Dynamic Regional Analysis of the California Alfalfa Market with Government Policy Impacts

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Alfalfa's heavy reliance on irrigation water and its role as an alternate to program crops makes it susceptible to changes in government farm policies. This article presents a dynamic spatial equilibrium model of the California alfalfa market. The model is used to forecast alfalfa acreage, prices paid and received, and transportation flows for the short run and the long run under the base year conditions. The base year results then are compared to a situation of changing demand due to reductions in federal water subsidies and the implementation of a cotton acreage-reduction program.

Key words: alfalfa supply, alfalfa demand, dynamic analysis, forecasting, government policy, irrigation water price.

Alfalfa is an important crop in the midwestern and western parts of the nation, both in terms of the acreage it occupies and as an input to the livestock industry. Despite its importance, there have been very few market studies of alfalfa. Schultz estimated national demand for hay in the early part of the century. Blake and Clevenger estimated a series of monthly autoregressive price forecasting equations, an annual alfalfa demand equation, and an annual autoregressive acreage forecasting equation for New Mexico. The model then was used to predict monthly alfalfa prices on a statewide basis. Myer and Yanagida estimated a demand function for alfalfa in 11 western states and combined it with a quarterly ARIMA model to forecast prices. Blank and Ayer constructed an econometric model for the Arizona alfalfa market, while Knapp and Konyar and Knapp (1988) provided analyses of the aggregate California market. Alfalfa also is included as a cropping activity in various programming models of regional agricultural production. These models generally are static and may or may not contain demand functions for alfalfa.

In this article a dynamic spatial equilibrium model of the California alfalfa market is presented. The model combines regional alfalfa demand and supply functions (acreage response) in a spatial equilibrium model and predicts regional alfalfa acreage, prices, quantities consumed, and transportation flows. The base run results then are compared to a situation of changing supply due to reductions in federal water subsidies and institution of cotton acreage-control programs.

Model

The analysis is based on a recursive, spatial equilibrium model of the California alfalfa market. There are 25 regions consisting of individual counties or aggregates of individual counties. Each region has an inverse demand curve giving regional price paid as a function of regional consumption. Regions that are major alfalfa-producing areas in California have acreage response functions. These functions give alfalfa acreage in year t as a function of lagged acreage, expected prices received, and

yields. The remaining regions are assumed to have a constant level of alfalfa acreage.

Acreage response functions predict alfalfa acreage in each region in year t, given the exogenous variables and lagged acreage. Alfalfa production in each region then is computed by multiplying the regional acreage by exogenously determined regional alfalfa yields. California is a net importer of alfalfa. Net imports are less than 3% of the state's production, and they stay relatively constant from year to year. Therefore, out-of-state imports and exports from each region are determined exogenously and are kept constant at base year levels. Regional alfalfa production, along with net imports into the state, determines total alfalfa supply in each region in the state in year t. Alfalfa can be shipped between regions. Transport costs are imposed on both inter- and intraregional shipments. A spatial equilibrium model then combines regional alfalfa supply with regional alfalfa demand. The model computes equilibrium transportation flows, consumption, and prices for year t. Equilibrium prices from year t then are used in the acreage response functions to compute regional alfalfa acreage in year $t + 1$. New regional acreage is multiplied by exogenously determined regional yields to give regional production in year $t + 1$. This process is repeated for every year over a multiyear period.

Model parameters first were estimated using data through 1982. The model was calibrated using 1982 data, and out-of-sample forecast tests for 1983–86 were conducted to determine model accuracy. Model parameters then were reestimated using data through 1986. These parameter values were used for the base and policy runs.

Demand

The primary consumers of alfalfa in California are dairy cattle, beef cattle, and horses. Konyar estimated 1982 consumption of alfalfa in California as follows: milk cows, 42%; other dairy cattle, 16%; beef cattle, 17%; and horses, 24%.

Alfalfa consumption data are not available for individual model regions. Therefore, alfalfa demand was estimated using statewide data and then disaggregated to individual model regions. Statewide demand was expressed and estimated in the context of a simultaneous model. Equations that define the model are equations for alfalfa consumption, yield, net imports, and carry-over stocks. Here the equation of interest, i.e., the consumption equation, is explored.

Statewide alfalfa demand is defined as

$$(1) \qquad TCONS_t = a_0 + (a_1 + a_2 PALF_t \\ + a_3 LPINDX_t \\ + a_4 FCINDX_t) \\ \cdot TCAT_t + e_{1t},$$

where $TCONS$ is total annual alfalfa consumption (10 million tons) in California, $PALF$ is the price paid for alfalfa by livestock producers ($/ton), $LPINDX$ is an index for livestock prices, $FCINDX$ is an index for prices of livestock feed other than alfalfa, $TCAT$ is the number of beef and dairy cattle in California, and e_{1t} is an error term.

