The Effects of Increasing Flex Acres on Farm Planning and Profitability

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Dynamic programming techniques were used to evaluate the effects of alternative levels of normal flex acreage requirements on a Midwestern corn-soybean farm and a Southeastern cotton farm. Results indicate that increasing normal flex acres from the current level of 15 percent to 35 percent would provide inducement for farmers in both regions to plant more soybeans. In general, the cotton farm incurs considerably higher expected losses from the change. Thus, there are unequal regional consequences of such a policy change.

Farm programs have provided significant sources of income support for many crop farmers. In eight of the last ten years, the target price for corn has exceeded the national average market price. In 1987, the year of the highest expenditures for this program, over $7 billion in program payments were given to U.S. corn farms, an amount equal to over 50 percent of sales receipts. Over the period 1983–88, program payments averaged 36 percent of corn producers' sales receipts, or 90 percent of returns above cash expenses (Mercier). For cotton, another major program commodity, target price has exceeded market price in every one of the last ten years. As with corn, in years of low prices such as 1986, government expenditures for cotton programs have risen to levels equivalent to half the gross value of production.

Given the importance of farm programs to corn and cotton producers, any change in program provisions has the potential to affect both profits and crop-mix decisions. The 1990 Farm Bill diverged in several aspects from the 1985 Farm Bill, but one provision in particular, the "flex acre" provision represented a fairly strong departure from previous legislation. This provision, enacted primarily as a cost-saving method for the government, reduces direct payments to producers while allowing more flexibility in planting decisions. The provision also has potential environmental benefits in that it may encourage the use of rotation, rather than chemical pesticides, as a way to increase yields.

Currently, there is much discussion of expanding normal flex acres from the present level of 15 percent to an even higher level. The purpose of this paper is, accordingly, to examine the effects of changing the flex acre provision on both a Midwest corn and soybean farm and a Southeastern cotton-soybean-wheat farm.

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Program Provisions

Base acreage is currently calculated as a moving average of acreage planted and considered planted. (Acres considered planted include any acres idled or diverted to other crops in compliance with farm program provisions.) A five-year average is used for corn base calculation and a three-year average for cotton base calculation. Farmers with a commodity base are allowed, but not required, to participate in the farm program for that crop. With participation, the farmer is limited to planting the commodity on a specified portion of base. In return, farmers receive deficiency payments on all eligible acres.

If target price exceeds market price, a payment, M, is calculated as:

$$(1)\quad M = [TP - max(PCN,CNL)] \cdot PY \cdot AE$$

where TP is the legislatively-set target price, PCN is the market price of the crop (corn or cotton), CNL is the loan rate, PY is the "program yield," and AE are acres eligible to receive the payment. "Program yield" is based either on average county yields or pre-1986 farm yields, which may or may not reflect actual current yields on a particular farm. If market price is above target price, the deficiency payment is zero.

Program acres eligible for deficiency payments are a portion of base. First, a percentage of the base must be idled (put in cover crop) if an acreage reduction program (*ARP*) is announced that year. The announced *ARP* level for a particular year is tied by legislation to the level of ending stocks, and hence, given the effect of stocks on prices, is inversely correlated with lagged price.

"Triple" base provisions in the Farm Bill further limit payment acreage. 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 the commodity or a substitute crop, but will receive no deficiency payment. Also, an additional 10 percent of acres are designated "Optional Flex Acres" (*OFA*). The farmer may plant these acres in the commodity 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 the commodity for the purpose of calculating future farm program base.

Producers enrolled in the farm program also have the option of using the Commodity Credit Corporation loan program as an aid in marketing. The loan rate is set so that in most years it will be below the market-clearing price. Producers have the option of using the loan program to receive cash income at harvesting while waiting for market prices to rise. The loan is nonrecourse, so that if prices do indeed fall below the loan rate, the producer may forfeit the commodity without penalty.[1]

Programming Models

In many previous studies, farm-level effects of policy changes have been examined using mathematical programming techniques, usually some variant of linear or quadratic programming (Scott and Baker; Persaud and Mapp; Kramer and Pope; Musser and Stamoulis; among others). Recently, advances in computer technology have allowed dynamic programming (DP) techniques to be used. Given the dynamic nature of program bases, the farm-planning problems for this study were formulated as multi-year dynamic programming models. Because the corn-soybean model has already been fully documented (Duffy and Taylor, 1994), only a short discussion will be provided here. The cotton model was largely adapted from the corn-soybean model, with appropriate changes. The time horizon selected for study is twenty years. Computer code for either or both models is available from the authors on request.

Corn-Soybean Farm[2]

The representative corn-soybean farm developed for this study is a 300-acre Illinois corn and soybean farm. With farm program participation, Π_t, the one-period profit function (ignoring variability) is:

$$
\begin{aligned}
(2)\quad \Pi_t = {} & (MAX(TP,PCN_t) \cdot YCN \\
& - VCCN) \cdot APDP_t \\
& + (MAC(CNLN,PCN_t) \cdot YCN \\
& - VCCN) \cdot ACTB - SA_t \cdot VCSA \\
& + (MAX(PSB_t,SBLN) \cdot YSB \\
& - VCSB) \cdot ASB_t \\
& - VCROT \cdot NROT \\
& - BL \cdot PCN_t \cdot NROT - FC
\end{aligned}
$$

where TP is the target price of corn, *YCN* is the yield of corn, *VCCN* is per acre variable costs of corn, *APDP* are planted acres of corn eligible for deficiency payment, *CNLN* is the corn loan rate, *ACTB* is corn planted on the flex acres (if any) and therefore ineligible for deficiency payment, *SA* is land idled due to program participation, *VCSA* is the variable cost of idling the land, *SBLN* is the soybean loan, *YSB* is the yield of soybeans, *ASB* is acres of soybeans, including any soybeans planted on normal flex acres and optional flex acres, *VCSB* is the variable cost per acre of soybeans, *NROT* is acreage of corn following corn, *VCROT* is the additional variable cost for corn planted after corn, *BL* is the yield loss on corn following corn, and *FC* is non-land fixed cost.

