The Acreage Response Model

The acreage response model employed in this study follows the same conceptual framework as the model in Lin et al., which postulates that the goal of producers is to maximize expected net returns—the difference between expected market revenues and variable costs of production. Acreage response equations in the model are treated as a system of acreage allocation decisions for dry peas, lentils, spring wheat, durum wheat, barley, and other minor field crops such as sunflower, canola, flaxseed, and rapeseed. The model consists of four acreage share equations for spring crops: (1) dry peas, (2) lentils, (3) spring wheat (including durum), and (4) barley. Spring wheat, durum, and barley are considered the major alternative crops to dry peas and lentils.

The dependent variable in the empirical model is the share of total cropland for spring crops planted to dry peas, lentils, spring wheat (including durum), and barley. The sum of the shares for these four crops and other minor field crops equals one.[6] However, only the shares of dry peas, lentils, spring wheat (including durum), and barley are estimated, using pooled time-series (1997-2005) and cross-section (four-States) data. The share for other minor field crops is treated as a residual that is not directly estimated, to avoid the singularity of the disturbance covariance matrix (Greene). The model takes the form:

(1) $$S_i = a_{i1} + b_j \sum_{j=1}^{4} NRT_j + c_{i1} S_{i,t-1} + \sum_{j=1}^{3} D_j + \mu_i \text{ and}$$

(2) $$\sum_{i=1}^{5} S_i = 1.0$$

where S_i = the share of combined acreage of dry peas, lentils, spring wheat (including durum), barley, and other minor crops planted to the i^{th} crop (1= dry peas, 2= lentils, 3= spring wheat, including durum, 4=barley, and 5= other minor field crops that potentially compete with dry peas and lentils),

NRT_j = expected net returns (\$/ac) for j^{th} commodity,

$S_{i, t-1}$ = lagged dependent variable for i^{th} commodity,

D_j = State dummies (D_1 = North Dakota, D_2 = Montana, and D_3 = Washington), and

μ_i = the error term.

This specification explicitly recognizes that as the share of the combined cropland planted to one commodity—say, dry peas—increases, the expanded dry pea acreage has to come from cropland that would otherwise be planted to competing crops or summer-fallowed land. The share specification stipulates that total cropland planted to crops that compete with dry peas or lentils is fixed, an assumption widely adopted in this kind of empirical work (Lin and Dismukes).

[6]Summer-fallow and pasture lands are not included in this category because of a lack of publicly available data for the former and relatively poor soil quality, not well suited for pulse crops, for the latter. Cropland planted to hay has the potential to be switched to pulses, which could be included in this residual category in future studies.

USDA data on State-level yields and prices for dry peas and lentils are not available for all major producing States before 1998.[7] The limited number of observations in this data series makes a study of supply response based on time-series data virtually impossible. In this study, pooled time-series (1997-2005) and cross-section (four-States) data are used in the analysis. The pooled data yields 36 (9 x 4) observations, which provide sufficient degrees of freedom.[8]

The acreage share equations are estimated using Seemingly Unrelated Regressions (SUR). SUR recognizes that the residuals across the share equations are correlated because each of the crops included in the system is competing with others. Both symmetry and linear homogeneity constraints are considered and tested for statistical significance in the estimation process (Barten and Vanloot; Chavas and Holt; Lin et al.). The symmetry restriction requires that cross-net return regression coefficients across the share equations be equal; that is, $b_{12} = b_{21}$, $b_{13} = b_{31}$, $b_{14} = b_{41}$, $b_{23} = b_{32}$, $b_{24} = b_{42}$, $b_{34} = b_{43}$. The linear homogeneity constraint requires that the sum of all own- and cross-net return regression coefficients be zero; that is, for example, $b_{14} = -(b_{11} + b_{12} + b_{13})$.

The symmetry restriction reflects the notion that the cross-price elasticities are linked to the ratios of the acreage shares and expected net returns for two competing crops. The linear homogeneity constraint reflects the fact that the same proportional change in net returns for dry peas, lentils, and competing crops does not alter the share of all the combined acreage planted to a specific crop. Intuitively, this restriction means that if both output and input prices change by a fixed proportion, the share of the combined acreage planted to a specific crop would remain unchanged.

