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Acreage Responses to Expected Revenues and Price Risk for Minor Oilseeds and Program Crops in the Northern Plains

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Wheat, barley, flaxseed, and oilseed sunflower acreage respond to different economic variables. Wheat and barley acreage must be divided among program-complying, program-planted, and nonprogram-planted acreage because these categories respond to different variables and respond to own expected-revenue and price-risk variables in opposite ways. Flaxseed, sunflower, and nonprogram-planted acreage of wheat and barley have highly significant, positive responses to their own expected revenue and negative responses to their own-price risk. Flaxseed and sunflower acreage have been more responsive to their lagged values than to expected revenues for wheat.

Key words: acreage supply responses, barley, censored regression, flaxseed, government programs, risk, sunflower, wheat

Introduction

Sunflower, canola, crambe, and other oilseed crops have attracted much attention in the northern plains as alternatives to the predominant wheat and barley crops. Although they are still called "minor oilseeds," demand for these crops has grown steadily. The popularity of sunflower and canola oil has increased because they have less saturated fat than other vegetable oils. Sunflower oil also is more stable than most other vegetable oils because it contains no linolenic acid (McCormick, Davison, and Hoskin). Demand for crambe oil has increased as new industrial uses have been found for the erucic acid that is extracted from it (VanDyne, Blase, and Carlson). Farmers' interest in growing minor oilseeds has also increased due to reductions in government target prices for wheat and barley. Chembezi and Womack and Krause, Lee, and Koo have shown that program compliance and program plantings of wheat are highly sensitive to the target price. Agricultural policy analysts need to understand the competitive supply relationships between the grain and oilseed crops before they forecast impacts of target price reductions on farmers in the northern plains region of North Dakota, South Dakota, and Minnesota. This study estimates acreage supply functions and competitive supply relationships among wheat, barley, flaxseed, and oilseed sunflower.

Wheat and barley dominate crop production in North Dakota, South Dakota, and northwest Minnesota. In 1993, 53% of North Dakota's crop acres, 25% of South Dakota's crop acres, and 49% of the acres in Minnesota's northwest crop reporting district were planted to wheat (North Dakota Agricultural Statistics Service; South Dakota Agricultural

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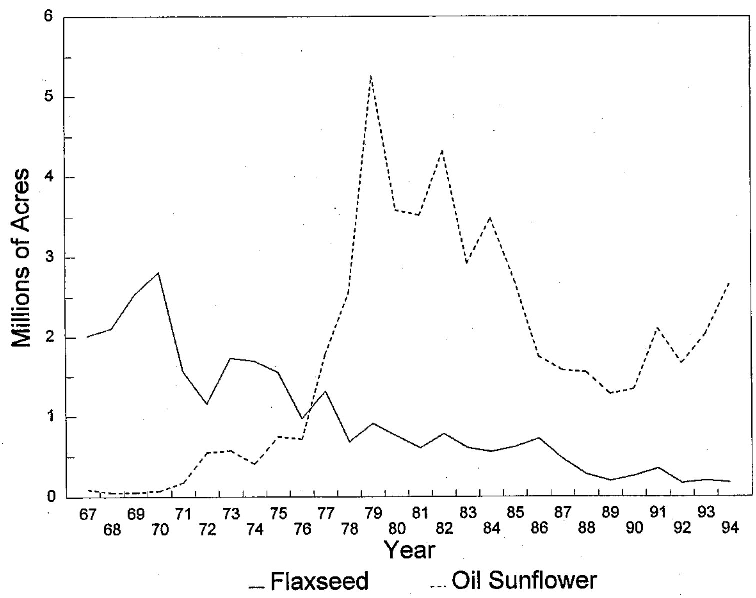

Figure 1. Flaxseed and oil sunflower acreage in ND, SD, and MN, 1967–94

Statistics Service; Minnesota Agricultural Statistics Service). In 1993, 13% of North Dakota's crop acres, 3% of South Dakota's crop acres, and 15% of the acres in Minnesota's northwest crop reporting district were planted to barley. Flaxseed once was the dominant oilseed in these three states (fig. 1), but it has generally been replaced by sunflower. Sunflower production increased dramatically in the late 1970s, due to high prices and the development of high-yielding hybrid seed, but fell to a much lower, fluctuating level in the 1980s (fig. 1). In 1993, 6% of North Dakota's crop acres, 4% of South Dakota's crop acres, and 8% of the acres in Minnesota's northwest crop reporting district were planted to sunflower.

Previous Acreage Response Models

Although several models of wheat acreage response to prices and government programs in the United States have been published (e.g., Bailey and Womack; Burt and Worthington; Chembezi and Womack; Houck et al.; Morzuch, Weaver, and Helmberger), barley, flaxseed, and sunflower acreage responses have largely been ignored. Barley was included in the multiproduct supply model of Villezca-Becerra and Shumway, but the last detailed analysis of government program and price effects on barley acreage was completed in the 1970s. Government programs and predominant alternative crops have changed substantially in the interim. Two analyses of sunflower acreage responses (Wendland and Glauber; McCormick and Hyberg) have appeared in the U.S. Department of Agriculture (USDA) Economic Research Service's *Oilseed Situation and Outlook Report.* No statistical analyses of flax acreage responses have been found.