Market prices in the model are stochastic and assumed to follow a Markovian process, which is described in detail, below. Yield and cost figures were drawn from USDA's *Economic Indicators of the Farm Sector, Cost of Production* and then modified based on Illinois Cooperative Extension Service records for 1992.[3] Yield for corn following soybeans was accordingly set at 123 bushels per acre, and soybean yield at 37 bushels per acre. Yield loss for corn following corn (*BL*) was set at 10 bushels per acre. Variable costs of production

[1] For corn, loan rate provisions have recently been changed to allow a marketing loan to be implemented, similar in effect to the cotton loan. This analysis was done under the 1992 loan rate provisions. The change in loan rate provisions has very limited effects on the results of this study, however, because the farm-level effects of the programs are not all that different. Further, the loan program is triggered only when market prices are extremely low.

[2] Much of this section appears, with more detail, in Duffy and Taylor, 1994. See also Duffy and Taylor, 1993, for a discussion of polynomial approximations of objective functions in problems of this type.

[3] The authors express their appreciation to Rob Hornbaker of the Illinois Cooperative Extension Service for providing budgetary information used in this study.

were set at $164 for corn following soybeans, and $84 per acre for soybeans. For corn following corn, variable costs of production were assumed to increase by $9.00 per acre, because of the need for additional pest control. Non-land fixed costs were set at $76.41 per acre.

While yields and nominal costs have trended upwards over the past several decades, they are held constant in the model for a number of reasons. First, important results of the model are driven by relative yield and cost levels, which determine relative profits, rather than absolute levels, so that results would not be significantly affected by changes in yield that are proportional. Secondly, real prices have trended downwards, so that real per acre profits have not shown any significant trend over time. While prices are stochastic in the model (see below), their means are stationary. Thus, conditions in the model reflect 1992–1993 norms, on which producers would be likely to base expectations.

Target prices and loan rates are set at current levels. The target price for corn is $2.75, a level that has been in effect since 1990. (Target prices are set by law and have lately been static.) Loan rates in the model are set at $1.80 for corn and $4.92 for soybeans. The $4.92 loan rate for soybeans is the fixed, legislated level ($5.02) net of a 2 percent loan origination fee. Unlike the soybean loan, under current legislation, corn loan rates change annually, based on a moving average of historic prices. Although dynamic programming can theoretically handle calculation of a loan rate based on historic prices, to do so in this model would increase the number of states to an unmanageable level. A "reasonable" loan level ($1.80), based on past prices, was accordingly selected and held constant across the twenty years of the model.

Without participation in the farm program, the one period profit function is:

$$(3)\quad \Pi_t = (PCN_t \cdot YCN - VCCN) \cdot ACN_t + (PSB_t \cdot YSB - VCSB) \cdot ASB_t - FC - VCROT \cdot NROT - BL \cdot PCN_t \cdot NROT$$

where ACN is nonprogram corn acreage.

The objective function, V, for our DP problem can be expressed as:

$$(4)\quad V = \underset{U_t}{MAX} \sum_{t=1}^{20} \beta^{t-1} E \{\Pi_t(U_t, PCN_{t-1}, PSB_{t-1}, Base_t)\}$$

where:

$$(5)\quad Base_t = \frac{1}{5}\sum_{i=1}^{5} A_{t-i}$$

Here, A is the acreage of corn either planted (whether in or out of the program) or considered planted for program purposes. E is the expectations operator, and expectations for profit (Π_t) are taken with respect to prices in period t, based on lagged prices. U_t is a decision vector concerning allocation of acreage between the two crops and participation in the farm program. Decision variables are discussed in detail, below.

The objective function in (4) can be reformulated as a dynamic programming recursive equation in terms of the time-subscripted optimal value function, V_t:

$$(6)\quad V_t\,(PCN_{t-1}, PSB_{t-1}, A_{t-1}, A_{t-2}, A_{t-3}, A_{t-4}, A_{t-5}) = MAX_{U_t}\, E\{(\Pi_t(PCN_t, PSB_t, Base_t, U_t)) + \beta V_{t+1}\,(PCN_t, PSB_t, A_t, A_{t-1}, A_{t-2}, A_{t-3}, A_{t-4})\}$$

The recursive equation is solved in a backwards, stepwise manner. First, the optimal strategy for each possible set of terminal state variables is found in the last stage of the problem. The optimal strategies and associated optimal value function, V_T, are stored and the program moves backwards one stage. At this stage, the optimal decision will depend not only on the profits from this second to last year of the time horizon, but also on the discounted profits from the last year of the time horizon, already calculated and stored. State transition equations link decisions in the second to last stage to the range of possible outcomes in the last stage, providing the dynamics of the program. Solution of the program continues in this fashion, until the first stage (beginning of the time horizon) is reached. (At this point, V_t will equal V from equation 4.) The decision rule for this problem "converges"; that is, after several "backwards" steps, the decision rule is the same regardless of the stage (year) of the system.

Because variable costs of production and non-land fixed costs are subtracted in the profit functions, the optimal value function for year one in this model represents the expected twenty-year discounted stream of returns to land. This discounted stream of returns should closely approximate sale price of agricultural land, because it represents the land's value in production.

Five acreage state variables (one for acreage planted or considered planted in each of the last five years) are needed in the corn farm DP model for base calculation. The one-period lagged acreage is also needed to determine the amount of corn following corn so that appropriate "penalties" in terms of reduced yield and increased variable costs can be assessed. Historical planted acreage in corn was represented as a percentage of the 300 total crop acres on the farm. Bounds for this variable were 0 and 1, with intermediate values of 0.25, 0.50, and 0.75 chosen for the discrete intervals.

