Long-Term Planning of a Livestock-Crop Farm Under Government Programs

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Abstract

Optimal crop and livestock mix was determined for a representative Alabama farm using a dynamic programming model. Results indicate that decisions concerning livestock production are highly influenced by the amount of cotton base available on the farm. In most cases, increasing cotton base results in less cattle production. The triple base provisions of the 1990 Farm Bill, however, may give some cotton farmers an incentive to produce more stocker cattle during the winter months. Research results also indicate that the availability of farm programs can alter the optimal enterprise mix on a farm with no beginning base in cotton.

Key words: farm programs, dynamic programming, livestock

While it has long been known that changes in farm programs for feed grains can affect the livestock industry through changes in feed price, little or no work has addressed the on-farm interaction of farm programs and cattle production. Winter stockering enterprises, in particular, can be highly influenced by the factors affecting the relative profitability of both summer and winter crops.

For many Alabama farms, cotton and soybeans are the principle summer crops. Soybeans can be followed with a winter annual, such as wheat, oats, rye or ryegrass, but, because of growing season, cotton generally cannot be followed by another enterprise. Thus, the acres available for winter grazing depend greatly on the choice of summer crops. Farm program provisions can significantly alter the relative profitability of cotton and soybeans, thus having an important indirect effect on stocker production during the winter months.

The objective of this study is to examine whole-farm planning for a representative Alabama crop and livestock farm, giving particular attention to the interaction of farm program provisions and livestock production decisions. To accomplish this objective, a multi-year dynamic programming model is used to account for the dynamic aspects of farm program base-acreage calculations.

The Representative Farm

The representative farm developed in this study is a 1000-acre livestock (stocker) and crop (cotton, soybean, and wheat) farm in Alabama. Based on records from the Alabama Farm Analysis

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Association and from the Alabama Cooperative Extension Service, per acre yields were assumed to be: 626 pounds per acre for cotton, 22 bushels per acre for soybeans, and 40 bushels per acre for wheat. Based on work by David Bransby of the Alabama Agricultural Experiment Station, cattle were assumed to be grazing rye + ryegrass mixture over a 100-day period at a stocking rate of 2.5 head per acre. Starting weight of a stocker was assumed to be 400 pounds and the selling weight was assumed to be 565.3 pounds, representing an average daily gain of 1.65 pounds.

From Alabama Cooperative Extension Service budgets, per acre variable costs were assumed to be: $284.05 for cotton, $82.54 for soybeans, $67.22 for wheat, and $185.19 for cattle. An additional cost of $18.52 per acre was assumed for any land idled due to farm program participation. Based on Alabama Farm Analysis Association records, unallocable fixed costs were assumed to be $53.24 per acre (see Cain).

Under the 1990 Farm Bill, base acreage for cotton is calculated as a three-year moving average of acreage planted and considered planted. Farmers with a cotton base may enroll in the farm program or may elect to remain out of the program. A producer who enrolls in the program agrees to limit cotton planting to a specified portion of base. In exchange, the farmer receives deficiency payments on all eligible acres. The per pound deficiency payment is the difference between the target price and the higher of market price or loan rate, with total payment based on "proven yield," a yield measure derived from county averages and/or pre-1986 farm records.

Participants in the farm program must idle a specified portion of base if an acreage reduction program (ARP) is announced. New "triple" base provisions in the Farm Bill further limit payment eligibility. Under the 1990 Farm Bill, 15 percent of a farmer's base acreage in a commodity is designated as "Normal Flex Acres" (NFA). On these acres, the farmer may plant cotton or a substitute crop, but will receive no deficiency payments. An additional 10 percent of acres are designated "Optional Flex Acres" (OFA). The farmer may plant these acres in cotton and receive a deficiency payment, or plant them in an alternative crop and forfeit the deficiency payment. ARP, NFA and OFA are acres "considered planted" in cotton for the purpose of calculating future farm program bases.