Equation (1) assumes that alfalfa demand in California is the sum of demand by horses and demand by cattle and calves. A consistent set of time-series data on horse numbers in California is not available. Therefore, we treat horse consumption as a constant and estimate it statistically; that is, the coefficient a_0 in equation (1). The remainder of the right-hand side of equation (1) is cattle consumption. The expression in the parentheses is per-head cattle consumption. From economic theory, input demand is a function of output and input prices. Per-head alfalfa consumption is assumed here to be a linear function of livestock product prices, alfalfa price, and other feed costs. Prices are expressed in nominal terms since livestock producers are assumed to solve a static optimization problem in every year with respect to feed demand, and the major cost categories are included. Multiplying per-head demand by cattle numbers gives total cattle consumption. Alfalfa demand is extensively investigated in Konyar and Knapp (1986); the formulation in (1) was shown to yield excellent results when compared to nonsample data.

Total alfalfa consumption ($TCONS$) was constructed as alfalfa production plus carryin stocks and imports of alfalfa products to California minus carryout stocks and exports of alfalfa products from California. The livestock price index ($LPINDX$) was calculated as the weighted average of milk and beef prices with weights of .7 and .3, respectively. Data on production, alfalfa price ($PALF$), milk and beef prices, and cattle numbers ($TCAT$) were obtained from *Field Crop Statistics, Field Crop Review,* and *California Livestock Statistics*

Table 1. Parameter Estimates of California Alfalfa Demand

	1945–82 Sample Period	1945–86 Sample Period
Intercept	1,689***	1,707***
	(434.19)	(425.69)
TCAT	0.710***	0.730***
	(0.135)	(0.132)
PALF·TCAT	−0.0168**	−0.014**
	(0.0074)	(0.007)
LPINDX· TCAT	0.0322**	0.0303***
	(0.0198)	(0.0163)
FCINDX· TCAT	0.0077*	0.0063*
	(0.0046)	(0.0046)
R^2	.80	.83
DW	2.04	1.78

Note: Standard errors are in parentheses. Single, double, and triple asterisks indicate significance at .10, .05, and .01 levels, respectively. *TCAT* is the total number of dairy and beef cattle in California; *PALF* is the price paid for alfalfa in California; *LPINDX* is an index for livestock prices; and *FCINDX* is an index for prices of livestock feed other than alfalfa.

(California Department of Food and Agriculture, Crop and Livestock Reporting Service). Data on imports, exports, and stocks were obtained from the Federal-State Market News Service (FSMNS). The feed price index (*FCINDX*) came from *Agricultural Statistics*, U.S. Department of Agriculture (USDA).

Alfalfa demand function (1) was estimated using two-stage least squares. Data used in estimation was for sample period 1945–82 and sample period 1945–86. Results are given in table 1. Both regressions (1982 and 1986) have R^2 values of .80 or greater. The estimated coefficients have the correct signs, they all are significant at the 10% level or better, and most are significant at the 1% level or better. Out-of-sample price forecast errors for the 1982 regression range from −3% to 15% for 1983–86 with an average of 5.4%. The forecast error generally increases with time.

In the initial regression estimation, price received by farmers was used in place of price paid. The reason for this is that data are available for statewide average prices received by alfalfa growers, whereas annual average prices paid for alfalfa by livestock producers are available only for selected milk-producing regions. Prices paid are subject to substantial spatial variations and consumption data are not available by region. Therefore, construction of a historical series of statewide average price paid index is difficult.

After the estimation, both demand regressions (1982 and 1986) were converted to a price-paid basis by assuming a constant statewide difference between prices paid and prices received. The difference was calculated for 1982 and 1986 demand by subtracting a statewide index for price received from a statewide index for price paid. The resulting amount then was added to the per-head intercept term (a_1 in the demand equations).

Alfalfa demand for each model region then was derived from the statewide estimate using the following specification

$$(2) \quad CONS_i = a_0 \frac{HORS_i}{THORS82} + (a_1 + a_2 PALF$$

$$+ a_3 LPINDX$$

$$+ a_4 FCINDX) \cdot CAT_i,$$

where $CONS_i$ is regional alfalfa consumption; $HORS_i$ and CAT_i are regional horse and cattle numbers, respectively; and $THORS82$ is the total number of horses in California in 1982. This equation disaggregates statewide demand by assuming that per-head livestock consumption is the same as that in the statewide demand function. Data on regional livestock numbers were obtained from Konyar. Equation (2) is used in the spatial equilibrium model after converting to price-dependent form in price paid and specifying values for $HORS_i$, $LPINDX$, $FCINDX$, and CAT_i.