Prices expectation functions were used to related the lagged (known) price to the expected price for the current crop. The expectation function was thus developed under the assumption that producers use last year's price as a reasonable predictor of prices at harvest.[4] Equations for expected prices, based on lagged prices, are:

$$(7)\quad PCN_t = PCN_{t-1}^{0.56} \cdot EXP^{0.60 + 0.38 \cdot Dum - 0.00845 \cdot T}$$

$$(8)\quad PSB_t = PSB_{t-1}^{0.48} \cdot EXP^{1.21 + 0.33 \cdot Dum - 0.00954 \cdot T}$$

where *Dum* is a dummy variable with value of 1 for years 1972–74, 0 otherwise; T is a time trend with 1966-1 and so on, and *EXP* is the natural exponent function. These equations were estimated as seemingly unrelated regressions, using Illinois price data for the period 1966 to 1991. Nominal prices were obtained from *Agricultural Statistics* and normalized to 1991 dollars using the implicit *GDP* price deflator. A time trend was included in the equations because real prices have been trending downwards, reflecting the downward trend in real per unit costs. In the *DP* model the trend variable is held constant at its 1991 value. We assume that farmers' decisions are based on current real returns, as the future is difficult to predict with accuracy, and accordingly have held the mean prices stationary along with real costs and yields. In both equations, lagged price was significantly different from zero at the 0.01 level of confidence and other statistical measures of "goodness of fit" were also satisfactory.[5]

The one-period lagged prices, included as state variables in the model, were rendered discrete ("discretized") over their assumed probable ranges. The lowest corn price state was assumed to be $1.50 and the highest $3.30. Five intermediate price states were used: $1.80, $2.10, $2.40, $2.70, and $3.00. Soybean price states were assumed to range from $4.00 to $8.50, also with five evenly distributed intermediate values. Thus, seven states on each of the stochastic price variables were specified. Given that each of the five lagged acreage state variables can take five possible values, the number of distinct combinations of the discrete manifestations of the state variable is 153,125 ($5 \cdot 5 \cdot 5 \cdot 5 \cdot 5 \cdot 7 \cdot 7$), near practical computational limits for any numerical technique applied to this problem.

The price series were assumed to have a bivariate log-normal distribution. Through a double numerical integration process (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.[6] Expected profits are calculated using the numerically derived probabilities to weight all possible price sets. The probability density function is also used to assign probabilities to the expected future returns, V_{t+1}, by relating the state of the system in stage t to the state of the system in stage $t + 1$. Given the inverse relationship between required acreage reduction (*ARP*) and lagged price, *ARP* levels in the model were determined by lagged price. For corn, *ARP* was assumed to be 20 percent at a lagged corn price of $1.50, and declined to zero at a lagged corn price of $3.00.

Yield is also random, but 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 producers' decision to participate in the program. The situation for yield thus approaches certainty equivalence, and yield is included in the model at its expected mean value.

The model decision vector, U_t, has two main components, the amount of acreage to plant in corn (with the remainder in soybeans), and the farm program participation option. Based on current legislation, we provide four participation options, modeled as a discrete integer variable with four Farm program participation options are (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. Initially, normal flex acres were kept

[4] More complicated expectation functions, involving more lags, would increase the number of state variables in this study beyond the point where a solution could be attained in a reasonable time.

[5] The corn price equation has an R-squared value of 0.76. The t-value on lagged price is 4.43. The soybean price equation has an R-squared of .69, and a t-value on lagged price of 2.69. Full discussion of these equations can be found in Duffy and Taylor, 1994.

[6] The Kolmogorov-Smirnov test was used to test whether the price distributions for Illinois corn and soybeans and for Alabama cotton, soybeans, and wheat follow a log-normal distribution. Results showed that this assumption fit the data well and that the hypothesis could not be rejected at any reasonable level of significance.

at their current level of 15 percent. In a second run of the model, the normal flex acreage required was increased to 35 percent of base.

Like the lagged acreage state variable, the portion of acreage to plant in corn is continuous and must be divided into discrete intervals. To allow each possible base (computed as a five-year average) to be matched by an acreage level, the range from 0 to 1 was subdivided into increments of 0.05, a five times finer grid than that used for the state variables. To translate the acreage decision variable into the "blockier" state variable for lagged acreage, we used linear interpolation of the optimal value function, $V_{t+1}(\cdot)$, in the right hand side of (6). This linear interpolation allows an approximation of a "finer" grid on the acreage state variable without significantly increasing computational time. (See Duffy and Taylor, 1994, for details of the interpolation procedure.)

Cotton Farm

The model for the Southeastern cotton-wheat-soybean farm is similar in mechanics to the corn-soybeans farm described above. Although three crops can be produced on the Southeastern farm, the wheat and soybeans are double-cropped. Thus, the acreage allocation decision still involves two choices, cotton (full season) versus wheat-soybeans double cropped. Although wheat is a farm program crop, farms on which cotton is grown as a principal enterprise usually do not participate in the farm program for wheat (Cain, Duffy et al.). Accordingly, farm program participation options in this model were limited to the cotton provisions.

The farm was assumed to be located in South Alabama, and to have 1000 tillable acres, representing commercial-sized farms in the area (Cain; Mims et al.; Duffy et al.). Costs and yields for crops on this farm were taken from 1992–1993 budgets of the Alabama Cooperative Extension Service. Cotton yield was set at 626 pounds per acre, wheat yield at 40 bushels per acre, and soybean yields at 22 bushels per acre. Variable costs of production were set at $284.05 for cotton and $149.76 for wheat-soybeans double cropped. Nonland fixed costs were set at $53.00 per acre. Based on current legislation, the target price for cotton was set at $0.729 per pound, and the loan rate at $0.50 per pound. Little if any rotational benefits are incurred among these crop alternatives in this region (Cain; Mims et al.); hence, yields and costs for one year in this model are not affected by the previous year's plantings.