Target price for cotton is currently $0.729/lb. For soybeans, a loan rate of $4.92/bu is in effect, but there is no deficiency payment program. Although there are farm program provisions for wheat, the majority of Alabama farmers do not participate in this program (see Cain). Including farm program provisions for wheat would result in a computationally intractable model; accordingly, those provisions were not included here.

Price Relationships

Market prices are important in the decision process as the expected prices affect the attractiveness of program participation. Because sales prices are unknown when production decisions are made, expectations concerning the selling price must be formulated. Sales price in one marketing year tends to be correlated with known past prices; thus prices can be modeled as following a first order Markovian process and conditional probabilities of receiving a particular market price in the current year can be calculated using econometric price estimates.

In our study, annual price data for the period 1966-1991 were obtained from the Alabama Cooperative and Extension Service and converted to constant dollars using the CPI (100=1991). Because real commodity prices have declined over time, following the decline in real per unit production costs, a time trend was included in the statistical equations.[1] All equations were estimated in double-log form. Full results of the estimation are reported in table 1.

In the programming model, the expected market prices were obtained by fixing time trend T

Table 1. Econometric Estimates of Price Relationships

$$\ln(PCT_t) = \underset{(0.5456)}{0.046832} + \underset{(3.0980)}{0.469105}*\ln(PCT_{t-1}) - \underset{(-1.7615)}{0.010597}*T$$

$$\ln(PSB_t) = \underset{(3.6972)}{1.421042} + \underset{(2.9547)}{0.438832}*\ln(PSB_{t-1}) - \underset{(-2.0076)}{0.014481}*T$$

$$\ln(PWT_t) = \underset{(2.2939)}{0.761534} + \underset{(4.2341)}{0.564004}*\ln(PWT_{t-1}) - \underset{(-1.2281)}{0.008461}*T$$

$$\ln(PBC_t) = \underset{(4.7108)}{3.772523} + \underset{(1.0448)}{0.180391}*\ln(PBC_{t-1}) - \underset{(-1.7760)}{0.009600}*T$$

PCT, *PSB*, *PWT*, and *PBC* are the prices of cotton, soybean, wheat and beef cattle, respectively, and *T* is a time trend. ln is the natural log function. Equations estimated using SUR. The system $R^2 = 0.78$. Figures in parentheses are *t*-statistics.

at a recent value ($T = 24$), so that expected prices are determined by:

(1) $E(PCT_t) = 0.812616 \cdot PCT_{t-1}^{0.469105}$

(2) $E(PSB_t) = 2.2925595 \cdot PSB_{t-1}^{0.438832}$

(3) $E(PWT_t) = 1.747981 \cdot PWT_{t-1}^{0.564004}$

(4) $E(PBC_t) = 34.540493 \cdot PBC_{t-1}^{0.180391}$

where *PCT* is the market price of cotton ($/lb), *PSB* is the market price of soybeans ($/bu), *PWT* is the market price of wheat ($/bu), *PBC* is the market price of beef cattle ($/cwt), *E* is the expectation operator, and t is a time subscript. The beef cattle price is the sales price per hundredweight of the stocker. Purchase price is found by adding a fixed margin of $0.06 per pound.

The four price series were assumed to have a multivariate normal distribution. Through a quadruple numerical integration process (involving a simple extension of the process described by Burden and Faires), the covariance matrix from the residuals of the regression equations was used to develop the joint probability of receiving particular ranges of prices.

If the farmer chooses to participate in the farm program, the one-year profit function will be:

$$(5)\quad \Pi_t = [MAX(TP,PCT_t) \cdot YCT - VCCT] \cdot APDP_t + [MAX(CTL,PCT_t) \cdot YCT - VCCT] \cdot ACTB + [MAX(PSB_t,SBLN) \cdot YSB - VCSB] \cdot ASB_t + (PWT_t \cdot YWT - VCWT) \cdot AWT_t + [PBC_t \cdot YBC - (PBC_t + DCL_t) \cdot BEGWT - VCBC] \cdot ACL - FC - SA_t \cdot VCSA$$