Ryan and Abel published barley acreage responses to prices and government programs based on data for 1949–71. Their explanatory variables included a lagged barley market price, an adjusted barley loan rate, barley diversion payments, an adjusted oats loan rate, wheat-planted acres, wheat-diverted acres, a linear trend, and an intercept shift after 1965. The barley and oat loan rates were adjusted for acreage restriction requirements and direct support payments for 1963–65 were added to the barley loan rate. Houck et al. published Ryan and Abel's estimates for the equation that excludes market barley price and diversion payments in their 1976 report of supply responses for seven major crops.

Wendland and Glauber estimated sunflower planted acreage in the three northern plains states as functions of the expected gross returns for sunflower, expected gross returns for barley, and total set-aside acreage. McCormick and Hyberg estimated sunflower acreage as functions of a ratio of sunflower gross returns over barley gross returns, a calculated opportunity cost for planting sunflowers on program acreage, a lagged three-year moving average of sunflower acreage, and a rainfall index. Wendland and Glauber found a statistically significant negative relationship between set-aside acreage and sunflower acreage in all three states. McCormick and Hyberg similarly found a statistically significant negative relationship between their variable for the opportunity cost of planting and program acreage.

A variety of models have been used to estimate wheat acreage response to prices and government program parameters (Bailey and Womack; Burt and Worthington; Chembezi and Womack; Houck et al.; Just; Krause, Lee, and Koo; Morzuch, Weaver, and Helmberger). Partly due to differences in how expected market prices, government support prices, and other government program parameters have been modeled, price elasticity estimates for wheat acreage have varied greatly. Different time periods, levels of data aggregation, and estimation methods also have contributed to differences in price elasticity estimates. Analyses that considered price risk (e.g., Krause, Lee, and Koo) also generally produced higher price elasticity estimates than similar analyses that ignored risk (e.g., Chembezi and Womack).

Chembezi and Womack establish an economic rationale for estimating program-complying acreage response and program-planted acreage response separate from nonprogram acreage response. Crops that can be enrolled in government programs are called program crops and acres that can be enrolled in the government programs are called program base acres.[1] Producers who have base acres must first decide whether to participate in the government program. If they do, their base acres are called program-complying acres. Many program-complying acres are not planted due to acreage set-aside and diversion programs. Program-complying acres that are planted to the program crop are called program-planted acres. All planted acres that are not program-complying acres, either because the producer has chosen not to participate in the government program or because there is no program for that crop, are called nonprogram-planted acres.

Chembezi and Womack found that their support price variable had a strong positive effect on program-planted acres, but the expected market price for wheat has a negative effect on program-complying acres and a positive effect on nonprogram-planted acres.[2] Krause, Lee, and Koo estimated similar contrasting market price and price-risk effects on program-complying acres and nonprogram-planted acres of wheat.

This study expands the wheat acreage model of Krause, Lee, and Koo to evaluate

[1] Prior to 1978 eligible wheat acres were called "allotment acres," and from 1978 through 1981 eligible wheat acres were called program acres (Green).

[2] In place of support or target price, Chembezi and Womack use a "program production inducing price" which equals the expected market price plus the deficiency payment or value of market certificates weighted by the ratio of program yield to average yield.

wheat, barley, flaxseed, and oilseed sunflower acreage responses to expected gross revenues, price risk, and government program parameters. By including minor oilseeds in the model, we are able to assess to what extent farmers in the northern plains will shift from wheat and barley production to oilseed production as government program parameters and prices change. The government program for barley has been similar to the program for wheat, so barley acreage is divided into program-complying, program-planted, and nonprogram-planted acreage. In several years there was no program participation decision for either wheat or barley, so censored regression models are used to estimate the complying and program-planted acreage for wheat and barley. Flaxseed and oilseed sunflower have not been subject to acreage restrictions, so their acreage is treated as nonprogram-planted acreage.

The Acreage Response Model

In the presence of a voluntary government program, an expected profit-maximizing crop farmer allocates acres among competing crops and conservation uses by maximizing (Lee and Helmberger; Morzuch, Weaver, and Helmberger):

$$\Pi = EP_p q_p NPA_p + EP_s q_s A_s + PSP \cdot q_p PA_p + P_d A_d - c'x - TFC, \tag{1}$$

where Π is expected profit, EP_p is the expected price of the program crop, q_g is the expected yield for the program crop, NPA_p is nonprogram-planted acres of the program crop, EP_s is a vector of expected prices for substitute crops, q_s is a vector of expected yields for substitute crops, A_s is a vector of acres for substitute crops, PSP is the government's support or target price for the program crop, the dot product denotes element-by-element multiplication, q_p is the government's program yield for the program crop, PA_p is program-planted acres of the program crop, P_d is the government's payment for diverting acres to conservation uses, A_d is acres diverted to conservation uses, c is a vector of variable input prices, x is a vector of variable input levels, and TFC is total fixed costs. Following Chavas and Holt, risk-averse farmers maximize expected utility. The econometric model assumes that the expected utility function of crop farmers is a function of gross revenue, as defined in equation (1) and the variance of market prices. Variance of crop yields is ignored in order to evaluate the influence that reducing price risk has on government program participation. Production costs are incorporated in the model by deflating all values by an index of prices paid. Crop-specific production costs are ignored because estimates for flax and sunflower production costs are available for fewer than half of the years in the data set.