Because base acreage for cotton is calculated as a three-year moving average, only three lagged acreage variables are needed. Increments on the lagged dependent variable in this case were 0.167, 0.333, 0.50, 0.667, and 0.75. The decision variable for cotton planting, as a portion of total acreage, ranged from 0 to 1 in increments of 0.0555. These increments were chosen to be one-third as large as the increments on lagged acreage so that all possible bases are matched by a decision variable. Because the base calculation period is three years for cotton, instead of the five used for corn, increments on lagged acreage variables and on the planting decision for the cotton farm could not be selected to correspond to those for the corn-soybean farm if each possible cotton base was matched with a decision variable. Program participation options are the same as those discussed previously for corn, only here wheat-soybeans double cropped are available for the triple base acreage, rather than full-season soybeans.

As with the corn-soybean farm, market prices are stochastic and Markovian. Although wheat-soybeans double cropped are considered as a single enterprise in the planting decision, separate price equations are needed. Accordingly, in the cotton farm model, there are three price equations and three lagged price state variables. Equations for expected prices, based on lagged prices, are:

$$(9) \quad PCT_t = PCT_{t-1}^{0.42} \cdot EXP^{0.48-0.01130 \cdot T}$$

$$(10) \quad PSB_t = PSB_{t-1}^{0.31} \cdot EXP^{1.74-0.01702 \cdot T}$$

$$(11) \quad PWT_t = PWT_{t-1}^{0.42} \cdot EXP^{1.04-0.01146 \cdot T}$$

where *PCT* is price of cotton in Alabama, *PWT* is price of wheat in Alabama, and *PSB* is the price of soybeans in Alabama.[7] Prices were obtained from *Agricultural Statistics* and normalized before estimation. Triple numerical integration of the trivariate normal probability density function, based on the covariance matrix of residuals, was used to generate joint probabilities of receiving particular ranges of prices, given a particular set of lagged prices.

Lagged cotton prices were assumed to range from $.48 to $.84 in $0.06 increments, lagged soybean prices were assumed to range from $4.00 to $8.50 in $0.75 increments, and lagged wheat prices were assumed to range from $2.50 to $4.30 in $0.30 increments. All together, there are three deterministic lagged acreage state variables, each

[7] R-squared for cotton price equation if 0.50, and the t-value on lagged price was 2.73. R-squared for soybean price equation is 0.52 and the t-value on lagged price is 1.96. R-squared for wheat price equation is 0.51 and the t-value on lagged price is 2.79. For a full description of these regression equations, see Duffy et al.

discretized into 7 states, and three stochastic lagged price state variables, each discretized into 7 states, for a total of 117,649 states in this model.

As with the corn farm, *ARP* rates vary with commodity price. At a lagged cotton price of $.48, 22 percent *ARP* is required. At a lagged price of $.54, 14 percent *ARP* was required. At $.60, a ten percent *ARP* was required. At $.66, a four percent *ARP* was required. At lagged prices above $.66, no *ARP* was required.

Results

Results of the dynamic programming models provide a decision rule, which is an optimal strategy to follow for every possible state described by a particular planting history and a particular set of lagged market prices. Because price is stochastic, the decision rule cannot be used at the outset of the problem to provide a multi-year solution. This type of solution could only be obtained as additional information (recorded price states) becomes available.

Clearly, decision rules with over 100,000 elements are too large to present in their entireties. Duffy and Taylor found that, because of rotational considerations, the optimal base for the corn farm was about 50 percent of total farm acreage. Similarly, Herriges et al. also found that for Midwest corn-soybean farmers "too much" corn base leads to a discount in rental premiums. In their studies of Alabama cotton farms, Mims et al. and Cain found that many farms of this type in that state have roughly half of tillable acres in cotton base. Accordingly, we present only the results for farms with a 50 percent base, achieved through a uniform planting history.

In table 1, the decision rule for each set of lagged prices is given for the Midwest corn-soybean farm with a 50 percent base under the current farm program's 15 percent normal flex acres. In table 2, changes in the decision rule and in the optimal value function associated with increasing normal flex acreage requirements to 35 percent are reported. The optimal value function represents the twenty-year discounted returns to each acre of land and should approximate the land's per acre selling price. Because of the convergence of the solutions, the decision rule for year one will also be the decision rule for subsequent years, until the end of the planting horizon is reached.[8]

As can be seen in table 2, two types of changes occur. In some instances, the farm remains in the program in spite of the higher normal flex acreage requirement, and increases flex acres in soybeans. This change occurs at lagged price states of $1.50/$4.00, $.180/$4.00, $2.10/$4.00, $2.10/$4.75, $2.40/$5.50, $2.40/$6.25, $2.70/$7.00, $2.70/$7.75, $3.00/$7.75, and $3.00/8.50. Other times, the higher flex acreage requirement triggers a move from program corn to full-farm plantings in soybeans. This change occurs at lagged price states of $1.50/$4.75, $1.80/$4.75, $2.10/$5.50, $2.40/$7.00, and $2.70/$8.50. It is worth noting that the changes in planting decisions occur where the corn/soybean price ratio ranges from 2.2 to 3.0. Price combinations in this range are fairly common as compared with some other possible price combinations (say $1.50/$8.50 or $3.30/$4.00), making these changes more important than they may seem in the table. All changes involved increased acreage of soybeans, a change that in the aggregate could lead to reduced soybean prices. This effect was not explicitly considered here, but would be worthy of analysis.

For the Midwest farm, the per acre "cost" of increased triple base (in terms of reduced discounted returns over the twenty-year horizon) can range from a low of about $4.00 under some lagged price combinations to a high of nearly $20.00. The highest losses occur when lagged soybean price is low. Thus, the economic consequences of implementation of such a program would be softened if implementation were in a year when soybean prices are expected to be relatively high.