In case of non-participation in the farm program, the one-year profit function will be

$$(6)\quad \Pi_t = (PCT_t \cdot YCT - VCCT) \cdot ACT_t + [PBC_t \cdot YBC - (PBC_t + DCL_t) \cdot BEGWT - VCBC] \cdot ACL + (PSB_t \cdot YSB - VCSB] \cdot ASB_t + (PWT_t \cdot YWT - VCWT) \cdot AWT_t - FC$$

where *TP* is the target price of cotton, *YCT* is the per acre cotton yield (lbs), *VCCT* is the per acre variable cost of cotton, *APDP* are planted acres of cotton eligible for deficiency payment, *CTL* is the cotton loan rate, *ACTB* is cotton planted on the normal flex acres (if any) and therefore ineligible for deficiency payment, *SA* is land idled due to program participation, *VCSA* is the per acre variable cost of idling the land, *SBLN* is the soybean loan rate, *YSB* is the per acre yield of soybeans (bu), *ASB* is the acreage of soybean, including any soybeans planted on normal flex acres and optional flex acres, *VCSB* is the per acre variable cost of soybeans, *YWT* is the per acre yield of wheat (bu), *VCWT* is the per acre variable cost of wheat, *AWT* is the number of acres planted to wheat (if any), *YBC* is the per acre yield of beef cattle in terms of weight of animals at selling time, *DCL* is the price differential between buying and selling times, *VCBC* is the per acre variable cost of beef cattle, *ACL* is total acreage for pasture, *BEGWT* is the beginning weight of cattle, and *FC* is the total non-land fixed cost. In both (5) and (6), the total acres available for wheat and/or cattle equal the amount of soybean acres, including triple base acres, if any. Thus, the profit function in this analysis is gross returns less production costs and all fixed costs for machinery and other non-land inputs. When cotton is enrolled in the farm program, program payments (if any) are added to gross returns and program compliance provisions are followed.

Dynamic Programming Model

Dynamic programming is a useful tool for modeling multi-year farm-level processes (Burt; Burt and Allison).[2] Here the objective function for a ten-year planning horizon can be expressed as:

$$(7)\ V(p) = \underset{Ut}{MAX} \sum_{t=1}^{10} \beta^{t-1} E\ \{\pi_t(U_t, PCT_{t-1}, PSB_{t-1}, PWT_{t-1}, PBC_{t-1}, Base_t)\}$$

where

$$(8)\ Base_t = 1/3 \sum_{i=1}^{3} A_{t-i},$$

and A is cotton acreage planted (whether in or out of the program) or considered planted for program purposes. Alternative cropping effects are captured in the profit function as described in equations (5) and (6). The decision vector, U_t, discussed in detail in the next section, involves livestock, crop-mix and program-participation decisions.

The objective function in (7) can also be expressed as a dynamic programming recursive equation in terms of the optimal value function, V_t:

$$(9)\ V_t = \text{MAX}_{Ut}\ E[(\pi_t, PCT_{t-1}, PSB_{t-1}, PWT_{t-1}, PBC_{t-1}, A_{t-1}, A_{t-2}, A_{t-3}, U_t)$$
$$+ \beta V_{t+1}(PCT_t, PSB_t, PWT_t, PBC_t, A_t, A_{t-1}, A_{t-2})]$$

where conditional expectations are formed over price states using the numerically integrated density function. The DP problem expressed in (9) is solved by a backwards recursive process (see Dreyfus and Law).[3]

State and Decision Variables

Because cotton base is calculated as a three-year moving average of past acreage, three lagged cotton-acreage state variables (one for acreage planted or considered planted in each of the last three years) are needed for cotton base calculation alone. Although wheat is also a farm program crop, it is assumed that, for farms of this type, wheat acreage will not be enrolled in the farm program. Any acreage reduction for wheat through the wheat program would also apply to soybeans, discouraging participation. Also, participation in the wheat program limits wheat plantings to base, sharply curbing whole-farm profits in most cases (see Cain). Hence program wheat was not included as an option in the DP model.

