OPTIMUM RESOURCE ALLOCATION FOR SELECTED U. S. AGRICULTURAL COMMODITIES*

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The commercial farm problem is often defined as a disequilibrium condition in which agriculture's productive capacity exceeds utilization at socially acceptable prices [6]. However, commodity supplies are determined by the level and composition of resources committed to their production. While the commercial farm problem surfaces as a production-utilization disequilibrium, basically it is a resource imbalance problem.

Resource imbalances in agriculture result in an inefficient organization of the industry. To be efficient, resource use in the farm industry must satisfy three conditions [4]:

1. the allocation of resources among agricultural and non-agricultural products must result in output and price levels that reward identical resources equally,
2. the use of resources in agriculture must result in a product mix geared to the relative demands for different products, and
3. each farm product must be produced at minimum factor cost.

The research reported in this paper focuses on the last efficiency condition. More specifically, we estimate the level and combination of resources for historical production levels of feed grains, wheat, soybeans, cotton and tobacco that minimize factor cost.

A series of Cobb-Douglas production functions were developed for each of the five crops in a previous study by Ray [2]. Factor share data were used by Ray to estimate production elasticities for nine input groups in four time periods beginning in 1930 for each crop. The elasticity estimates were then used to construct the crop production functions. The estimated parameters of the functions are used in this study to normatively determine the optimum level and combinations of resources for specified crop outputs. In addition, two other sets of normative calculations are made; (1) product supply elasticities, and (2) factor demand elasticities. The classical assumptions used in normative analyses are made here including profit maximization and perfect resource mobility. Hence, the reported resource levels and elasticity estimates of demand and supply represent benchmark or maximum response estimates.

The input categories and their respective elasticity estimates for four time periods for each of the five crops are presented in Table 1. The imputed intercepts which complete the production function specifications also appear in Table 1. The estimation procedure used to calculate the elasticities and constant terms was developed by Tyner and Tweeten [5]. Briefly, the procedure to estimate the production elasticities is as follows. Factor shares are used as initial elasticity estimates. However, factor shares are valid estimates of partial production elasticities for the power production function only if economic equilibrium prevails. An adjustment model, suggested by Tyner and Tweeten, is used to correct the elasticity estimates for divergence from the equilibrium position. Estimates of standard errors for the production elasticities are not possible as part of this procedure. The intercept is estimated with least squares using the predicted values of the estimated power function (less the constant term) as the sole regressor. The regressions to estimate the intercept terms facilitates a measure of the goodness of fit of the production functions. The R^2 values for all production function relationships were .98 or .99.

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Table 1. ESTIMATES OF PRODUCTION ELASTICITIES AND INTERCEPTS FOR PRODUCTION FUNCTIONS FOR FEED GRAINS, WHEAT, SOYBEANS, COTTON AND TOBACCO FOR SELECTED PERIODS.

