*, Vol 64, 1974, pp 758-62

(2) Arzac E R , and Maurice Wilkinson. "A Quarterly Econometric Model of United States Livestock and Feed Grain Markets and Some of its Policy Implications," *American Journal of Agricultural Economics*, Vol 61, 1979, pp 297-308

(3) Chavas, J. P , and Glenn S Collins "Welfare Measures from Technological Distortions in General Equilibrium," *Southern Economic Journal*, Vol 48, 1982, pp 745-53

(4) Diewert, W. E "Functional Forms for Profit and Transformation Functions," *Journal of Economic Theory*, Vol 6, 1973, pp 284-316

(5) Harberger, A C "Three Basic Postulates for Applied Welfare Economics An Interpretive Essay," *Journal of Economic Literature*, 1971, pp 785-97

(6) Jarvis, Lovell S "Cattle as Capital Goods and Ranchers as Portfolio Managers An Application to the Argentine Cattle Sector," *Journal of Political Economy*, May-June 1974, pp 489-520

(7) Just, Richard E , and D L Hueth "Welfare Measures in Multi-Market Framework," *American Economic Review*, Vol 69, 1979, pp 947-54

(8) Mishan, E J "What is Producer Surplus," *American Economic Review*, Vol 58, 1968, pp 1269-82

(9) Silberberg, E "A Revision of Comparative Statics Methodology in Economics, or How to Do Comparative Statics on the Back of an Envelope," *Journal of Economic Theory*, Vol 7, 1974, pp 159-72

(10) Zellner, A. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," *Journal of the American Statistical Association*, Vol 57, 1962, pp 348-68

Appendix

Consider minimization of the following primal-dual problem

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

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

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[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

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

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

$$\partial^2 L^*/\partial\pi_i\partial\pi_j = \partial^2 \Pi^*/\partial\pi_i\partial\pi_j - \partial^2 \Pi/\partial\pi_i\partial\pi_j \qquad (A2)$$

Silberberg has shown that equation (A2) is equivalent to

$$\partial^2 L^*/\partial\pi_i\partial\pi_j = \Sigma_k^n \, (\partial^2 \Pi/\partial\pi_i\partial A_k)\,(\partial A_k^*/\partial\pi_j) \qquad (A3)$$

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)

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

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

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

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

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