Farmers with acres eligible for the wheat or barley program (henceforth called base acres) have three options: (*a*) participate in the program, (*b*) plant wheat or barley outside the program, or (*c*) plant a substitute crop.[3] Program participation is defined here as agreeing to set aside and not plant the required percentage of base acres in order to qualify for receiving the support or target price for that year. In some years, program participation also allowed farmers to divert additional acres in exchange for diversion payments.

[3] Acres eligible for government programs have been labeled "allotment acres" from 1961–77, "program acres" from 1977–81, and "base acres" from 1982 to the present.

The choice among the three options is determined by their relative expected revenues and relative risk. Program compliance (CA_t) is encouraged by high expected revenues under the program [$RCA_t = PSP_t\ (q_p)\ (1 - ARP_t)$], where ARP_t is the acreage set-aside requirement for program participation. Conversely, whenever expected gross revenues based on market prices for the program crop [$RPC_t = EP_t^p\ (q_g)$] or for substitute crops [$RSC_t = EP_t^s\ (q_s)$] are high, program participation will be discouraged. Oil sunflower is selected as the primary substitute crop. However, oil sunflower only became a significant alternative to wheat and barley in 1976, when hybrid sunflower seed was first available for most farmers (Helgeson et al.). An intercept shift after 1975 ($SUNSHIFT_t$) accounts for this structural change in the substitute crop. Program participation among risk-averse farmers is encouraged by high uncertainty about the expected market price of the program crop ($PRISK_t$) or uncertainty about the expected market price of the substitute crop, ($SRISK_t$) because the support or target price received by program participants is known at planting time. Furthermore, the number of complying acres depends on the number of eligible base acres (BA_t). Therefore, the equation for program-complying acres is

$$(2) \qquad CA_t = f_C(RPC_t, RSC_t, PRISK_t, SRISK_t, RCA_t, BA_t, SUNSHIFT_t, e_{2t}).$$

Following the Chembezi and Womack model, acres planted by farmers participating in the government program (PA_t) are essentially fixed by the number of program-complying acres (CA_t) and the required acreage set-aside provisions (ARP_t), unless an optional acreage diversion payment (DP_t) is offered that year. An exception is the wheat program from 1971 to 1973, in which marketing certificates were only paid for wheat produced on a small "domestic allotment" acreage, but participating farmers were able to plant wheat on more than the "domestic allotment" acres. An intercept shift variable ($D7173_t$) accounts for this change in the wheat base acre definition. Participating farmers do have the option of fallowing more than the required number of acres or planting nonprogram crops on acres that are not part of the set-aside. High expected revenues on program-planted acres [$RPA_t = PSP_t\ (q_p)$] encourage participating farmers to plant all eligible acres to wheat. The equation for program-planted acres is

$$(3) \qquad PA_t = f_P(RPA_t, CA_t, ARP_t, DP_t, D7173_t, e_{3t}).$$

For wheat and barley farmers who do not participate in the government program, planted acreage (NPA_t) is encouraged by high expected revenues based on market prices [$RPC_t = EP_t^p\ (q_g)$] and discouraged by high expected revenues for substitute crops [$RSC_t = EP_t^s\ (q_s)$]. Risk-averse farmers also will be discouraged from planting the program crop by high uncertainty about the expected market price of the program crop ($PRISK_t$) and encouraged by high uncertainty about the expected price of the substitute crop ($SRISK_t$). Since the number of acres that are well adapted to wheat or barley production is finite, a high number of program-complying acres (CA_t) reduces the number of non-program wheat or barley acres. The sudden increase in wheat prices in 1972–73 encouraged many farmers to cultivate additional acres (Frey and Hexem), which increased the intercept for nonprogram wheat acres for years after 1973 ($WHTSHIFT_t$). On the other hand, the introduction of hybrid sunflower as a viable substitute crop reduced the intercept for nonprogram barley for years after 1975 ($SUNSHIFT_t$). The equation for nonprogram-planted wheat and barley acreage is therefore:

$$(4) \quad NPA_t = f_N(RPC_t, RSC_t, PRISK_t, SRISK_t, CA_t, WHTSHIFT_t \text{ or } SUNSHIFT_t, e_{4t}).$$

Flaxseed and sunflower can be planted without restriction on acres that are not wheat or barley base acres or by farmers who are not participating in the wheat or barley programs. Acreage reduction or set-aside requirements for the wheat and barley programs usually exclude the planting of minor oilseeds on program-complying acreage. However, wheat and barley program provisions in 1971–73, 1978–79, and 1991–93 allowed oilseeds to be planted on program-complying acreage. The 1971–73 wheat program allowed up to 10% of wheat allotment acres to be planted to other crops without a loss of future allotment (Green). The 1972–73 barley program allowed 30–45% of feed grain base acres be planted to alternative crops (Green). Many set-aside acres also were diverted to sunflower production in 1972 and 1973 (Thomason). The wheat and barley programs of 1978–79 also allowed considerable flexibility to plant sunflowers on base acres (Kleingartner).[4] The 1991–93 wheat and barley programs allowed participating farmers to plant minor oilseeds on the 15% normal flex acres, the 10% optional flex acres, plus the 0/92 option of planting minor oilseeds on complying acres while still receiving 92% of the wheat or barley deficiency payment (Kleingartner; McCormick, Davison, and Hoskin).