Crop and period	Fertilizer	Seed	Labor	Machinery	Real estate	Fuel, oil repairs	Misc.	Int.	Real estate tax	Intercept[a]
Feed Grains										
1930-39	.03243	.03939	.28743	.20900	.24063	.14243	.06989	.04776	.05665	.06320*
1940-49	.04486	.03434	.18963	.12227	.10796	.11465	.03860	.04002	.01880	11.07778
1950-58	.08321	.03903	.12936	.26726	.17451	.18028	.06271	.04156	.03357	.15513
1959-67	.13257	.03479	.08478	.26219	.29539	.15898	.10000	.04558	.05673	.06593
Wheat										
1930-39	.03327	.10712	.16947	.12740	.24783	.11129	.07631	.02159	.05353	6.97984*
1940-49	.02755	.06657	.11183	.07586	.10996	.09281	.04091	.02159	.01896	50.12276*
1950-58	.04563	.06706	.07606	.15052	.15638	.13657	.06014	.01996	.02826	22.03056*
1959-67	.07591	.05735	.06768	.20694	.27100	.16005	.10491	.02148	.04729	5.51658*
Soybeans										
1930-39	.00760	.12419	.11918	.14939	.18878	.10507	.10876	.01631	.04679	5.83512*
1940-49	.00807	.07615	.07615	.09074	.08768	.08866	.03608	.01777	.01557	30.84373*
1950-58	.01716	.07046	.07110	.20449	.14599	.14698	.04724	.01987	.02601	17.47182
1959-67	.02292	.05864	.07099	.21233	.14771	.08874	.02165	.02165	.03608	7.49232
Cotton										
1930-39	.08028	.02930	.59900	.08157	.29961	.10179	.23047	.01381	.05439	.00126*
1940-49	.04843	.01850	.43399	.05491	.11398	.09420	.11888	.00704	.01284	.04502*
1950-58	.05498	.01319	.30093	.07483	.14163	.09426	.12674	.00887	.01521	.10002
1959-67	.06529	.01298	.22691	.09111	.25292	.10004	.19043	.09935	.02545	.06230
Tobacco										
1930-39	.06041	--[b]	.38559	.01978	.28661	.06364	.09763	.02981	.03977	11.75250
1940-49	.04570	--[b]	.34342	.01386	.13224	.06521	.05163	.01654	.01362	49.80891*
1950-58	.03709	--[b]	.32368	.02045	.16542	.06384	.06375	.06375	.01362	49.47014*
1959-67	.03034	--[b]	.30764	.02079	.20103	.05518	.07527	.01006	.01599	48.58644

[a]Constant terms indicated by * were calculated under multiple error assumptions. All others were calculated under additive error assumptions. The R^2 values for all functions were .98 or greater. The factor share procedure for calculating the production elasticities does not include a means for calculating standard errors.

[b]Seed expense for tobacco is included in the miscellaneous category so no production elasticities for tobacco were calculated.

Details on the estimation methods and a complete listing of data and sources can be found in Ray [2].

The labor elasticity of production has declined between 1930-1939 and 1959-1967 for all crops. Generally, during the 37-year period, the productivity estimates for fertilizer, machinery, fuel, oil and repairs and miscellaneous inputs have increased. The real estate elasticities of production for the four periods exhibit a u-shape. The elasticities are similar for the 1930-1939 and the 1959-1967 periods but dip sharply during the forties and rise somewhat in the 1950-1958 period. Also, the estimated productivities of machinery, fuel and machinery operating expenses, miscellaneous expense, and real estate taxes deviate from their general upward trend during the 1940-1949 period. Due to war-induced scarcity of inputs and high crop prices during the forties, factor share estimates may have underestimated input productivities during the 1940-1949 period.

MINIMUM COST INPUT LEVELS

The elasticity estimates and intercept terms provide the framework to calculate the minimum-cost quantities of inputs which will provide specified output levels. In general terms, the values in Table 1 provide estimates for the function:

$$PROD = a\ FERT^{b1}\ SEED^{b2}\ LABR^{b3}\ MACH^{b4}\ RE^{b5}\ FOR^{b6}\ MISC^{b7}\ INT^{b8}\ RETX^{b9}$$

where PROD is production, a is the intercept, the capital symbols on the right of the equation are abbreviations for the input categories listed in Table 1 and the b_i are elasticities of production for the respective inputs.

A computer program written by Wilson and Billingsley [8] was used to calculate the least-cost resource combination for the production of specified crop outputs. The program minimizes the sum of input quantities times their respective prices subject to the production function and specified output restraints.

Optimal input combinations to produce the actual average output of each period for the five commodities were calculated with (1) all inputs variable and (2) with real estate levels fixed. The optimum levels of inputs, allowing all inputs to vary, are given in Table 2.

Comparisons of the least-cost input levels (0)

Table 2. ESTIMATED OPTIMAL LEVELS OF INPUTS REQUIRED FOR AVERAGE ACTUAL OUTPUT OF FEED GRAINS, WHEAT, SOYBEANS, COTTON AND TOBACCO, FOR SELECTED TIME PERIODS, ALL INPUTS VARIABLE, WITH AVERAGE ACTUAL INPUTS FOR COMPARISON.