Because prices are modeled as following a stochastic Markovian process (table 1), lagged prices are needed as state variables in the model. For the problem at hand, the lagged-price state variables were discretized over their assumed probable ranges with three evenly distributed intermediate values. Cotton price states were assumed to range from \$0.45 to \$0.80. The range for soybean price states was \$4.00-\$8.50. Wheat price states were assumed to range from \$1.50 to \$4.50. Cattle price states ranged from \$60.00 to \$90.00. All together, there are three deterministic acreage state variables, each discretized into five states, and four stochastic price state variables, each with five states, for a total of 78,125 states.[4]

While yield is also random, it should not be strongly Markovian given that unusual weather in one production season is generally uncorrelated with unusual weather in the next. Additionally, it is the relationship of expected market price to target price and loan rate that most influences the producer's decision to participate in the program. The variability of yield is of secondary importance. The situation for yield thus approaches certainty equivalence, and yield can be included in the model at its expected mean value.

In the model, required program acreage reduction (ARP) for a particular year was linked to lagged cotton price. Because the 1990 Farm Bill mandates that the Secretary of Agriculture base annual ARP rates on ending stock levels, one would expect to see a strong correlation between ARP rate and lagged price, given the strong inverse relationship between price and stock levels. Set-aside was assumed to be 20 percent at a lagged cotton price of $0.45, 15 percent at a lagged cotton price of $0.54, 10 percent at a lagged cotton price of $.625, 5 percent at a lagged cotton price of $0.71, and zero at a lagged cotton price of $0.80.

The decision variables are livestock and crop acreages and farm program participation options. Four farm program participation options were allowed: (1) no participation, (2) participation with no soybeans grown on any triple base, (3) participation with soybeans grown on normal flexed acres but not on optional flexed acres, and (4) participation with soybeans grown on both normal and optional flexed acres. The portion of acreage to plant in cotton, however, is continuous and must, like the state variable, be discretized. The range from 0 to 1 was therefore subdivided, so that there were 11 intermediate values. Soybean acreage is the difference between total acreage and cotton acreage. A second acreage allocation decision involved the winter enterprise to follow any soybeans chosen for a summer enterprise. As with the cotton-soybean decision, the acreage allocation decision for wheat-stockers involved discretizing the range from 0 to 1 into 11 intermediate values, each representing a portion of total acreage. Decisions in which winter enterprise acreage exceeded summer soybean acreage were "ruled out" in the model.

In this study, capital was not constrained. If capital availability is a limiting factor, the capital-intensive stocker enterprise would probably be seriously limited.

Results and Discussion

Results described here were obtained from maximizing expected net returns over a ten-year planning horizon. Because of the enormous amount of output generated from the model, only selected results are reported.

In table 2, some results from a model without farm programs are presented.[5] These results can be used as a benchmark against which to measure distortions in enterprise mix caused by the farm programs. Because relative, rather than absolute, prices are important in determining acreage allocation, results are presented for all lagged cotton and wheat prices, but for fixed levels of lagged soybean and beef cattle price ($6.25/bu. and $82.50/cwt, respectively). Additional results are available on request.

In the no program case, acreage in any year is allocated based on the most profitable combination of enterprises for that year, without concern for future program base; hence, these results are relatively easy to interpret. Cotton is planted in the summer when the expected one-year profit exceeds the expected one-year profit from soybeans followed by either wheat or cattle. When soybeans are the summer crop, the winter enterprise is determined by the relative profitability of cattle and wheat.

Tables 3 to 7 provide results for a situation in which farm programs are available, with each table representing the situation for a producer with a specific level of initial cotton base on the farm. Because base acreage is calculated as a three-year moving average, a number of alternative routes exist for the farmer to achieve a given amount of base acreage. While the route by which a farmer arrives at a particular base sometimes impacts the optimal decision rule, it does not appear to have a large effect on the optimal value function. Consequently, the results reported here focus on the case in which a producer arrived at the current base by having equal acreage histories over the planning horizon.

When farm programs are available but the farm has no beginning base (table 3), acreage allocation sometimes is altered from the "no program" case. At $0.62 lagged price for cotton, the whole farm is planted in cotton when lagged wheat price is less than $4.50. Because no cotton was planted in the "no farm programs" case for these prices, one can conclude that these cotton plantings are made to establish a base for future farm program benefits.