Expected net returns equal the expected yield times the expected price by State, plus the value of using dry peas or lentils as the rotation crop with grains (including the reduction in yield losses for grains and nitrogen left for other crops by dry peas or lentils through nitrogen fixation), minus variable cash costs of production.[9] Unlike many grains in the Midwest whose yields have shown an upward trend, peas and lentils mostly show no discernable trends at national or State levels. As a result, 5-year moving averages of yields are taken to be the expected yields. Similarly, 5-year moving averages are taken as the expected yields for spring wheat and barley in North Dakota and spring soft white wheat in Washington. In contrast, trend yields estimated from data from 1979 to 1996 for spring wheat and barley in Montana and Idaho are regarded as the expected yields because of the statistical significance of trends in the yield equations.

The expected price that farmers will receive for lentils, and competing crops is based on an adaptive expectation scheme, augmented by a behavioral hypothesis that farmers adjust their price expectations based on the discrepancies between the expected farm prices and actual market prices in the past (Chavas and Holt). The absence of futures trading for pulse crops prevents us from directly forming the expected farm price based on futures settlement prices, although later studies can explore the possibility of linking component pricing based on energy and protein content of dry peas for feed use in the

[7]Lentil data for North Dakota and Montana, where most of the growth in dry pea and lentil area has occurred this decade, were not published separately by USDA for these two States until 1998. Dry pea data publication for North Dakota and Montana was resumed by USDA after being discontinued in 1972. However, price and yield data in 1997 for “Other States” (which includes North Dakota and Montana), as reported in USDA’s *Crop Values*, are used to represent those for North Dakota and Montana in that year.

[8]The pooled data has its limitations. Multicollinearity and endogeneity issues arising from the limited number of observations are addressed through the use of extraneous estimates from the Lin et al. study (Maddala). Also, the 36 observations obtained from the use of pooled time-series and cross-section data in this study are not much different from the methodology of another study on supply response, which yields 40 observations (Lin et al.). While the use of extraneous information from previous studies offers some remedies, future studies that include longer time-series data as they become available would be warranted.

[9]This study abstracts from a formal treatment of risk about prices and yields, which otherwise requires the inclusion of a covariance term between crop yields and farm prices in expected net returns calculation (Lin and Dismukes). Also, truncation (from below) of the price distribution from the marketing loan program would have to be explicitly taken into consideration and incorporated into the calculation of expected net returns and the expected variance of revenues. Finally, acreage response equations would include expected covariance of revenues if commodity prices are correlated.

East region to corn and soybean futures prices.[10] The adaptive expectation scheme takes the form:

$$(3) \qquad E_i(P_{it}) = \alpha_i + \sum_{j=1} w_j P_{i,t-j}$$

where

$$\alpha_i = E\left(P_{it} - \sum_{j=1}^{3} w_j P_{i,t-j} \right)$$

[10]No similar extrapolation is applicable for the food-use component. In addition, this approach becomes even more difficult for dry peas in the West and lentils in both regions, because in the West dry peas and lentils are largely used for human food.

A weighting scheme, which is consistent with a few previous studies, has the following weighting factors: 0.5 for t-1, 0.3 for t-2, and 0.2 for t-3 (Lin; Chavas and Holt; Lin and Dismukes).[11]

[11]It is conceivable that these weighting factors may vary by commodity. However, this weighting scheme has shown the best estimated results for grains and oilseeds in previous studies (Lin, 1977; Chavas and Holt; Lin and Dismukes).

Tables 4 and 5 show how the expected grower prices for dry peas and lentils are calculated for North Dakota during 1997-2005. For example, the unadjusted expected grower price is estimated at $5.64 per cwt for dry peas in North Dakota in 2003, based on the fixed-weights scheme described above. However, based on the comparisons between the expected grower prices and actual market prices in the past (1996-2002), growers would expect actual market prices, on average, to fall short of the expected grower prices by $0.93 per cwt. Adding this adjustment factor to the expected grower price brings an adjusted expected grower price of $4.71. Similarly, this "learning-by-doing" adjustment process changes the expected grower price for lentils in North Dakota in 2003 from $10.53 to $9.08 per cwt (table 5). Prior to this year, unadjusted expected grower prices overestimated actual grower prices by an average of $1.45 per cwt. This error of overshooting results in a lower expected grower price after the adjustment. Similar illustrations for Montana are presented in appendix tables A-1 and A-2.