Input	Item[a]	Commodity Group				
		Feed Grains	Wheat	Soybeans	Cotton	Tobacco
		Million 1947-1949 Dollars				
Fertilizer						
1932-1939	O	68.1	24.5	0.5	61.6	16.9
	A	55.0	19.8	0.4	59.3	16.6
1940-1949	O	219.1	51.9	3.3	72.7	33.5
	A	189.9	46.3	2.8	72.9	33.3
1950-1958	O	400.7	87.4	13.2	120.0	39.1
	A	476.0	105.8	15.2	138.6	45.3
1959-1967	O	604.3	114.1	29.6	97.6	30.9
	A	1021.9	207.4	47.7	180.9	51.7
Seed						
1932-1939	O	82.8	78.8	7.4	22.5	--[c]
	A	157.3	151.6	10.7	70.9	--[c]
1940-1949	O	167.7	125.5	31.4	27.8	--[c]
	A	206.9	160.3	39.8	41.1	--[c]
1950-1958	O	188.0	128.4	54.1	28.8	--[c]
	A	235.9	149.9	70.9	36.4	--[c]
1959-1967	O	158.6	86.2	75.7	19.4	--[c]
	A	212.1	140.1	188.5	27.6	--[c]
Labor[b]						
1932-1939	O	4136.3	725.0	66.0	3734.6	878.8
	A	2797.4	485.9	27.9	2857.6	632.1
1940-1949	O	2594.2	486.8	101.2	2255.6	820.6
	A	2279.1	407.3	84.4	1972.5	727.8
1950-1958	O	897.6	187.9	94.8	1083.4	640.0
	A	1163.0	241.6	99.2	1276.3	703.6
1959-1967	O	421.9	109.9	119.7	457.8	458.3
	A	604.6	145.2	148.7	605.2	536.8
Machinery						
1932-1939	O	439.1	93.7	8.8	62.6	5.5
	A	480.4	101.5	7.8	76.9	6.6
1940-1949	O	597.2	143.0	37.4	82.5	10.2
	A	605.5	139.6	37.9	89.6	11.1
1950-1958	O	1287.0	288.2	157.1	163.5	21.6
	A	1108.6	255.5	138.9	135.9	17.2
1959-1967	O	1195.1	311.0	297.4	136.2	21.2
	A	959.6	246.6	247.1	100.5	15.3
Real estate						
1932-1939	O	505.6	182.4	11.2	230.0	80.3
	A	546.1	182.6	9.1	263.3	101.4
1940-1949	O	527.3	207.3	36.2	171.2	97.0
	A	611.8	235.6	40.8	213.5	120.1
1950-1958	O	840.4	299.4	112.1	309.0	174.4
	A	758.0	266.2	108.9	264.7	154.7
1959-1967	O	1346.4	407.3	274.2	378.1	204.9
	A	1019.0	319.1	233.5	277.5	157.6
Fuel, oil, repairs						
1932-1939	O	299.2	81.9	6.2	78.1	17.8
	A	266.1	74.7	4.8	77.7	18.3
1940-1949	O	559.9	174.9	36.5	141.5	47.8
	A	566.8	175.1	38.5	156.4	53.1
1950-1958	O	868.2	261.5	112.9	205.7	67.3
	A	852.0	257.6	114.2	190.2	62.6
1959-1967	O	724.7	240.6	190.8	149.6	56.2
	A	772.1	259.1	207.4	148.0	57.7
Miscellaneous						
1932-1939	O	146.8	56.2	6.4	176.7	27.4
	A	164.7	57.6	6.4	214.3	34.4
1940-1949	O	188.5	77.1	14.9	178.6	37.9
	A	199.8	80.3	17.6	201.6	42.6
1950-1958	O	302.0	115.2	36.3	276.5	67.2
	A	292.7	108.6	37.8	256.7	62.5
1959-1967	O	455.8	157.7	114.6	284.7	76.7
	A	487.3	170.0	119.2	297.7	79.6
Interest on stocks						
1932-1939	O	100.3	15.9	1.0	10.6	8.4
	A	190.7	30.0	1.6	26.3	15.6
1940-1949	O	195.5	40.7	7.3	10.6	12.1
	A	264.8	51.7	9.6	15.4	14.0
1950-1958	O	200.1	38.2	15.3	19.4	9.4
	A	290.9	47.6	23.0	20.3	9.2
1959-1967	O	207.8	32.3	28.0	14.0	10.3
	A	384.4	53.0	43.3	20.9	8.8
Real estate taxes						
1932-1939	O	119.0	39.4	2.8	41.7	11.1
	A	128.4	39.0	2.1	52.2	14.8
1940-1949	O	91.8	35.7	6.4	19.3	7.8
	A	108.4	41.2	7.1	25.3	10.6
1950-1958	O	161.7	54.1	20.0	33.2	14.4
	A	145.6	48.0	20.1	29.0	12.9
1959-1967	O	258.6	71.1	46.6	38.0	16.3
	A	222.0	63.4	45.6	31.8	13.6
Average Output		Mil. Tons	Mil. Bu.	Mil. Bu.	Mil. Bales	Mil. lbs.
1932-1939		78.6	703.5	41.6	12.7	1346.8
1940-1949		106.2	1064.2	179.9	12.0	1685.0
1950-1958		118.7	1091.8	391.2	13.4	2076.9
1959-1967		151.7	1264.1	731.9	13.4	2044.7