The equations for flaxseed and sunflower acreage are the same as equation (4) except for a change in the complying-acreage variable, the addition of a lagged dependent variable, and a planting-progress variable. A no-flexibility complying-acreage variable ($NFCA_t$), which combines wheat and barley program-complying acreage and is set to zero in 1971–73, 1978–79, and 1991–93, replaces the complying-acreage variable (CA_t), in equation (4). A spring wheat planting-progress variable ($PLTPRO_t$) is added to the flaxseed and sunflower acreage equations because farmers often will switch to other crops if they are not able to plant wheat by 20 May. This variable is defined as 100 minus the percentage of spring wheat that is planted in North Dakota by 20 May. A lagged sunflower acreage variable (NPA_{t-1}) is needed to reflect the adjustment costs for farmers planting sunflower for the first time.[5] A lagged flaxseed acreage variable is added to reflect the declining proportion of farmers who are familiar with flaxseed production. Finally, the sunflower intercept shift ($SUNSHIFT_t$) is added for years after 1975 to reflect the general introduction of hybrid sunflowers in 1976.

There were no government program participation decisions for wheat in 1974–77, 1980–81, and 1993 because there were no allotment or set-aside requirements in those years. For the same reason, there were no program participation decisions for barley in these seven years plus 1967–68 and 1971. The program-complying acres (CA_t) and program-planted acres (PA_t) variables are therefore censored at zero in these seven years for wheat and ten years for barley. Ordinary least squares (OLS) estimates are biased in this case (Tobin). Consistent estimates can be obtained using the tobit model, which is specified as:

$$(5) \qquad Y_t = \begin{cases} X_t'\beta + e_t & \text{if } X_t'\beta + e_t > 0, \\ 0 & \text{otherwise,} \end{cases}$$

where Y_t is the dependent variable, X_t is a vector of explanatory variables, β is a vector of unknown parameters, and e_t is a random error term which is assumed independently,

[4] Larry Kleingartner is the executive director of the National Sunflower Association and editor of *The Sunflower* magazine.

[5] Because sunflower is a row crop, wheat and barley farmers who began growing sunflower first had to acquire row-crop planting and harvesting machinery. Furthermore, weed management and insect pest management are quite different for sunflower than for small grains, so there is a substantial learning curve in the first years of sunflower production.

normally distributed with mean zero and variance σ^2. In the tobit model, the expected value of the dependent variable is

$$(6) \qquad E(Y_t) = X_t'\beta F(z) + \sigma f(z),$$

where $z = X_t'\beta/\sigma$, $f(z)$ is the normal probability density function, and $F(z)$ is the normal cumulative density function.

Data and Procedure

Price and planted-acreage data for 1962–93 were obtained from various issues of *Agricultural Statistics* (USDA). Acreage and price statistics for oilseed sunflower were first reported in 1967 (Thomason), so 1967 is the first observation included in the data set. Wheat and barley base acres, program-planted acres, and program yield data were obtained from James Langley at USDA-ASCS. Regional values for these variables were calculated by weighting state values by their wheat production in each year. The support prices for 1991–93 were multiplied by 0.85, the proportion of acres qualifying for deficiency payments under normal flex acreage provisions. All prices are deflated by the index of prices paid by farmers for production (USDA). Data for planting progress of spring wheat in North Dakota were taken from the North Dakota Agricultural Statistics Service.

The expected market prices are assumed to equal a weighted average of the average price received by farmers for the previous three years, where the weights are 0.50 for the previous year ($t - 1$), 0.33 for two years before ($t - 2$), and 0.17 for three years before ($t - 3$).[6] The price-risk variable used in the model is the weighted variance of prices received in the previous three years around the expected prices in those years. The weights are the same as for the expected prices. The calculation of market prices and price risk for oilseed sunflower used reported prices for all sunflowers prior to 1967.

Expected crop yields are assumed to equal the Olympic average of yields in the previous five years (the highest and lowest yields are excluded). This procedure keeps extremely high and low yields from producing large fluctuations in expected crop yields but allows expected crop yields to show trends due to changing technology or pest populations (e.g., sunflower).

Because the complying-acres variable used in the program-planted acre and nonprogram-planted acre equations is endogenous, (3) and (4) were estimated using an instrumental variable for complying acres. The complying-acres estimate determined by (2) was used as the instrumental variable for equation (3) since it meets the criterion of zero correlation between the instrumental variable and the residuals of (3). An acceptable instrumental variable for wheat or barley complying acres in (4) was obtained by estimating complying acres as a function of wheat or barley base acres, the expected yield and price of the substitute grain crop (wheat for barley program-complying acres and barley for wheat program-complying acres), production cost, expected revenues under the program (RCA_t), the optional diversion payment, and the wheat planting-progress variable.