Acreage Response

Acreage response functions were estimated for 16 of the 25 model regions. The 16 regions with econometrically estimated acreage response functions accounted for over 95% of statewide alfalfa area and production in 1986. The remaining model regions were assumed to have constant levels of alfalfa acreage. Acreage response functions were not estimated for these regions due to the relatively small levels of production in these regions and the time and expense involved in data collection and analysis.

Several studies have estimated alfalfa acreage response functions (Blake and Clevenger; Shumway; Just; and Konyar and Knapp 1988). Following previous work, a stock-adjustment model was used to model regional alfalfa acreage response. Desired acreage in year t is

a function of expected alfalfa price, alfalfa yield, expected price received for competing crops, competing crop yields, and expected production costs. After some experimentation at an aggregate, statewide level, it was concluded that a naive expectations model was most appropriate. Thus, expectations for alfalfa price, price of competing crops, and production costs are assumed to equal the one-year lagged values. A stock-adjustment equation for alfalfa acreage is assumed in which the change in alfalfa acreage is proportional to the difference in desired acreage in year t and acreage in the previous year. The resulting equation for estimating alfalfa acreage response is:

$$(3) A_t = b_0 + b_1 A_{t-1} + b_2 TR_{t-1} + b_3 CCINDX_{t-1} + b_4 PCINDX_{t-1} + u_t,$$

where A is acreage of alfalfa, TR is total revenue per acre from growing alfalfa, $CCINDX$ is an index of revenue from growing competing crops, and $PCINDX$ is a cost of production index. The bs are the coefficients to be estimated, and u is an independently and identically distributed error term. The competing crops in a given region are defined to be those field crops that compete with alfalfa for land in that region. The index was constructed by calculating total revenue per acre for each of the crops included and then computing a weighted average where weights are quantity produced. The regressions were estimated using data from 1957–82 and 1957–86. The price, acreage, and yield data were from various California County Agricultural Commissioners' annual crop reports, and the production cost index was from the USDA's *Agricultural Statistics.*

Three combinations of equation (3) were used: first, as it appears above; second, the revenue variables were divided by the cost of production index; and third, alfalfa revenue was divided by competing crop revenue. Variables with coefficient estimates that had a theoretically unexpected sign and at the same time were statistically insignificant were dropped from the regression. In regions where cotton and rice are significant crops, a dummy variable also was included to account for the changes in the government's acreage allotment program for those crops. The regressions were estimated with OLS, and the significance of autocorrelation was checked using Durbin's h statistic. If serial correlation was significant at the .05 level, the equation was reestimated by

a maximum likelihood procedure and asymptotic standard errors reported.

The regression results for 1957–82 are shown in table 2. Most of the adjusted R^2 values are high (.74–.98). The coefficient estimates of the lagged acreage variable are highly significant, and the magnitudes are generally within the expected range. The majority of the revenue variables have coefficient estimates that are significant at the .05 level. Using only the non-zero coefficient estimates, short-run elasticities of acreage response with respect to alfalfa revenue, evaluated at 1982 levels of exogenous variables, are .21 on average with a range of .02–.67, while long-run elasticities range between .16 and 4.44 with an average of 1.18. The revenue variable was dropped from the regression in only two regions due to a theoretically unexpected sign and an insignificant coefficient.

The estimated equations were tested with an out-of-sample forecast for the years 1983 to 1986 using the actual levels of the exogenous variables. The mean absolute percentage error, over the regions and years, was 8.25. A similar figure for state-wide acreage forecasts over the four years was 1.5. The acreage response relations were reestimated for the years 1957–86. The results are similar to those in table 2 and are not reported. The 1957–86 regressions were used for the base runs and policy analysis.

Spatial Equilibrium Model

The spatial equilibrium model calculates equilibrium consumption and trade flows given production and imports/exports to and from California. C_i is regional alfalfa consumption (10,000 tons/year), T_{ij} is the quantity of alfalfa shipped from region i to region j (10,000 tons/year), where $i, j = 1, \ldots, 25$.