[a] O is the optimal level; A is the actual average for the time period and commodity indicated.
[b] Labor is in million man-hours.
[c] Seed expense for tobacco is included in the miscellaneous category.

Table 3. ESTIMATED OPTIMAL LEVELS OF INPUTS REQUIRED FOR AVERAGE ACTUAL OUTPUT OF FEED GRAINS, WHEAT, SOYBEANS, COTTON AND TOBACCO FOR SELECTED TIME PERIODS, REAL ESTATE FIXED, WITH AVERAGE ACTUAL INPUTS FOR COMPARISON.

Input	Item[a]	Commodity Group				
		Feed Grains	Wheat	Soybeans	Cotton	Tobacco
		Million 1947-1949 Dollars				
Fertilizer						
1932-1939	0	66.7	24.5	0.5	59.5	15.4
	A	55.0	19.8	0.4	59.3	16.6
1940-1949	0	213.3	50.3	3.2	70.5	31.8
	A	189.9	46.3	2.8	72.9	33.3
1950-1958	0	409.4	90.2	13.3	123.8	40.6
	A	476.0	105.8	15.2	138.6	45.3
1959-1967	0	663.8	124.7	31.1	108.8	34.2
	A	1021.9	207.4	47.7	180.9	51.7
Seed						
1932-1939	0	81.0	78.8	7.8	21.7	--[c]
	A	157.3	151.6	10.7	70.9	--[c]
1940-1949	0	163.3	121.7	30.6	26.9	--[c]
	A	206.9	160.3	39.8	41.1	--[c]
1950-1958	0	192.0	132.5	54.5	29.7	--[c]
	A	235.9	149.9	70.9	36.4	--[c]
1959-1967	0	174.2	94.2	79.6	21.6	--[c]
	A	212.1	140.1	188.5	27.6	--[c]
Labor[b]						
1932-1939	0	4050.4	724.7	69.9	3608.7	798.6
	A	2797.4	485.9	27.9	2857.6	632.1
1940-1949	0	2526.1	472.0	98.6	2184.8	779.3
	A	2279.1	407.3	84.4	1972.5	727.8
1950-1958	0	917.1	193.9	95.5	1118.5	664.5
	A	1163.0	241.6	99.2	1276.3	703.6
1959-1967	0	463.5	120.1	125.9	510.2	507.7
	A	604.6	145.2	148.7	605.2	536.8
Machinery						
1932-1939	0	430.0	93.7	9.4	60.4	5.0
	A	480.4	101.5	7.8	76.9	6.6
1940-1949	0	581.5	138.6	36.4	79.9	9.7
	A	605.5	139.6	37.9	89.6	11.1
1950-1958	0	1315.0	297.4	158.2	168.5	22.4
	A	1108.6	255.5	138.9	135.7	17.2
1959-1967	0	1312.9	340.1	312.8	151.8	23.5
	A	959.6	246.6	247.1	100.5	15.3
Real Estate						
1932-1939	A	546.1	182.6	9.1	263.3	101.4
1940-1949	A	611.8	235.6	40.8	213.5	120.1
1950-1958	A	758.0	266.2	108.9	264.7	154.7
1959-1967	A	1019.0	319.1	233.5	277.5	157.6
Fuel, oil, repairs						
1932-1939	0	293.0	81.9	6.6	75.4	16.2
	A	266.1	74.4	4.8	77.7	18.3
1940-1949	0	545.2	169.6	35.6	137.1	45.4
	A	566.8	175.1	38.5	156.4	53.1
1950-1958	0	887.0	269.9	113.7	212.3	69.9
	A	852.0	257.6	114.2	190.2	62.6
1959-1967	0	796.1	263.0	200.6	166.7	62.3
	A	772.1	259.1	207.4	148.0	57.7
Miscellaneous						
1932-1939	0	143.8	56.1	6.8	170.8	24.9
	A	164.7	57.6	6.4	214.3	34.4
1940-1949	0	183.6	74.8	14.5	173.0	36.0
	A	199.8	80.3	17.6	201.6	42.6