With a 25 percent initial base (table 4), changes in acreage allocation over the "no

Table 2. Expected Net Returns Per Acre and Acreage Distribution for a Crop-Livestock Operation over a Ten-Year Planning Horizon Given Lagged Prices of $82.50 for Beef Cattle and $6.25 for Soybeans, No Farm Programs.

PCT	*PWT*	Cotton (Acres)	Soybean[a] (Acres)	Wheat (Acres)	Cattle (Acres)	Net Returns ($/acre)
0.45	1.50	0	1000	0	1000	701.70
	2.25	0	1000	0	1000	710.46
	3.00	0	1000	0	1000	716.26
	3.75	0	1000	1000	0	731.67
	4.50	0	1000	1000	0	749.29
0.54	1.50	0	1000	0	1000	709.31
	2.25	0	1000	0	1000	717.70
	3.00	0	1000	0	1000	722.68
	3.75	0	1000	1000	0	737.43
	4.50	0	1000	1000	0	754.62
0.62	1.50	0	1000	0	1000	716.13
	2.25	0	1000	0	1000	724.34
	3.00	0	1000	0	1000	728.34
	3.75	0	1000	1000	0	742.24
	4.50	0	1000	1000	0	758.90
0.71	1.50	1000	0	0	0	733.23
	2.25	1000	0	0	0	741.21
	3.00	1000	0	0	0	744.66
	3.75	1000	0	0	0	748.99
	4.50	0	1000	0	1000	762.24
0.80	1.50	1000	0	0	0	755.05
	2.25	1000	0	0	0	761.63
	3.00	1000	0	0	0	765.66
	3.75	1000	0	0	0	769.34
	4.50	1000	0	0	0	773.29

PCT is price of cotton ($/lb.) lagged one period. *PWT* is price of wheat ($/bu.) lagged one period. Lagged prices used to form expectations concerning sales price of the commodities. Net returns are the ten year discounted returns to land.

programs" case are even more pronounced. At a lagged cotton price of $0.54, cotton program participation (rather than soybeans) is selected in almost all cases, leaving less acreage available for a winter enterprise. Normal flex acres are planted in soybeans, but optional flex acres remain in cotton. At a $0.62 lagged price, nonprogram cotton is planted for lagged wheat prices below $3.75, and program cotton is planted at higher lagged wheat prices, with normal flex acres in soybeans. Available winter acreage is then either grazed (low wheat prices), or harvested for wheat (higher wheat prices.)

As base acreage increases to 50 percent (table 5), program cotton is produced even when the lagged market price for cotton is low, meaning less land is available for either cattle or wheat production. By comparing tables 4 and 5, one can see that the level of initial cotton base on a farm can have a large impact on the cattle production decision. At a lagged cotton price of $0.45, for example, land available for winter grazing or winter wheat falls from 1000 acres to 575 acres, as base increases from 25 percent to 50 percent.

At a 75 percent base (table 6), land available for winter grazing or winter wheat decreases when cotton price is $0.62 or less, but often increases at higher cotton prices. When the lagged cotton price is $0.80, for example, the optimal decision involves staying in the program. Although the target price of $0.729 cents is lower than the lagged price, the stochastic price specification in the model makes program participation the optimal choice, in spite of the high lagged market price. With a base of 25 percent or 50 percent, the same lagged cotton price resulted in

Table 3. Expected Net Returns Per Acre and Acreage Distribution for a Crop-Livestock Operation over a Ten-Year Planning Horizon Given Lagged Prices of $82.50 for Beef Cattle and $6.25 for Soybeans, No Initial Base.