The problem is to maximize

$$(4) \qquad \sum_{i=1}^{n} B(C_i) - \sum_{i=1}^{n} \sum_{j \in J_i} c_{ij} T_{ij},$$

subject to

$$(5) \quad C_i + EXPT_i \leq \sum_{j \in J_i'} T_{ji} \qquad i = 1, \ldots, n,$$

and

$$(6) \quad \sum_{j \in J_i} T_{ij} \leq QPROD_i + IMPT_i \quad i = 1, \ldots, n,$$

Table 2. Parameter Estimates of Regional California Alfalfa Acreage Response Equations

Region Name	Intercept	Lagged Acreage	Alfalfa Rev./ Competing Crop Revenue	Alfalfa Rev./Cost of Prod. Index	Alfalfa Revenue	Dummy	Adjusted R^2
Mountain	8,532.400* (5,689.8)	.931** (.0669)		8.312 (24.333)			.95
Sacramento Valley	-906.720 (8,013.7)	.860** (.067)	3,435.300 (2,738.9)			9,090.900** (2,500.4)	.94
Sacramento	-2,955.400** (1,497.2)	.770** (.088)	2,341.800** (697.11)			1,683.900* (991.97)	.88
Solano	2,166.345** (1,042.3)	.754** (.098)	1,059.672 (1,088.9)				.77
San Joaquin	41,355.000** (7,614.5)	.347** (.121)					.22
Stanislaus	-2,437.310 (3,101.3)	.945** (.065)	2,156.284 (1,849.6)				.93
Merced[+]	18,217.700 (27,127)	.533** (.289)			12.001 (26.18)	17,371.030** (5,362.8)	.74
Madera	-6,892.380 (6,780.2)	.955** (.103)		10.798** (5.77)		4,203.509** (1,456.2)	.78
Fresno[+]	56,417.070** (8,198.4)	.348** (.081)				34,785.650** (3,940.5)	.98
Tulare[+]	18,663.020 (14,879)	.485** (.125)		28.558** (15.44)		23,620.960** (5,415)	.68
Kings[+]	7,147.114 (5,545.4)	.627** (.098)		14.682** (5.728)		7,613.706** (1,440.9)	.75
Kern	-11,999.400 (14,446)	.744** (.107)		44.111** (13.374)		11,858.610** (3,597.7)	.82
Los Angeles[+]	10,045.390 (13,131)	.508** (.177)		4.234** (2.392)			.93
San Bernardino[+]	3,488.193 (2,767.4)	.747** (.158)			4.810** (1.621)		.42
Riverside[+]	16,098.270** (5,434.3)	.549** (.129)	2,053.674** (991.45)			3,349.728** (977.04)	.44
Imperial Valley	68,602.760** (25,676)	.485** (.174)	12,727.070* (7,656)				.34

Note: Standard errors are in parentheses. The regions with a + sign are corrected for autocorrelation and the standard errors are asymptotic. Single and double asterisks indicate significance at .10 and .05 levels, respectively. Data is for 1957–82. Dummy is one for the years 1957–73 in the Sacramento Valley and Sacramento and it is one for the years 1957–72 in the other regions.

where n is the number of regions, $B(C_i)$ represents consumption benefits defined as the area under the inverse demand curve, c_{ij} is the transportation cost from region i to j ($\$$/ton), $EXPT_i$ denotes out-of-state exports from region i, $IMPT_i$ equals out-of-state imports to region i, and $QPROD_i$ is the quantity of alfalfa produced in region i. J_i denotes the set of regions to which region i can ship alfalfa, while J_i' denotes the set of regions which ship to region i. Note that all regions can ship to themselves, i.e., i is an element of both J_i and J_i'.

Transport costs are calculated by

$$(7) \qquad c_{ij} = c_{ij}' + MRKUP,$$

where c_{ij}' represents the trucking costs for alfalfa between regions, and $MRKUP$ includes loading/unloading costs, distributor's markup, and within-region transport costs. Values for c_{ij}' were obtained from distance tables and tariff schedules published by the California Public Utilities Commission (1976, 1984). The value for $MRKUP$ was obtained using a calibration procedure described later. The quantity of alfalfa produced in region i, $QPROD_i$, was calculated as regional alfalfa acreage times regional yield. Regional yields were obtained from various California County Agricultural Commissioners' reports, and values for $IMPT_i$ and $EXPT_i$ were calculated using data from FSMNS.

The equilibrium model was solved with MINOS (Murtagh and Saunders), given $QPROD_i$ and the exogenous variables. Prices paid by alfalfa users are the shadow prices associated with (5), while prices received by alfalfa producers are the shadow prices associated with (6). Existing acreage levels and regional prices received were used to calculate alfalfa acreage in the following year via the acreage response functions. This procedure then was repeated for every year.