1950-1958	0	308.5	118.8	36.5	285.5	69.8
	A	292.7	108.6	37.8	256.7	62.5
1959-1967	0	500.7	172.4	120.5	317.3	85.0
	A	487.3	170.0	119.2	297.7	79.6
Interest on stocks						
1932-1939	0	98.3	15.9	1.0	10.2	7.6
	A	190.7	30.0	1.6	26.3	15.6
1940-1949	0	190.3	39.5	7.1	10.2	11.5
	A	264.8	51.7	9.6	15.4	14.0
1950-1958	0	204.5	39.4	15.4	20.0	9.7
	A	290.9	47.6	23.0	20.3	9.2
1959-1967	0	228.2	35.3	29.4	15.6	11.4
	A	384.4	53.0	43.3	20.9	8.8
Real estate taxes						
1932-1939	0	116.6	39.4	2.9	40.3	10.1
	A	128.4	39.0	2.1	52.2	14.8
1940-1949	0	89.4	34.6	6.2	18.7	7.4
	A	108.4	41.2	7.1	25.3	10.6
1950-1958	0	165.2	55.8	20.1	34.3	14.9
	A	145.6	48.0	20.1	29.0	12.9
1959-1967	0	284.1	77.7	49.0	42.4	18.0
	A	222.0	63.4	45.6	31.8	13.6
Average output		Mil. Ton	Mil. Bu.	Mil. Bu.	Mil. Bales	Mil. lbs.
1932-1939		78.6	703.5	41.6	12.7	1346.8
1940-1949		106.2	1064.2	179.9	12.0	1685.0
1950-1958		118.7	1091.8	391.2	13.4	2076.9
1959-1967		151.7	1264.1	731.9	13.4	2044.7

[a] 0 is the optimal level; A is the actual average for the time period and commodity indicated.

[b] Labor is in million man-hours.

[c] Seed expense for tobacco is included in the miscellaneous category.

with actual levels (A) for the 1950-1958 and 1959-1967 time periods indicate that increased machinery investment and large use of the real estate input allow a decline in the use of the remaining inputs. Declines of 25 to 30 percent in labor usage are noted for the 1959-1967 period. Actual levels of fertilizer approximate the optimal levels for 1950-1958, but actual fertilizer levels are much larger than the programmed optimums during the 1959-1967 period. This was an unexpected result and may suggest that the fertilizer production elasticities were underestimated. Optimal real estate input estimates increase considerably from the 1932-1939 to the 1959-1967 periods even though acreages for each of the crops during this time declines except for soybeans. Undoubtedly, the adoption of land-improvement practices including irrigation, drainage and terracing accounts for an important portion of the increase in land productivity. Given the fixed nature of land, it would be desirable to have separate productivity estimates for land and improvements. As an alternative to separate estimates, the real estate input was held constant in the calculation of the optimal input levels presented in Table 3.