PCT	*PWT*	Cotton (Acres)	Soybean[a] (Acres)	Wheat (Acres)	Cattle (Acres)	Net Returns ($/acre)
0.45	1.50	0	1000	0	1000	743.97
	2.25	0	1000	0	1000	749.76
	3.00	0	1000	0	1000	752.41
	3.75	0	1000	1000	0	765.35
	4.50	0	1000	1000	0	781.39
0.54	1.50	0	1000	0	1000	758.03
	2.25	0	1000	0	1000	763.29
	3.00	0	1000	0	1000	764.67
	3.75	0	1000	1000	0	776.36
	4.50	0	1000	1000	0	791.45
0.62	1.50	1000	0	0	0	784.63
	2.25	1000	0	0	0	789.39
	3.00	1000	0	0	0	788.49
	3.75	1000	0	0	0	788.78
	4.50	0	1000	0	1000	800.67
0.71	1.50	1000	0	0	0	816.81
	2.25	1000	0	0	0	821.71
	3.00	1000	0	0	0	820.74
	3.75	1000	0	0	0	820.64
	4.50	1000	0	0	0	821.42
0.80	1.50	1000	0	0	0	842.84
	2.25	1000	0	0	0	847.91
	3.00	1000	0	0	0	846.65
	3.75	1000	0	0	0	846.41
	4.50	1000	0	0	0	847.10

PCT is price of cotton ($/lb.) lagged one period. *PWT* is price of wheat ($/bu.) lagged one period. Lagged prices used to form expectations concerning sales price of the commodities. Net returns are the ten year discounted returns to land.

the whole farm planted in nonprogram cotton. At the lower base levels, expanding base for the future has a high expected payoff, while this payoff is smaller when the base level is already high. These results, in terms of base expansion, are similar to those obtained by Cain using a mixed-integer programming model.

Finally, at 100 percent base (table 7) the only acreage available for cattle or wheat is triple base acreage. Without triple base, neither cattle nor wheat would be produced. Thus, the triple base provision of the 1990 Farm Bill may give some cotton farmers an incentive to produce stocker cattle during the winter months, an unanticipated consequence of this provision.

In table 2 to 7, the discounted ten-year expected returns to land are also presented. By comparing these numbers, the implicit value of base acreage can be estimated. It is interesting to note that when base is low (25 percent), the initial endowment has little economic value. High initial levels of base (75 or 100 percent), however, can be worth up to $100.00 per acre or more, depending on market price conditions. It is also interesting to note, by comparing tables 2 and 3, that the availability of farm programs has an economic value even for those with no initial base. Because base can be obtained fairly quickly, the possibility of future farm program benefits increases the economic value of land.

Conclusions

Farm program provisions were incorporated in a stochastic dynamic programming model to demonstrate that they have a considerable impact on

Table 4. Expected Net Returns Per Acre and Acreage Distribution for a Crop-Livestock Operation over a Ten-Year Planning Horizon Given Lagged Prices of $82.50 for Beef Cattle and $6 25 for Soybeans, 25 percent Base Acreage

PCT	*PWT*	Cotton (Acres)	Soybean[a] (Acres)	Wheat (Acres)	Cattle (Acres)	Net Returns ($/acre)
0.45	1.50	0	1000	0	1000	743.97
	2.25	0	1000	0	1000	749.76
	3.00	0	1000	0	1000	752.41
	3.75	0	1000	1000	0	765.35
	4.50	0	1000	1000	0	781 39
0.54	1.50	212[b]	788	0	788	760.71
	2.25	212[b]	788	0	788	766.34
	3.00	212[b]	788	0	788	768.07
	3.75	212[b]	788	788	0	778.12
	4.50	0	1000	1000	0	791.45
0.62	1.50	1000	0	0	0	784.70
	2.25	1000	0	0	0	789.49
	3.00	1000	0	0	0	788.65
	3.75	212[b]	788	788	0	792.89
	4.50	212[b]	788	788	0	804.85
0.71	1.50	1000	0	0	0	816 84
	2.25	1000	0	0	0	821.76
	3.00	1000	0	0	0	820.83
	3.75	1000	0	0	0	820.77
	4.50	1000	0	0	0	821.59
0.80	1 50	1000	0	0	0	842.86
	2.25	1000	0	0	0	847.94
	3.00	1000	0	0	0	846.69
	3.75	1000	0	0	0	846.48
	4.50	1000	0	0	0	847.19

PCT is price of cotton ($/lb.) lagged one period. *PWT* is price of wheat ($/bu.) lagged one period. Lagged prices used to form expectations concerning sales price of the commodities. Net returns are the ten year discounted returns to land.