Results for the Southeastern cotton farm are presented in tables 3 and 4. Because the 3 lagged price variables, discretized into 7 states each, yield 343 possible lagged price combinations, only a section of the decision rule for the 50 percent base can be presented here.

For the cotton farm with 50 percent base, the optimal decision rule under 15 percent NFA frequently involves planting the entire farm in nonprogram cotton (table 3). Previous research has shown that these extensive cotton plantings are undertaken to increase cotton base for future years (Mims et al.; Cain). For cotton farms, unlike corn-soybean farms, rotational considerations do not

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[8] At the end of the planning horizon, when no future farm programs are assumed to be available, the decision rule becomes "myopic" as there is no concern about adjusting base for the future. For a discussion of how uncertainty about the continuation of the farm programs affects producer decisions, see Duffy and Taylor, 1994. In this current study, we choose to present only results from year one of the time horizon, as these results would be of greatest interest to policy makers considering any change in flex acreage requirements.

Table 1. Decision Rule and Optimal Value Function for Corn-Soybean Farm, 50% Base, 15% Normal Flex Acres. First Year of a Twenty Year Planning Horizon

Lagged Corn Price	Lagged Soybean Price	ARP Acreage	Program Corn Planted Acreage	Nonprogram Corn Average	Nonprogram Soybean Acreage	Program Soybean Triple Base Acreage	Per Acre Optimal Value Function
1.50	4.00	30	97.5	0	150	22.5	1079.58
1.50	4.75	30	97.5	0	150	22.5	1098.85
1.50	5.50	0	0	0	300	0	1122.29
1.50	6.25	0	0	0	300	0	1143.20
1.50	7.00	0	0	0	300	0	1166.34
1.50	7.75	0	0	0	300	0	1181.08
1.50	8.50	0	0	0	300	0	1191.47
1.80	4.00	30	97.5	0	150	22.5	1092.88
1.80	4.75	30	97.5	0	150	22.5	1100.66
1.80	5.50	0	0	0	300	0	1121.76
1.80	6.25	0	0	0	300	0	1143.66
1.80	7.00	0	0	0	300	0	1166.59
1.80	7.75	0	0	0	300	0	1179.70
1.80	8.50	0	0	0	300	0	1192.86
2.10	4.00	22	105.5	0	150	22.5	1100.88
2.10	4.75	22	105.5	0	150	22.5	1111.76
2.10	5.50	22	105.5	0	150	22.5	1127.86
2.10	6.25	0	0	0	300	0	1146.33
2.10	7.00	0	0	0	300	0	1164.98
2.10	7.75	0	0	0	300	0	1182.09
2.10	8.50	0	0	0	300	0	1204.09
2.40	4.00	15	135	0	150	0	1120.11
2.40	4.75	15	135	0	150	0	1132.34
2.40	5.50	15	112.5	0	150	22.5	1148.03
2.40	6.25	15	112.5	0	150	22.5	1157.85
2.40	7.00	15	112.5	0	150	22.5	1173.24
2.40	7.75	0	0	0	300	0	1187.68
2.40	8.50	0	0	0	300	0	1200.87
2.70	4.00	8	142	0	150	0	1138.65
2.70	4.75	8	142	0	150	0	1147.26
2.70	5.50	8	142	0	150	0	1162.47
2.70	6.25	8	142	0	150	0	1176.54
2.70	7.00	8	119.5	0	150	22.5	1184.07
2.70	7.75	8	119.5	0	150	22.5	1196.58
2.70	8.50	8	119.5	0	150	22.5	1210.44
3.00	4.00	0	150	0	150	0	1150.05
3.00	4.75	0	150	0	150	0	1166.15
3.00	5.50	0	150	0	150	0	1181.53
3.00	6.25	0	150	0	150	0	1188.62
3.00	7.00	0	150	0	150	0	1203.95
3.00	7.75	0	127.5	0	150	22.5	1211.68
3.00	8.50	0	127.5	0	150	22.5	1226.94
3.30	4.00	0	150	0	150	0	1158.65
3.30	4.75	0	150	0	150	0	1172.08
3.30	5.50	0	150	0	150	0	1186.14
3.30	6.25	0	150	0	150	0	1200.19
3.30	7.00	0	150	0	150	0	1210.38
3.30	7.75	0	150	0	150	0	1219.83
3.30	8.50	0	150	0	150	0	1233.17

Lagged corn price and lagged soybean price in dollars per bushel. Results for a 300-acre Midwest corn and soybean farm. Per acre value function is the per acre discounted stream of returns to land over the twenty year horizon. Program corn planted acreage is amount of corn acreage planted and covered by farm program. *ARP* is acres set-aside to satisfy requirements of corn program. Nonprogram corn acreage is corn acreage planted, not covered by farm programs. Nonprogram soybean acreage is normal soybean acreage, exclusive of any soybeans planted on the corn base. Program soybean triple base acreage is soybean acreage on the corn base. *NFA* is 15% of corn base (22.5 acres).

Table 2. Differences in Decision Rule and Optimal Value Function for Normal Flex Acres of 35% versus Normal Flex Acres of 15%, 50% Base. First Year of a Twenty Year Planning Horizon. Midwest Corn-Soybean Farm