Optimal fertilizer levels exceeded actual use during 1932-1939 and 1940-1949, but during the last two periods actual usage surpassed optimal quantities. Apparently, some of the productivity of fertilizer has been confounded with the productivity estimates of other inputs. Least-cost use of resources calls for a considerable increase in machinery use and moderate increases in fuel, oil, and repairs and in miscellaneous inputs during 1950-1958 and 1959-1967. Actual machinery inputs for the 1959-1967 period were over 30 percent below optimum levels for all crops except soybeans in which machinery inputs were 21 percent short of the optimum level. Machinery and other capital inputs substitute for the over-committed labor input. The interest on stock expense for all commodities except tobacco is far above minimum-cost levels suggesting that commodity inventories have not been kept at optimum levels. Real estate taxes were below the optimum levels for all crops in the last two periods with the exception of soybeans in the 1950-1958 period.

If the actual 1959-1967 average production levels for the five crops had been produced with the optimum level and combination of resources, farmer costs would have been reduced by 228.6 million 1947-1949 dollars or 9.2 percent for feed grains, $55.4 million or 3.6 percent for wheat, $93.3 million or 8.6 percent for soybeans, $53.6 million or 3.6 percent for cotton and $12.2 million or 1.7 percent for tobacco. Assuming actual resource use for all other commodities, least-cost input combinations to produce actual average 1959-1967 outputs of the five crops would have reduced total input usage in agriculture by 443.1 million 1947-1949 dollars or 2.1 percent.

OUTPUT-SUPPLY ELASTICITIES

The mathematical properties of the Cobb-Douglas production function allow the derivation of normative estimates of (1) the elasticity of output supply and (2) the elasticity of demand for a particular factor solely from the parameters of the function.

Supply elasticities measure the percentage change in production associated with a 1 percent change in product price. Table 4 presents the percentage change in production associated with a change in use of an individual input holding other inputs fixed. The input change which influences output via the production function results from a change in the product price. These "simple" supply elasticities provide measures of the relative influence each input has on output supply following a change in product price if only the one input were allowed to vary. Of course, in reality the levels of other inputs would also respond to a change in product price, but the estimates indicate the effects IF other inputs were fixed.

The simple supply elasticity for the i^{th} input (E_{S_i}) is computed as:

$$E_{S_i} = \frac{dPROD}{dP_{PROD}} \cdot \frac{P_{PROD}}{PROD} = \frac{dPROD}{dX_i} \cdot \frac{X_i}{PROD} \cdot \frac{dX_i}{dP_{PROD}} \cdot \frac{P_{PROD}}{X_i} = E_{P_i} \cdot E_{cd_i} = \frac{b_i}{1-b_i}$$

where PROD is output, P_{PROD} is the price of the output, X_i is the i^{th} input, P_i is the price i^{th} input, E_{cd_i} is the elasticity of demand for the i^{th} input with respect to product price and E_{P_i} is the elasticity of production for the i^{th} input.