Effective expected grower prices are simply the loan rates if the expected grower price (after correcting errors through the adjustment process) falls short of the loan rate. Starting from 2003, the first time that marketing loan programs in the 2002 Farm Act could have had an impact on producers' planting decisions, expected farm prices are replaced with loan rates if the expected prices are smaller. Expected LDP or MLG for producers, if applicable, equaled the difference between loan rates and the expected farm prices for dry peas, lentils, and competing crops. For example, while dry pea producers in North Dakota in 2003 faced the expected grower price of $4.71 per cwt, the effective expected price was $5.89—the loan rate—after adding the expected LDP or MLG to the grower price.[12] Similarly, the effective expected grower price for lentils in North Dakota in 2003 was altered from $9.08 per cwt to $11.94.

[12]This calculation implies that expected LDPs in an *ex ante* context differ across the West and East regions, which deviates from the way that the marketing loan program was implemented. In an *ex post* context, the program was implemented so that LDPs across the regions are identical, which is tantamount to requiring that the difference of the regional loan repayment rates is the same as that for the regional loan rates. However, the expected grower price is not governed by the way the program is implemented. Also, it is highly unlikely that growers in one region will take into account the expected grower price in the other region to ensure that the expected LDPs in the two regions are identical in forming their price expectations.

Producers also take loan rates into consideration in their production decisions in two further respects. First, the marketing loan program reduces price risk by truncating (from below) the producer's subjective price distribution at the loan rate, which has to be explicitly taken into account for supply response under risk. Producers received MLGs or LDPs when farm prices fell below the loan rates. But this price-risk protection can have a downside when the market price is expected to exceed the loan rate. Second, producers, if selling food-quality dry peas below the loan rate, have the possibility of achieving an

Table 4
Calculating the expected grower prices of dry peas in North Dakota: 1997-2005

Year	Grower price	Unadjusted expected grower price	P_t[1] - UEP_t[2]	Adjustment factor	Adjusted expected grower price	Effective expected grower price (incl. LDP or MLG)
	$/cwt				$/cwt	
1997	6.40	9.05	-2.65	0.00	9.05	9.05
1998	5.90	7.71	-1.81	-2.65	5.06	5.06
1999	4.50	6.81	-2.31	-2.23	4.58	4.58
2000	4.40	5.30	-0.90	-2.26	3.04	3.04
2001	4.70	4.73	-0.03	-1.92	2.81	2.81
2002	6.70	4.57	2.13	-1.54	3.03	3.03
2003	6.54	5.64	0.90	-0.93	4.71	5.89
2004	5.45	6.22	-0.77	-0.67	5.55	5.84
2005	n.a.	6.03	n.a.	-0.68	5.35	6.03

[1]Expected grower price.

[2]Unadjusted expected grower price has the following weighting scheme: 0.5, t-1; 0.3, t-2; and 0.2, t-3.

Table 5
Calculating the expected grower prices of lentils in North Dakota: 1997-2005

Year	Grower price	Unadjusted expected grower price	P_t[1] - UEP_t[2]	Adjustment factor	Adjusted expected grower price	Effective expected grower price (incl. (P_t) loan rate)
	$/cwt				$/cwt	
1997	13.20	15.49	-2.29	0.00	15.49	15.49
1998	9.10	14.54	-5.44	-2.29	12.25	12.25
1999	11.00	11.79	-0.79	-3.87	7.93	7.93
2000	10.50	10.87	-0.37	-2.84	8.03	8.03
2001	9.60	10.37	-0.77	-2.22	8.15	8.15
2002	11.10	10.15	0.95	-1.93	8.22	8.22
2003	15.00	10.53	4.47	-1.45	9.08	11.94
2004	14.80	12.75	2.05	-0.61	12.14	12.14
2005	n.a.	14.12		-0.27	13.85	13.85

[1]Expected grower price.

[2]Unadjusted expected grower price has the following weighting scheme: 0.5, t-1; 0.3, t-2; and 0.2, t-3.

effective price greater than the loan rate because the LDP or MLG is based on the feed dry pea price, instead of the lower food dry pea price.

Variable cash costs of production for dry peas, lentils, and competing crops are from North Dakota State University Extension Service (Swenson and Akre, (a) and (b)) and the University of Idaho Cooperative Extension System (Smathers). In the North Dakota crop budgets, variable costs from the North Central and Northwest—the two most important regions in the production of dry peas and lentils—are averaged to arrive at State average variable costs of production. In addition, North Dakota crop budgets are used as a proxy for those in Montana. Northern Idaho crop cost budgets for dry peas and lentils are available for 1997, 1999, 2001, 2003, and 2005, as they are updated only every other year (Smathers). Cost budgets in the missing years are approximated based on year-to-year proportional variations of the budgets in North Dakota. The Idaho crop budgets were also used as a proxy for Washington costs due to the lack of a systematic, complete data series (tables 6-7 and appendix tables A-3 and A-4).