[a] Includes triple base acres from cotton program participation if any.

[b] Cotton acres enrolled in farm program; excluding triple base acres planted in soybeans, but including ARP acreage if any.

decisions made by farmers concerning the livestock sector. Results of this study show that for a representative crop-livestock farmer, acres allocated for winter stockering depend on expected prices for cotton and soybeans, as well as the amount of initial base endowment on the farm. Overall, results underscore the important effect that farm program provisions for cotton can have on a winter stocker enterprise. While the impact of feed grain and dairy policy provisions on the livestock sector are generally known, the connection between cotton programs and cattle has not previously been analyzed. Results of this study provide evidence that this connection can have important consequences.

When farm program participation for cotton is selected, triple basing soybeans can be an attractive option in some cases. These triple base acres are then available for a winter enterprise, either wheat for grain or stocker cattle, depending on relative prices. Thus, triple base may provide some farmers with an incentive to produce more cattle.

Table 5. Expected Net Returns Per Acre and Acreage Distribution for a Crop-Livestock Operation over a Ten-Year Planning Horizon Given Lagged Prices of $82.50 for Beef Cattle and $6.25 for Soybeans, 50 percent Base Acreage.

PCT	*PWT*	Cotton (Acres)	Soybean[a] (Acres)	Wheat (Acres)	Cattle (Acres)	Net Returns ($/acre)
0 45	1.50	425[b]	575	0	575	746.88
	2.25	425[b]	575	0	575	754.08
	3.00	425[b]	575	0	575	757.38
	3.75	425[b]	575	575	0	766.44
	4.50	0	1000	1000	0	781.52
0.54	1.50	425[b]	575	0	575	768.51
	2.25	425[b]	575	0	575	775.41
	3.00	425[b]	575	0	575	778.09
	3.75	425[b]	575	575	0	786.73
	4.50	425[b]	575	575	0	797.07
0.62	1.50	425[b]	575	0	575	789.03
	2.25	425[b]	575	0	575	795.74
	3.00	425[b]	575	0	575	797.56
	3.75	425[b]	575	575	0	805 62
	4.50	425[b]	575	575	0	815.65
0.71	1.50	1000	0	0	0	816.96
	2.25	1000	0	0	0	821 90
	3 00	1000	0	0	0	821.02
	3.75	500[b]	500	500	0	822.22
	4.50	425[b]	575	575	0	831.53
0.80	1.50	1000	0	0	0	842.92
	2.25	1000	0	0	0	848.00
	3.00	1000	0	0	0	846.78
	3.75	1000	0	0	0	846.62
	4.50	1000	0	0	0	847.40

PCT is price of cotton ($/lb.) lagged one period. *PWT* is price of wheat ($/bu.) lagged one period. Lagged prices used to form expectations concerning sales price of the commodities. Net returns are the ten year discounted returns to land

[a] Includes triple base acres from cotton program participation if any.

[b] *Cotton acres enrolled in farm program;* excluding triple base acres planted in soybeans, but including ARP acreage
if any.

Table 6. Expected Net Returns Per Acre and Acreage Distribution for a Crop-Livestock Operation over a Ten-Year Planning Horizon Given Lagged Prices of $82.50 for Beef Cattle and $6.25 for Soybeans, 75 percent Base Acreage.