Supply estimates in Table 5 provide a more realistic norm of the MAXIMUM response of production to changes in product price. The estimates no longer reflect the change in production resulting from product price-induced changes of one input at a time. Rather, the number of inputs allowed to vary is related to the practical consideration of length of time needed to make input adjustments. In the long run it is assumed that all inputs can be varied. In the short run the fertilizer, seed and fuel, oil and repair inputs are assumed variable. The machinery and interest on stock inputs are added to the short-run

Table 4. SIMPLE SUPPLY ELASTICITIES FOR EIGHT INPUT CATEGORIES FOR FEED GRAINS, WHEAT, SOYBEANS, COTTON AND TOBACCO, 1950-1958 AND 1959-1967.[a]

Input	Commodity Group				
	Feed Grains	Wheat	Soybeans	Cotton	Tobacco
Fertilizer					
1950-1958	.09076	.04781	.01746	.05818	.03852
1959-1967	.16283	.08215	.02346	.06985	.03129
Seed					
1950-1958	.04062	.07188	.07580	.01337	--[b]
1959-1967	.03604	.06084	.06229	.01315	--[b]
Labor					
1950-1958	.14858	.08232	.07654	.43047	.04859
1959-1967	.09263	.07259	.07641	.29351	.44434
Machinery					
1950-1958	.36474	.17719	.25706	.08088	.02088
1959-1967	.35536	.26094	.29921	.10024	.02123
Fuel, oil, repairs					
1950-1958	.21993	.15817	.17231	.10407	.06819
1959-1967	.18903	.19055	.17331	.11116	.05840
Miscellaneous					
1950-1958	.06691	.06399	.04958	.14513	.06809
1959-1967	.11111	.11721	.09738	.23522	.08140
Interest on stocks					
1950-1958	.04336	.02037	.02027	.00895	.00898
1959-1967	.04776	.02195	.02213	.00944	.01016
Real estate taxes					
1950-1958	.03474	.02908	.02670	.01545	.01381
1959-1967	.06014	.04964	.03743	.02611	.01625

[a]Real estate is fixed.

[b]Seed expense for tobacco is included in the miscellaneous category so no production elasticities for tobacco seed were calculated.

variables to form an intermediate run, while adding in labor results in the intermediate-long length of run. The elasticity estimates are computed as:

$$E = \Sigma \left[b_i \cdot \frac{1}{1-b_i} \right]$$

where b_i is the elasticity of production for the i^{th} input and the summation is over those input elasticities corresponding to the length of run under consideration.

The interpretation of the supply elasticity for tobacco is that a 1 percent increase in price would increase production .17 percent in the short run. Allowing time for changes in machinery investment and inventories, a 1 percent price increase would increase tobacco production by .20 percent. In the intermediate-long run the percentage change in output per 1 percent change in price would be .65 percent and the long run percentage change in output per 1 percent change in price is .91 percent.

The Cobb-Douglas derived supply elasticities are the maximum potential response and overestimate the true response [7]. In the real world the assumptions on which these estimates are based including profit maximization, perfect resource mobility and instantaneous adjustments are not fulfilled. They do, however, provide benchmark estimates of supply parameters that are associated

Table 5. AGGREGATE SUPPLY ELASTICITIES FOR FEED GRAINS, WHEAT, SOYBEANS, COTTON AND TOBACCO, FOUR LENGTHS OF RUN, DERIVED FROM COEFFICIENTS OF 1959-1967.

Commodity	Length of Run[a]			
	Short	Intermediate	Intermediate long	Long
Feed Grains	.48966	.89278	.98541	1.46471
Wheat	.45015	.73364	.80623	1.22761
Soybeans	.35644	.67778	.75419	1.06119
Cotton	.42938	.53906	.83257	1.19722
Tobacco	.17109	.20248	.64682	.91468

[a]The short-run input variables are fertilizers; seed; fuel, oil, repairs and miscellaneous. The intermediate-run input variables include those of the short run plus machinery and interest on stocks. The intermediate-long run includes the above inputs and labor. The long run includes all input variables.

with an efficient organization of the farm industry. After reviewing a number of empirical supply-price response studies, Ray [3] presents "consensus" short-run supply elasticity estimates of .25 for feed grains, .20 for wheat, .45 for soybeans and .35 for cotton.

FACTOR-DEMAND ELASTICITIES

The final set of optimal response calculations concerns the demand for specific factors of production. Static firm theory relates the levels of resource use to their prices and productivities and to product price. The elasticity of input demand measures the percentage change in factor use associated with a 1 percent change in factor price. While the cross elasticity of factor demand often refers to the percentage change in input use following a 1 percent change in the price of another factor, here it refers to the factor demand elasticity with respect to product price.