Lagged Corn Price	Lagged Soybean Prie	ARP Acreage	Program Corn Planted Acreage	Nonprogram Corn Average	Nonprogram Soybean Acreage	Program Soybean Triple Base Acreage	Per Acre Optimal Value Function
1.50	4.00	0	−30	0	0	30	−17.00
1.50	4.75	−30	−97.5	0	150	−22.5	−9.66
1.50	5.50	0	0	0	0	0	−5.52
1.50	6.25	0	0	0	0	0	−4.93
1.50	7.00	0	0	0	0	0	−4.61
1.50	7.75	0	0	0	0	0	−4.34
1.50	8.50	0	0	0	0	0	−4.17
1.80	4.00	0	−30	0	0	30	−19.38
1.80	4.75	−30	−97.5	0	150	−22.5	−12.65
1.80	5.50	0	0	0	0	0	−6.62
1.80	6.25	0	0	0	0	0	−5.87
1.80	7.00	0	0	0	0	0	−5.32
1.80	7.75	0	0	0	0	0	−4.96
1.80	8.50	0	0	0	0	0	−4.71
2.10	4.00	0	−30	0	0	30	−21.17
2.10	4.75	0	−30	0	0	30	−18.07
2.10	5.50	−22.5	−105.5	0	150	−22.5	−13.38
2.10	6.25	0	0	0	0	0	−6.96
2.10	7.00	0	0	0	0	0	−6.28
2.10	7.75	0	0	0	0	0	−5.79
2.10	8.50	0	0	0	0	0	−5.49
2.40	4.00	0	0	0	0	0	−20.64
2.40	4.75	0	0	0	0	0	−19.19
2.40	5.50	0	−30	0	0	30	−17.21
2.40	6.25	0	−30	0	0	30	−14.61
2.40	7.00	−15	−112.5	0	150	−22.5	−8.72
2.40	7.75	0	0	0	0	0	−6.76
2.40	8.50	0	0	0	0	0	−6.32
2.70	4.00	0	0	0	0	0	−19.72
2.70	4.75	0	0	0	0	0	−18.63
2.70	5.50	0	0	0	0	0	−17.55
2.70	6.25	0	0	0	0	0	−16.47
2.70	7.00	0	−30	0	0	30	−14.33
2.70	7.75	0	−30	0	0	30	−12.36
2.70	8.50	−8	−119.5	0	150	−22.5	−7.82
3.00	4.00	0	0	0	0	0	−18.74
3.00	4.75	0	0	0	0	0	−18.01
3.00	5.50	0	0	0	0	0	−17.18
3.00	6.25	0	0	0	0	0	−16.28
3.00	7.00	0	0	0	0	0	−15.47
3.00	7.75	0	−30	0	0	30	−14.34
3.00	8.50	0	−30	0	0	30	−12.80
3.30	4.00	0	0	0	0	0	−17.96
3.30	4.75	0	0	0	0	0	−17.34
3.30	5.50	0	0	0	0	0	−16.72
3.30	6.25	0	0	0	0	0	−16.08
3.30	7.00	0	0	0	0	0	−15.42
3.30	7.75	0	0	0	0	0	−14.79
3.30	8.50	0	0	0	0	0	−14.26

Lagged corn price and lagged soybean price in dollars per bushel. Results for a 300-acre Midwest corn and soybean farm. Per acre optimal value function is the per acre discounted stream of returns to land over the twenty year horizon. Program corn planted acreage is amount of corn acreage planted and covered by farm program. *ARP* is acres set-aside to satisfy requirements of corn program. Nonprogram corn acreage is corn acreage planted, not covered by farm programs. Nonprogram soybean acreage is normal soybean acreage, exclusive of any soybeans planted on the corn base. Program soybean triple base acreage is soybean acreage on the corn base. Figures in acreage columns and value column are changes induced by an increase of *NFA* from 15% to 35% of base.

Table 3. Decision Rule and Optimal Value Function for Cotton Farm, 50% Base, 15% Normal Flex Acres. First Year of a Twenty Year Planning Horizon

Lagged Cotton Price	Lagged Wheat Price	Lagged Soybean Price	ARP Acreage	Program Cot. Planted Acreage	Nonprogram Cotton Acreage	Normal Wheat-Soy Acreage	Triple Base Wheat-Soy Acreage	Per Acre Optimal Value Function
0.48	2.80	4.75	0	0	1000	0	0	1235.94
0.48	3.10	4.75	110	315	0	500	75	1239.30
0.48	3.40	4.75	110	315	0	500	75	1243.13
0.48	2.80	5.50	110	315	0	500	75	1238.02
0.48	3.10	5.50	110	315	0	500	75	1242.47
0.48	3.40	5.50	110	315	0	500	75	1246.22
0.48	2.80	6.25	110	315	0	500	75	1240.69
0.48	3.10	6.25	110	315	0	500	75	1245.24
0.48	3.40	6.25	110	315	0	500	75	1249.29
0.54	2.80	4.75	0	0	1000	0	0	1252.38
0.54	3.10	4.75	0	0	1000	0	0	1253.72
0.54	3.40	4.75	0	0	1000	0	0	1254.86
0.54	2.80	5.50	0	0	1000	0	0	1253.07
0.54	3.10	5.50	0	0	1000	0	0	1254.54
0.54	3.40	5.50	80	345	0	500	75	1257.35
0.54	2.80	6.25	0	0	1000	0	0	1253.89
0.54	3.10	6.25	80	345	0	500	75	1256.40
0.54	3.40	6.25	80	345	0	500	75	1260.28
0.60	2.80	4.75	0	0	1000	0	0	1268.85
0.60	3.10	4.75	0	0	1000	0	0	1270.11
0.60	3.40	4.75	0	0	1000	0	0	1271.27
0.60	2.80	5.50	0	0	1000	0	0	1269.55
0.60	3.10	5.50	0	0	1000	0	0	1271.10
0.60	3.40	5.50	0	0	1000	0	0	1272.21
0.60	2.80	6.25	0	0	1000	0	0	1270.37
0.60	3.10	6.25	0	0	1000	0	0	1271.99
0.60	3.40	6.25	0	0	1000	0	0	1273.20
0.66	2.80	4.75	0	0	1000	0	0	1284.77
0.66	3.10	4.75	0	0	1000	0	0	1286.26
0.66	3.40	4.75	0	0	1000	0	0	1287.39
0.66	2.80	5.50	0	0	1000	0	0	1285.58
0.66	3.10	5.50	0	0	1000	0	0	1287.18
0.66	3.40	5.50	0	0	1000	0	0	1288.57
0.66	2.80	6.25	0	0	1000	0	0	1286.37
0.66	3.10	6.25	0	0	1000	0	0	1287.94
0.66	3.40	6.25	0	0	1000	0	0	1289.28
0.72	2.80	4.75	0	0	1000	0	0	1300.07
0.72	3.10	4.75	0	0	1000	0	0	1301.61
0.72	3.40	4.75	0	0	1000	0	0	1302.64
0.72	2.80	5.50	0	0	1000	0	0	1300.91
0.72	3.10	5.50	0	0	1000	0	0	1302.51
0.72	3.40	5.50	0	0	1000	0	0	1303.76
0.72	2.80	6.25	0	0	1000	0	0	1301.70
0.72	3.10	6.25	0	0	1000	0	0	1303.42
0.72	3.40	6.25	0	0	1000	0	0	1304.74