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[6] This is the weighting scheme used by Chavas and Holt. Alternative weighting schemes were used to evaluate the sensitivity of the results obtained to the specification of expected prices. The alternative weights used were (1, 0, 0), (0.8, 0.15, 0.05), (0.7, 0.2, 0.1), (0.5, 0.3, 0.2), and (0.33, 0.33, 0.33). The chosen weighting scheme produced higher log-likelihood and R^2 measures for most of the estimates. Signs and statistical significance levels for government program variables were not affected by alternative weights. The statistical significance and elasticities for price and risk variables are sometimes affected by the use of alternative weights.

Complying acres and program-planted acres were estimated with the tobit model for censored data in the LIMDEP econometrics software package (Greene). Nonprogram acres were estimated with the generalized least squares (GLS) estimator for seemingly unrelated regressions procedure in LIMDEP. The LIMDEP procedure for estimating individual equation autocorrelation coefficients and reestimating the system of equations was employed.

Because the wheat and barley program-planted acreage and nonprogram-planted acreage equations include a complying-acre variable and complying acres are a function of several prices (1), elasticities of acreage response to prices for these equations include the indirect influences of prices acting through the complying-acreage variable. The total elasticities for program-planted acreage responses, including both direct and indirect price effects, are as follows:

(7) $$\xi_{PM} = \left[\frac{\partial PA_t}{\partial CA_t}\frac{\partial CA_t}{\partial P_{Mt}}\right]\frac{P_{Mt}}{PA_t}, \quad \text{and}$$

(8) $$\xi_{PG} = \left[\frac{\partial PA_t}{\partial P_{Gt}} + \frac{\partial PA_t}{\partial CA_t}\frac{\partial CA_t}{\partial P_{Gt}}\right]\frac{P_{Gt}}{PA_t},$$

where ξ_{PM} is elasticity of program-planted acres to market prices or price risk, ξ_{PG} is elasticity of program-planted acres to the government support price, P_{Mt} is market price or price risk, and P_{Gt} is the government support price. All the elasticities are calculated at the means.

The total elasticities for nonprogram-planted acreage responses of wheat and barley are

(9) $$\xi_{NM} = \left[\frac{\partial NPA_t}{\partial P_{Mt}} + \frac{\partial NPA_t}{\partial CA_t}\frac{\partial CA_t}{\partial P_{Mt}}\right]\frac{P_{Mt}}{NPA_t}, \quad \text{and}$$

(10) $$\xi_{NG} = \left[\frac{\partial NPA_t}{\partial CA_t}\frac{\partial CA_t}{\partial P_{Gt}}\right]\frac{P_{Gt}}{NPA_t},$$

where ξ_{NM} is elasticity of nonprogram-planted acres to market prices or price risk, and ξ_{NG} is elasticity of nonprogram-planted acres to the government support price.

Results and Discussion

The estimated responses for wheat and barley program-complying acreage confirm that farmers participate in government programs when market prices are low and highly uncertain (table 1). Coefficients for the nonprogram-planting expected revenue, sunflower expected revenue, and own market price risk are all statistically significant at, at least, a 5% level for both wheat and barley. Nonprogram-planting expected revenue and sunflower expected revenue both equal expected market price times expected yield. Complying acreage also rises when the expected revenue from program participation increases. However, the expected revenue from program participation is only significant at a 10% level for wheat and is not statistically significant for barley. Sunflower price risk does not have a statistically significant effect on either wheat or barley complying acres. The intercept shift after 1975 (*SUNSHIFT*$_t$) has a strong negative effect on barley program compliance and a weak negative effect on wheat program compliance. This indicates that the introduction of hybrid seed made sunflower a much more attractive alter-

Table 1. Tobit Estimates of Wheat and Barley Program-Complying Acreage Responses, 1967–93

Variables	Wheat	Barley
Intercept	8,333.6	2,691.8
Nonprogram-planting expected revenue	−99.85	−29.15
	(3.15)	(2.00)
Sunflower expected revenue	−88.53	−27.91
	(5.85)	(4.55)
Own-price risk	1,398.2	3,173.6
	(2.91)	(4.77)
Sunflower price risk	72.90	−74.51
	(0.37)	(1.16)
Program participation expected revenue	37.14	5.07
	(1.73)	(0.66)
Program base acres	1.0680	1.0797
	(10.51)	(12.75)
Intercept shift after 1975 (*SUNSHIFT*$_t$)	−1,746.5	−879.29
	(1.09)	(5.35)
Standard deviation of residuals	817.0	186.7

Notes: Figures in parentheses indicate *t*-statistics. Nonprogram-planting expected revenues and sunflower expected revenues equal a weighted average of prices received in the three previous years times an Olympic average of yields in the five pervious years; price risk equals a weighted average of variance around the expected prices over the previous three years; program participation expected revenue equals the support price times the program yield times the proportion of complying acreage that may be planted; and the intercept shift after 1975 accounts for the introduction of hybrid sunflower seed, equals one for 1976–93, and equals zero for 1967–75.

native crop, particularly in comparison to barley. Program base acres have the strongest effect on program-complying acres for wheat and barley, which indicates that the expected utility from program participation has greatly exceeded the expected utility from the expected yield and market prices in most years.