PCT	*PWT*	Cotton (Acres)	Soybean[a] (Acres)	Wheat (Acres)	Cattle (Acres)	Net Returns ($/acre)
0.45	1.50	638[b]	362	0	362	776.57
	2.25	638[b]	362	0	362	783.19
	3.00	638[b]	362	0	362	785.09
	3.75	638[b]	362	362	0	790.71
	4.50	638[b]	362	362	0	797.55
0.54	1.50	638[b]	362	0	362	804.31
	2.25	638[b]	362	0	362	811.21
	3.00	638[b]	362	0	362	812.94
	3.75	638[b]	362	362	0	818.50
	4.50	638[b]	362	362	0	825.29
0.62	1.50	637[b]	363	0	363	830.17
	2.25	637[b]	363	0	363	837.47
	3.00	637[b]	363	0	363	838.88
	3.75	637[b]	363	363	0	844.31
	4.50	637[b]	363	363	0	851.10
0.71	1.50	750[b]	250	0	250	853.52
	2.25	750[b]	250	0	250	860.92
	3.00	750[b]	250	0	250	862.42
	3.75	750[b]	250	250	0	866.73
	4.50	638[b]	362	362	0	873.05
0.80	1.50	750[b]	250	0	250	864.54
	2.25	750[b]	250	0	250	871.97
	3.00	750[b]	250	0	250	873.22
	3.75	750[b]	250	250	0	877.51
	4.50	750[b]	250	250	0	882.89

PCT is price of cotton ($/lb.) lagged one period. *PWT* is price of wheat ($/bu.) lagged one period. Lagged prices used to form expectations concerning sales price of the commodities. Net returns are the ten year discounted returns to land.

[a] Includes triple base acres from cotton program participation if any.

[b] Cotton acres enrolled in farm program; excluding triple base acres planted in soybeans, but including ARP acreage if any.

Table 7. Expected Net Returns Per Acre and Acreage Distribution for a Crop-Livestock Operation over a Ten-Year Planning Horizon Given Lagged Prices of $82.50 for Beef Cattle and $6.25 for Soybeans, 100 percent Base Acreage.

PCT	*PWT*	Cotton (Acres)	Soybean[a] (Acres)	Wheat (Acres)	Cattle (Acres)	Net Returns ($/acre)
0.45	1.50	850[b]	150	0	150	809.67
	2.25	850[b]	150	0	150	814.66
	3.00	850[b]	150	0	150	814.45
	3.75	850[b]	150	150	0	816.23
	4.50	850[b]	150	150	0	819.12
0.54	1.50	850[b]	150	0	150	845.67
	2.25	850[b]	150	0	150	850.98
	3.00	850[b]	150	0	150	850 54
	3.75	850[b]	150	150	0	852.21
	4.50	850[b]	150	150	0	855.01
0.62	1.50	850[b]	150	0	150	879.57
	2.25	850[b]	150	0	150	885.33
	3.00	850[b]	150	0	150	884.51
	3.75	850[b]	150	150	0	886.02
	4.50	850[b]	150	150	0	888.78
0.71	1.50	1000	0	0	0	910.47
	2.25	1000	0	0	0	916.36
	3.00	1000	0	0	0	915.60
	3.75	1000	0	0	0	915.63
	4.50	850[b]	150	150	0	917.79
0.80	1.50	1000	0	0	0	925.00
	2.25	1000	0	0	0	930.93
	3.00	1000	0	0	0	929.89
	3.75	1000	0	0	0	929.86
	4.50	1000	0	0	0	930.74

PCT is price of cotton ($/lb.) lagged one period. *PWT* is price of wheat ($/bu.) lagged one period. Lagged prices used to form expectations concerning sales price of the commodities. Net returns are the ten year discounted returns to land.

[a] Includes triple base acres from cotton program participation if any.

[b] Cotton acres enrolled in farm program; excluding triple base acres planted in soybeans, but including ARP acreage if any.

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Endnotes

1. The decline in real per unit costs of production has interesting policy implications, not explored in this study, with regard to the parity concept.

2. For a recent empirical application of dynamic programming to a farm management problem, see Duffy and Taylor.

3. In this study, risk neutrality of the decision maker was assumed. Further research is needed to investigate whether risk considerations can have important effects on the optimal plan.

4. Price limits were chosen to represent the range of possible prices entering into a producer's long-term decisions and are consistent with ranges experienced during the last decade.

5. These results should be interpreted with caution as elimination of the farm program could result in changes in the market price distribution.