Lagged cotton price in cents per pound. Lagged wheat price in dollars per bushel. Lagged soybean price in dollars per bushel. Results for a 1000-acre Southeast cotton-wheat-soybean farm. Per acre optimal value function is the per acre discounted stream of returns to land over the twenty-year horizon. Program cotton planted acreage is amount of cotton acreage planted and covered by farm programs. *ARP* is acres set-aside to satisfy requirements of corn program. Nonprogram cotton acreage is cotton acreage planted, not covered by farm programs. Nonprogram wheat-soybean acreage is acres of soybeans and wheat double cropped, exclusive of any soybeans planted on the cotton base. Program soybean triple base acreage is wheat-soybean acreage on the corn base. *NFA* is 15% of cotton base (75 acres).

limit the optimal amount of base. Simple budgeting can be used to show that, for current farm program provisions, cotton planted in the program is a more profitable venture than either nonprogram cotton or wheat-soybeans double-cropped. Hence, under current farm programs, cotton producers have an incentive to expand base for future years, unless expected cotton price is unusually low and/or expected wheat-soybean prices are unusually high.

Table 4. Differences in Decision Rule and Optimal Value Function for Normal Flex Acres of 35% Versus Normal Flex Acres of 15%, 50% Base. First Year of a Twenty Year Planning Horizon. Southeast Cotton-Wheat-Soybean Farm

Lagged Cotton Price	Lagged Wheat Price	Lagged Soybean Price	ARP Acreage	Program Cot. Planted Acreage	Nonprogram Cotton Acreage	Normal Wheat-Soy Acreage	Triple Base Wheat-Soy Acreage	Per Acre Optimal Value Function
0.48	2.80	4.75	110	215	−1000	500	175	−84.54
0.48	3.10	4.75	0	−100	0	0	100	−82.77
0.48	3.40	4.75	0	−100	0	0	100	−82.03
0.48	2.80	5.50	0	−100	0	0	100	−83.06
0.48	3.10	5.50	0	−100	0	0	100	−82.27
0.48	3.40	5.50	0	−100	0	0	100	−81.52
0.48	2.80	6.25	0	−100	0	0	100	−82.58
0.48	3.10	6.25	0	−100	0	0	100	−81.78
0.48	3.40	6.25	−110	−315	0	500	−75	−80.53
0.54	2.80	4.75		0	0	0	0	−88.81
0.54	3.10	4.75	80	245	−1000	500	175	−86.80
0.54	3.40	4.75	80	245	−1000	500	175	−83.50
0.54	2.80	5.50	80	245	−1000	500	175	−87.74
0.54	3.10	5.50	80	245	−1000	500	175	−84.15
0.54	3.40	5.50	0	−100	0	0	100	−82.36
0.54	2.80	6.25	80	245	−1000	500	175	−85.30
0.54	3.10	6.25	0	−100	0	0	100	−82.62
0.54	3.40	6.25	0	−100	0	0	100	−81.90
0.60	2.80	4.75	0	0	0	0	0	−89.15
0.60	3.10	4.75	0	0	0	0	0	−88.92
0.60	3.40	4.75	0	0	0	0	0	−88.70
0.60	2.80	5.50	0	0	0	0	0	−89.04
0.60	3.10	5.50	0	0	0	0	0	−88.82
0.60	3.40	5.50	50	275	−1000	500	175	−86.20
0.60	2.80	6.25	0	0	0	0	0	−88.96
0.60	3.10	6.25	50	275	−1000	500	175	−87.03
0.60	3.40	6.25	50	275	−1000	500	175	−83.75
0.66	2.80	4.75	0	0	0	0	0	−89.46
0.66	3.10	4.75	0	0	0	0	0	−89.28
0.66	3.40	4.75	0	0	0	0	0	−89.09
0.66	2.80	5.50	0	0	0	0	0	−89.38
0.66	3.10	5.50	0	0	0	0	0	−89.20
0.66	3.40	5.50	0	0	0	0	0	−89.00
0.66	2.80	6.25	0	0	0	0	0	−89.32
0.66	3.10	6.25	0	0	0	0	0	−89.10
0.66	3.40	6.25	20	305	−1000	500	175	−88.34
0.72	2.80	4.75	0	0	0	0	0	−89.76
0.72	3.10	4.75	0	0	0	0	0	−89.62
0.72	3.40	4.75	0	0	0	0	0	−89.44
0.72	2.80	5.50	0	0	0	0	0	−89.70
0.72	3.10	5.50	0	0	0	0	0	−89.54
0.72	3.40	5.50	0	0	0	0	0	−89.36
0.72	2.80	6.25	0	0	0	0	0	−89.64
0.72	3.10	6.25	0	0	0	0	0	−89.47
0.72	3.40	6.25	0	0	0	0	0	−89.29

Lagged cotton prie in cents per pound. Lagged wheat price in dollars per bushel. Lagged soybean price in dollars per bushel. Results for a 1000-acre Southeast cotton-soybean-wheat farm. Per acre optimal value function is the per acre discounted stream of returns to land over the twenty year horizon. Program cotton satisfy requirements of cotton program. Nonprogram cotton acreage is cotton acreage planted, not covered by farm programs. Nonprogram wheat-soybean acreage is acres of soybeans and wheat double cropped, exclusive of any soybean planted on the cotton base. Program soybean triple base acreage is wheat-soybean acreage on the corn base. Figures in acreage columns and value column are changes induced by an increase of *NFA* from 15% to 35% of base.