After adjustment for acreage reduction requirements, wheat and barley base acres have a highly significant, approximately one-for-one effect on program-planted acreage for wheat and barley, respectively (table 2). Expected revenue for program planting also has a positive, statistically significant relationship on program-planted acreage for wheat (10% significance level) and barley (5% significance level). Optional land-diversion payments have the expected negative influence on program-planted acreage, although the effect on barley program-planted acreage is not significant. The change in the base acre definition from 1971 to 1973 had a strong positive influence on program-planted wheat acreage and a strong negative influence on program-planted barley acreage.

The own expected-revenue and price-risk effects on wheat and barley nonprogram-planted acreage (table 3) are opposite to their effects on wheat and barley program-complying acreage (table 1). Nonprogram-planting expected revenue (expected market price times expected yield) has a positive influence on nonprogram-planted acreage of wheat (1% significance level) and barley (10% significance level). Variance around the

Table 2. Tobit Estimates of Wheat and Barley Program-Planted Acreage Responses, 1967–93

Variables	Wheat	Barley
Intercept	−5,769.2	−3,482.2
Program-planting expected	60.94	39.51
revenue	(1.82)	(2.29)
Complying acreage (1−*ARP*)	1.0115	1.0558
	(13.49)	(6.96)
Diversion payment	−1,301.1	−757.05
	(2.41)	(1.52)
Intercept shift for 1971–73	5,419.6	−2,130.8
	(3.89)	(2.88)
Standard deviation of residuals	1,480.2	560.7

Notes: Figures in parentheses indicate *t*-statistics. Program-planting expected revenue equals the support price times the program yield; and the intercept shift for 1971–73 equals one for 1971–73 and zero otherwise.

Table 3. Estimates of Nonprogram Acreage Responses for Wheat and Barley, 1967–93

Variables	Wheat	Barley
Intercept	1,666.9	3,925.2
Nonprogram-planting	89.59	14.86
expected revenue	(2.68)	(1.73)
Sunflower expected revenue	−13.85	−10.02
	(0.55)	(2.16)
Own-price risk	−1,082.8	−1,385.7
	(2.99)	(3.96)
Sunflower price risk	−23.08	29.05
	(0.50)	(3.00)
Program-complying	−0.8235	−0.5721
acreage	(14.41)	(17.47)
Intercept shift after 1973	11,912	
($WHTSHIFT_t$)	(10.34)	
Intercept shift after 1975		−267.91
($SUNSHIFT_t$)		(2.32)
Standard deviation of residuals	1,776.0	301.0
R^2	0.96	0.95

Notes: Figures in parenthesis indicate *t*-statistics. Nonprogram-planting expected revenues and sunflower expected revenues equal a weighted average of prices received in the three previous years times an Olympic average of yields in the five previous years; price risk equals a weighted average of variance around the expected prices over the previous three years; program-complying acreage is for wheat or barley, not both; the intercept shift after 1973 equals one for 1974–93 and zero otherwise; and the intercept shift after 1975 equals one for 1976–93, and zero otherwise.

own expected market price has a highly significant negative influence on both wheat and barley nonprogram-planted acreage. Sunflower expected revenue and price risk have no significant effect on wheat nonprogram-planted acreage, but barley nonprogram-planted acreage is reduced by sunflower expected revenue (5% significance level) and increased by sunflower price risk (1% significance level).

Other large influences on nonprogram-planted acreage of wheat and barley include program-complying acreage, the intercept shift for wheat after 1973 and the intercept shift for barley after 1975. As expected, the amounts of wheat and barley base acres that producers enroll in the wheat and barley programs significantly reduce the amounts of nonprogram-planted wheat and barley. The 1972–74 increase in cropland used for crops causes nearly a 12-million-acre increase in the intercept for nonprogram-planted wheat acreage after 1973. In contrast, the introduction of hybrid sunflower causes a significant reduction in the intercept for nonprogram-planted barley acreage after 1975.

Own expected revenue and market price risk have significant positive and negative effects, respectively, on flaxseed acreage (table 4). Thus, falling prices for flaxseed largely explain the decline in flaxseed acreage (fig. 1). Expected revenue for nonprogram-planted wheat has a statistically insignificant influence on flaxseed acreage, but variance around the expected market price of wheat has a positive effect that is significant at a 10% level. No-flex program-complying acreage of wheat and barley ($NFCA_t$) has no significant effect on flaxseed acreage. The influence of lagged flaxseed acreage is significant at a 1% level, suggesting that as acreage has fallen, fewer farmers have considered planting flaxseed. The intercept shift after 1975 ($SUNSHIFT_t$) has a large negative influence on flaxseed acreage. This suggests that development of sunflower hybrids substantially reduced flaxseed acreage.