Table 6

Expected net returns for dry peas in North Dakota: 1997-2005

Year	Expected yield	Expected price	Variable cost of production	Undeflated expected net returns/acre	Value of yield loss reduction	Value of nitrogen credit for next crop	Augmented expected net returns/acre	Deflated (yr. 2000 $) augmented expected net returns
	Cwt/acre		*$/acre*					*Constant 2000 $/acre*
1997	18.70	9.05	60.18	109.06	14.21	1.70	124.97	130.98
1998	18.90	5.06	60.8	34.83	10.86	1.70	47.39	49.12
1999	18.78	4.58	55.57	30.44	7.99	1.20	39.63	40.50
2000	18.82	3.04	53.77	3.44	7.59	1.25	12.28	12.28
2001	19.26	2.81	49.87	4.25	8.08	1.77	14.10	13.77
2002	19.72	3.03	53.06	6.69	8.82	1.50	17.01	16.33
2003	19.06	5.89	62.07	50.19	9.66	1.85	61.71	58.05
2004	18.92	5.84	62.73	47.76	11.29	2.30	61.35	56.24
2005	19.80	6.03	64.62	54.77	12.10	2.54	69.41	62.16

Source: Estimated and compiled by USDA, ERS from data of North Dakota State University Extension Service and Northern Great Plains Research Laboratory.

Table 7

Expected net returns for lentils in North Dakota: 1997-2005

Year	Expected yield	Expected price	Variable cost of production	Undeflated expected net returns/acre	Value of yield loss reduction	Value of nitrogen credit for next crop	Augmented expected net returns/acre	Deflated (yr. 2000 $) augmented expected net returns
	Cwt/acre		*$/acre*					*Constant 2000 $/acre*
1997	9.00	15.49	50.96	88.45	14.21	1.70	104.36	109.38
1998	9.50	12.25	56.06	60.32	10.86	1.70	72.87	75.54
1999	10.23	7.93	55.21	25.91	7.99	1.20	35.10	35.87
2000	11.28	8.03	52.06	38.52	7.59	1.25	47.35	47.35
2001	12.32	8.15	53.50	46.91	8.08	1.77	56.75	55.42
2002	13.22	8.22	52.07	56.60	8.82	1.50	66.92	64.23
2003	13.22	11.94	60.43	97.42	9.66	1.85	108.93	102.47
2004	13.08	12.14	68.74	90.05	11.29	2.30	103.64	95.00

Source: Estimated and compiled by USDA, ERS from data of North Dakota State University Extension Service and Northern Great Plains Research Laboratory.

The benefits of dry peas and lentils as rotation crops are added to market returns and marketing loan benefits. Based on the crop yield response model developed by the Northern Great Plains Research Laboratory (2002), this study assumes that relative to wheat-wheat operations, a dry peas-wheat rotation would have a yield advantage of 10 percent (tables 6 and 7 and appendix tables A-3 and A-4). The value of yield loss reduction also applies to dry peas and lentils in other States.

Nitrogen credits are also regarded as a part of the expected net returns for peas and lentils. In this study, we assume that dry peas and lentils can fix the bulk of nitrogen needed for their own production and leave, after the growing season is over, about 10 pounds per acre of nitrogen on the soil for the crop following in the rotation. Based on this assumption, which could be somewhat conservative, the per acre value of the nitrogen credit ranged from $1.20/ac to $2.50/ac for dry peas and lentils in North Dakota and Montana. In 2005, for example, the use of dry peas as a rotation crop results in an extra value of about $15 per acre in North Dakota. This additional benefit includes a value of about $12.10 from the 10-percent wheat yield advantage for the wheat-dry pea rotation over the wheat-wheat rotation and a "nitrogen credit" worth $2.54 per acre.

The estimation of aggregate acreage response equations involves the use of cross-section data, raising an issue regarding the fixed effects of individual States. In our analysis, Idaho is chosen as the base or benchmark State for comparison, which is captured in the intercept term.[13] Differentials across individual States, relative to Idaho, are reflected in State dummies, which are part of the estimated results.

[13]The choice of the benchmark State does not affect relative differentials among major producing States.