When NFA are increased to 35 percent of base, the incentive for base expansion disappears in many cases. Under several lagged price combinations, the farm switches from 1000 acres of nonprogram cotton to 500 acres enrolled in the cotton program (whether planted in cotton, set-aside, or planted in wheat-soybeans triple base), with the remainder in nonprogram wheat-soybeans. It is no-table, too, that the reduction in the optimal value function is considerably higher for cotton farms than for corn-soybean farms. Reductions in the range of $80 to $90 per acre occur for the lagged price combinations presented here. (Reductions of over $100 an acre occurred at lower wheat-soybean prices than those presented in the table, and reductions of about $70 an acre at higher wheat-soybean prices.) Thus, we conclude that an increase in *NFA* to 35 percent would have unequal regional effects, with Southeastern cotton farmers facing a greater reduction in returns than Midwestern corn-soybean farmers.

Conclusions

Dynamic programming models of a Midwest corn and soybean farm and a Southeastern cotton-wheat-soybean farm were used to analyze the possible farm-level consequences of expanding normal flex acreage from its current level of 15 percent of base to 35 percent of base. For the Midwest farm, in some cases, the optimal decision resulting from such a change would be to drop out of the farm program for corn and plant the entire farm in soybeans. In other cases, the Midwest farmer would remain in the program but would expand soybean acreage through increased flex acreage in soybeans. For the cotton farm, the change in normal flex acres most frequently induces a change from full-farm planting in nonprogram cotton (for base expansion) to a strategy of remaining in program limits for cotton with the remainder of the acreage planted in wheat-soybeans double-cropped.

The "cost" to Midwest corn-soybean farmers of this change in policy depends largely on market price conditions and is relatively low ($4.00 to $5.00 per farm acre reduction in the twenty-year discounted returns to land) when soybean prices are high, but can reach nearly $20.00 an acre when soybean prices are low. For the cotton farm, the policy change would result in per acre losses of $80 to $90. These estimated farm-level costs did not include explicit consideration of the possible negative price effects that expanded soybean flex acreage could trigger. An aggregate analysis of the issue would also be in order before the change was made.

The reduction in corn and cotton acreage, and the consequent increase in soybean acreage or wheat-soybeans double cropped, would also have environmental impacts. As can be seen from Extension budgets, in the Midwest soybeans generally require less pesticides per acre than corn, and in the Southeast wheat-soybeans double-cropped requires less pesticides per acre than cotton. Thus, the increased flex acreage could be beneficial to the environment in terms of less potential for chemical run-off problems. Soybeans can be more erosive than corn, however, depending on practices used, so that increased erosion may result in the Midwest. Conversely, given typical cultural practices in South Alabama, cotton is more erosive than wheat and soybeans double-cropped. Hence, increased wheat-soybeans acreage would likely reduce erosion in that area.

References

Burden, R.L. and J.D. Faires. *Numerical Analysis*. Third Edition. Boston: Prindle, Weber, and Schmidt, 1985:153–198.

Cain, D.L. "Acreage and Farm Program Participation Decisions Made on Alabama Cotton Farms under the 1990 Farm Bill." Unpublished M.S. Thesis. Auburn University, 1992.

Duffy, P.A. and C.R. Taylor. "Long-Term Planning on a Corn-Soybean Farm: A Dynamic Programming Approach." *Agricultural Systems*. 42(1993):57–71.

Duffy, Patricia A. and C. Robert Taylor. "The Effects of Uncertainty about the Future of Farm Programs on a Corn-Soybean Farm." *American Journal of Agricultural Economics*. 76(February, 1994):141–152.

Duffy, Patricia A., C. Robert Taylor, Danny L. Cain, and George J. Young. "The Economic Value of Farm Program Base." *Land Economics*. 70(August, 1994). Forthcoming.

Herriges, J.A., N.E. Barickman, and J.F. Shogren. "The Implicit Value of Corn Base Acreage." *American Journal of Agricultural Economics*. 74(February, 1992):50–58.

Kramer, R.A. and R.P. Pope. "Participation in Farm Commodity Programs: A Stochastic Dominance Analysis." *American Journal of Agricultural Economics*, 63(February, 1981):119–28.

Mercier, S. *Corn: Background for 1990 Farm Legislation*. Staff Report No. 89–47. ERS-USDA. Washington, D.C., September, 1989.

Mims, A.M., P.A. Duffy, and G. Young. "Effects of Alternative Acreage Restriction Provisions on Alabama Cotton Farms." *Southern Journal of Agricultural Economics*. 21,2(1989):85–94.

Musser, W.N. and K.G. Stamoulis. "Evaluating the Food and Agriculture Act of 1977 with Firm Quadratic Risk Programming." *American Journal of Agricultural Economics*, 63(August, 1981):448–56.

Persaud, T. and H.P. Mapp, Jr. "Analysis of Alternative Production and Marketing Strategies in Southwestern Oklahoma: A MOTAD Approach." *Risk Analysis in Agriculture: Research and Educational Development*. Department of Agricultural Economics, AE-4492, University of Illinois, June, 1980.

Scott, J.T., Jr. and C.B. Baker. "A Practical Way to Select an Optimal Farm Plan under Risk." *American Journal of Agricultural Economics*, 54(November, 1972):657–60.

United States Department of Agriculture. *Economic Indicators of the Farm Sector, Costs of Production—Major Field Crops, 1989*. USDA-ERS. Washington, D.C.