The positive influence of own expected revenue and negative influence of own-price risk on sunflower acreage are both significant at a 1% level (table 4). Neither the expected revenue nor price risk for wheat had a statistically significant effect on sunflower acreage. As in the case of flaxseed acreage, program-complying acreage of wheat and barley ($NFCA_t$) has no significant effect on sunflower acreage. All of the other variables have effects that are statistically significant at a 1% level. The intercept shifts up 1.374 million acres after 1975. Lack of planting progress for spring wheat ($PLTPRO_t$) has a positive effect on sunflower acreage, although the elasticity of this effect is only 0.25. Lagged sunflower acreage has a strong positive effect on current sunflower acreage, indicating that lack of necessary equipment and familiarity with sunflower has constrained sunflower acreage in many years.

Most of the elasticities of program-planted acreage and nonprogram-planted acreage responses to own expected revenue are close to one in absolute value (table 5). Because expected revenue is defined in this analysis as expected price times expected yield, the revenue elasticities also may be interpreted as price elasticities for a constant expected yield. The only unusually large elasticity is for nonprogram-planted wheat acreage, which has a direct elasticity of response to own expected revenue of 1.08, but the elasticity of the combined direct response and the indirect response to the expected revenue is 2.08. The elasticity of wheat program-planted acreage to own expected revenue is −0.89 and the elasticity of barley program-planted acreage to own expected revenue is −1.18. The elasticity of nonprogram-planted acreage to own expected revenue is 0.99 for barley, 1.43 for flaxseed, and 0.98 for sunflower. The elasticity of program-planted acreage to

Table 4. Estimates of Acreage Responses for Flaxseed and Oilseed Sunflower, 1967–93

Variables	Flaxseed	Sunflower
Intercept	−155.66	−2,240.2
Own expected revenue	24.93	18.58
	(2.96)	(4.08)
Wheat expected nonprogram revenue	−3.60	7.34
	(0.52)	(0.65)
Own-price risk	−75.69	−39.80
	(2.34)	(2.69)
Wheat price risk	129.45	−109.16
	(1.68)	(1.00)
No-flex complying acreage	0.0058	−0.0075
	(0.96)	(0.76)
Lagged acreage	0.3926	0.5118
	(3.48)	(5.86)
Wheat planting progress	0.5563	17.24
	(0.23)	(3.95)
Intercept shift after 1975	−555.40	1,374.1
	(3.17)	(4.24)
Standard deviation of residuals	234.5	489.5
R^2	0.90	0.93

Notes: Figures in parenthesis indicate *t*-statistics. Expected revenues equal a weighted average of prices received in the three previous years times an Olympic average of yields in the five previous years; price risk equals a weighted average of variance around the expected prices over the previous three years; no-flex complying acreage is wheat and barley program-complying acreage, set to zero in 1971–73, 1978–79, and 1991–93 when oilseeds could be planted on complying acres; lagged acreage is the flaxseed or sunflower acreage in the previous year; wheat planting progress equals 100 minus the percentage of spring wheat planted by 20 May in North Dakota; and the intercept after 1975 equals one for 1976–93 and zero otherwise.

the expected revenue for program planting (support price times program yield) is 0.80 for wheat and 1.41 for barley.

Elasticities of wheat and barley program-planted acreage response to expected sunflower revenues are also close to one in absolute value. These elasticities of response to sunflower revenues are much greater than the −0.36 elasticity of wheat program-planted acreage response to expected barley price estimated by Krause, Lee, and Koo, indicating that acreage of wheat or barley in the northern plains is now more sensitive to expected sunflower prices than to the expected price of the other grain crop.

Although the estimated effects of own-price risk have high levels of statistical significance, the absolute value of elasticities of these effects range from only 0.15 to 0.50. Furthermore, because the own-price risk has a positive influence on program-planted acreage and a negative influence for nonprogram-planted acreage, the weighted average of the program-planted and nonprogram-planted acreage elasticities is only −0.05 for wheat and 0.01 for barley. Elasticities of acreage response to price risk for substitute

Table 5. Elasticities of Wheat, Barley, and Oilseed Acreage Responses, 1967–93

	Expected Revenues				Own-Price Risk	Program Revenues
Acreage	Wheat	Barley	Flaxseed	Sunflower		
			Program-Complying Acreage Elasticities			
Wheat	−0.781***			−0.793***	0.135***	0.158*
Barley		−0.789***		−0.977***	0.336***	0.112
			Program-Planted Acreage Elasticities[a]			
Wheat	−0.888			−0.902	0.154	0.729*
Barley		−1.182		−1.464	0.503	1.412**
			Nonprogram-Planted Acreage Elasticities[b]			
Wheat	2.084***			0.692	−0.335***	−0.202
Barley		1.699***		−0.194	−0.394***	−0.075
Flaxseed	−0.280		1.428***		−0.253***	
Sunflower	0.337			0.977***	−0.185***	

Notes: *** denotes statistical significance of the direct effect at the 1% level; ** denotes statistical significance of the direct effect at the 5% level; and * denotes statistical significance of the direct effect at the 10% level.