For the Cobb-Douglas production function the elasticity of factor demand depends only on the coefficients of production. It can be shown [1], that the elasticity of input demand for input i (E_{d_i}) (other inputs fixed) is calculated as:

$$E_{d_i} = \frac{-1}{1-b_i}$$

Further, for the Cobb-Douglas function, the cross demand elasticity E_{cd_i} is equal to the elasticity of factor demand E_{d_i} multiplied by -1.

Table 6 presents the cross elasticites of demand for the input categories for the 1950-1958 and 1959-1967 periods under the assumption that factors other than the i^{th} are held fixed.

SUMMARY AND CONCLUSIONS

Estimates of the efficient organization of agriculture provide a useful norm to judge resource imbalances in the industry. In this study least cost resource estimates and normative output supply and factor demand elasticities are derived in a Cobb-Douglas production function framework using actual feed grain, wheat, soybean, cotton and tobacco output levels. Assuming profit maximizing behavior, perfect resource mobility and undelayed resource adjustments, actual 1959-1967 average feed grain, wheat and cotton output could have been produced with about 4 percent fewer inputs had resources been allocated optimally. For soybeans the resource savings were 8 percent while saves of 2 percent were indicated for tobacco. Aggregate input usage in agriculture during this period would have been reduced by 2.1 percent with a least cost resource structure for the five crops holding resource use constant in the production of other commodities. Using an aggregate Cobb-Douglas production function for all U.S. output, Tyner and Tweeten [7] estimated that actual 1952-1961 total agricultural output could have been produced with 5.6 percent fewer inputs had resources been allocated optimally. The 2 percent savings estimated in this study appear reasonable since only five crops are produced with least-cost input levels while other commodity input allocations are held fixed.

Table 6. **CROSS ELASTICITIES OF DEMAND FOR NINE INPUT CATEGORIES USED IN THE PRODUCTION OF FEED GRAINS, WHEAT, SOYBEANS, COTTON AND TOBACCO, 1950-1958 AND 1959-1967.**

Input	Commodity Group				
	Feed Grains	Wheat	Soybeans	Cotton	Tobacco
Fertilizer					
1950-1958	1.09073	1.04778	1.01748	1.05820	1.03856
1959-1967	1.15283	1.08220	1.02356	1.06984	1.03131
Seed					
1950-1958	1.04074	1.07188	1.07579	1.01365	--[a]
1959-1967	1.03593	1.06085	1.06224	1.01310	--[a]
Labor					
1950-1958	1.14858	1.08230	1.07651	1.43047	1.47859
1959-1967	1.09259	1.07255	1.07649	1.29351	1.44435
Machinery					
1950-1958	1.36474	1.17719	1.25708	1.08085	1.02103
1959-1967	1.35535	1.26095	1.29922	1.10021	1.02116
Real estate					
1950-1958	1.21139	1.18538	1.17097	1.16501	1.19822
1959-1967	1.41921	1.37173	1.26958	1.33857	1.25160
Fuel, oil, repairs					
1950-1958	1.21994	1.15816	1.17234	1.10407	1.06814
1959-1967	1.18902	1.19057	1.17331	1.11116	1.05835
Miscellaneous					
1950-1958	1.06698	1.06402	1.04953	1.14510	1.06808
1959-1967	1.11110	1.11724	1.09736	1.23520	1.08144
Interest on stocks					
1950-1958	1.04331	1.02054	1.02013	1.00902	1.00899
1959-1967	1.04783	1.02188	1.02217	1.00963	1.00994
Real estate taxes					
1950-1958	1.03485	1.02902	1.02653	1.01578	1.01395
1959-1967	1.06011	1.04969	1.03742	2.02633	1.01626

[a]Seed expense for tobacco is included in the miscellaneous category so no production elasticities for tobacco seed were calculated.

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