[a] Including the indirect effects on complying acreage and the complying-acreage effect.

[b] Wheat and barley acreage response elasticities include the indirect effects on complying-acreage and the complying-acreage effect. Flaxseed and sunflower acreage response elasticities are for the direct effects only because the indirect effects only occur in 12 out of the 28 years in the sample.

crops range from −0.06 to 0.26. Barley acreage is the most sensitive to its own-price risk and to price risk for the substitute crop (sunflower).

The sums of the predicted values for program-planted and nonprogram-planted wheat and barley acreage in North Dakota, South Dakota, and Minnesota are good predictors of total wheat- and barley-planted acreage from 1967 to 1993. The standard deviation of residuals for total wheat-planted acreage is 11.5% of the mean and the standard deviation of residuals for total barley-planted acreage is 6.5% of the mean. The predicted total acreages for wheat and barley in 1994 are 2.2% less and 11.3% more than the actual values, respectively. The standard deviation of residuals for flaxseed acreage is 22.9% of the mean and the standard deviation of residuals for sunflower acreage is 28.2% of the mean. The predicted values for flaxseed and sunflower acreage in 1994 are 18.1% and 27.5% less than the actual values. Most of the 1994 prediction errors for flaxseed and sunflower are due to the large amount of minor oilseeds planted on normal flex acres and optional flex acres of wheat and barley (Kleingartner). The acreage response model does not include any variables to represent incentives for planting normal flex acres and optional flex acres to minor oilseeds.

Conclusions

The results suggest that the impact of reduced target prices on acreage of wheat, barley, and minor oilseeds in the northern plains will depend on market prices. Reduced expected revenue from program participation would only modestly reduce wheat or barley program compliance but would substantially reduce program-planted acres. If expected market prices increase in response to fewer program-planted acres, nonprogram-planting of wheat and barley would increase strongly, with response elasticities of 2.08 and 0.99, respectively. Any increase in price risk for wheat or barley would partly counteract the effects of reduced target price on program-planted and nonprogram-planted acreage. Furthermore, any reduction in expected revenues for oilseed sunflower would increase program-planted and nonprogram-planted acreage of wheat and barley.

If expected market prices were held constant at their means, reducing target prices for wheat and barley would modestly reduce wheat and barley total planted acreage. A 1% reduction in the expected revenue from program planting would reduce total wheat-planted acreage by 0.38% and total barley-planted acreage by 0.59%.

The estimated acreage responses for flaxseed and sunflower indicate that farmers in the northern plains would increase their acreage of minor oilseeds if oilseed prices or yields increase or if oilseed prices become less variable. Since sunflower expected revenue has had a negative influence on wheat and barley program-complying acreage, policymakers could reduce the dependence of northern plains farmers on the wheat and barley programs by expanding markets and thereby increasing expected revenues for sunflower. Examples of current market expansion programs include the Export Credit Guarantee Program (GSM 102/103), Food for Peace Program (PL-480), Export Enhancement Program (EEP), and Sunflowerseed Oil Assistance Program (SOAP) (McCormick, Davison, and Hoskin).

The results also indicate that wheat, barley, flaxseed, and sunflower acreage in the northern plains respond to different economic variables. Wheat and barley acreage must be divided among program-complying, program-planted, and nonprogram-planted acreage because these categories of acreage respond either to different variables or to the same variables in opposite ways. Expected revenues based on market prices decrease program-complying and program-planted acreage of wheat and barley but increase nonprogram-planted acreage of wheat and barley. Price risk increases program-complying and program-planted acreage but reduces nonprogram-planted acreage. Support prices and program yields increase program-complying acreage and program-planted acreage of wheat and barley but decrease nonprogram-planted acreage of wheat and barley. Program-planted acreage for wheat and barley is determined by complying-acreage, set-aside provisions, and other government program parameters. Nonprogram-planted acreage of both wheat and barley are strongly influenced by program-complying acreage and moderately influenced by expected revenues for a substitute crop.

Flaxseed and sunflower acreage are strongly influenced by their own expected revenues and price risk but are not significantly influenced by either program-complying acreage of wheat and barley or expected nonprogram-planting revenues for wheat. Both flaxseed and sunflower acreage are strongly influenced by their lagged values, suggesting the presence of high adjustment costs. However, only sunflower is significantly influenced by planting progress for wheat.

This study provides further support for the need to include price risk in models of acreage supply responses. Estimated responses of program-complying acreage of wheat and barley and nonprogram-planted acreage of wheat, barley, flaxseed, and sunflower to own-price risk are all significant at a 1% level. Price-risk effects on total wheat and barley acreage are small because the effects on program-complying acreage and nonprogram-planted acreage are opposite in sign.

Although planted acreage of wheat, barley, flaxseed, and sunflower respond to different economic variables, they all respond to their own expected prices and price risk. This study indicates that dependence on wheat and barley programs on government programs for wheat and barley can be reduced by increasing the relative prices of minor oilseeds. Policies to expand or stabilize markets for minor oilseeds could therefore mitigate the impacts in the northern plains of reducing government support for wheat and barley production.

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