Model Calibration/Verification

The spatial equilibrium model was first run using the 1982 demand relations and 1982 values for the exogeneous variables and alfalfa production. A value for $MRKUP$ was chosen so that the weighted average price received by growers in the model equaled the actual California average price received in 1982. The estimated value of $MRKUP$ by this procedure was $\$19.17$/ton.

Table 3. Static Spatial Equilibrium Model Forecast Tests

	1983	1984	1985	1986	1983–86 Average
Prices Received	6.0	10.4	12.4	5.8	8.6
Prices Paid	2.7	5.5	7.5	10.7	6.6

Note: Values in the table are weighted mean-absolute percentage errors. Actual alfalfa production was used.

Two sets of tests were carried out for 1983–86 to test the model's accuracy. The first set of tests assessed the model with respect to its ability to predict regional alfalfa prices paid and received given the actual alfalfa production. The second set of tests measured the model's overall accuracy when both prices paid and received and production levels are predicted within the model.

For the first test the spatial equilibrium model was run separately for each year in the 1983–86 period. The data for these runs were 1982 demand, estimated transportation cost (c_{ij}) adjusted for inflation using an index of diesel fuel prices, and actual levels of alfalfa production and exogenous variables. Predictions of prices paid and received were compared to actual regional prices reported by FSMNS. FSMNS reports California alfalfa prices received by growers for individual counties based on California Agricultural Commissioners' data and prices paid for four consuming regions as defined by FSMNS. Weighted averages of these prices were calculated for comparison to model region prices.

Results are given in table 3. The first row gives static forecast errors when comparing model results to prices received in producing regions, and the second row compares model prices to prices paid in consuming regions. Forecast errors are calculated as the weighted mean of the absolute value of regional percentage forecast errors. Prices-received forecast errors range from 6% to 12.4% with an average error of 8.6%. Prices-paid forecast errors are even better. They range from 2.7% to 10.7% with an average of 6.6%.

Spatial variability in California alfalfa prices is significant. In 1986, for example, prices paid in consuming regions varied from $\$92.17$/ton to $\$109.07$/ton for good quality hay. In the same year, prices received in producing re-

Table 4. Dynamic Spatial Equilibrium Model Forecast Tests

	1983	1984	1985	1986	1983–86 Average
Prices Received	6.5	10.2	12.0	7.0	8.9
Prices Paid	2.5	3.9	7.9	11.7	6.5

Note: Values in the table are the weighted average of the absolute percentage forecast errors in each region. Alfalfa production was calculated using alfalfa acreage response functions.

gions varied from $66.50/ton to $92.34/ton for good quality hay. (These are seasonal average prices.) The above results suggest that the spatial equilibrium model does a good job in capturing the relative variability of prices statewide.

For the second set of tests the spatial equilibrium model was simulated over 1983–86. However, in contrast to the first series of tests, forecasted alfalfa production from the acreage response relations was used instead of actual alfalfa production, providing a test of the complete alfalfa market model including supply response. As before, 1982 demand and estimated *MRKUP* were used, along with actual values of the exogenous variables. The procedures for comparing model results to reported prices were the same as those in the first test.

Results are given in table 4. Annual average dynamic forecast errors for prices received range from 6.5% to 12% with a four-year average of 8.9%. Annual average forecast errors for prices paid range from 2.5% to 11.7% with a four-year average of 6.5%. With some exceptions, the forecast errors generally increase with time.

Overall, the results suggest that the model has a reasonable level of accuracy. The forecasting ability perhaps is not strong enough to be used for price forecasting, especially for periods greater than two to three years. However, the accuracy should be good enough for analysis of the relative changes in the alfalfa market due to changing agricultural and resource policies.

Market Structure

After the calibration/verification runs, the model was updated using the most current data available. Demand and acreage response re-

Table 5. Total Elasticities for the Dynamic Spatial Equilibrium Model

Para-meter	Area		Average price paid	
	S-R	L-R	S-R	L-R
TCINDX	−.03	−.07	.02	.05
THORS	.03	.10	.21	.15
FCINDX	.08	.23	.43	.32
LPINDX	.08	.21	.41	.30
PCINDX	−.11	−.19	.10	.16
CCINDX	−.07	−.13	.06	.11

Note: S-R: Short-run elasticity. Year 1 for prices, year 2 for acreage. L-R: Long-run elasticity. Year 99 for acreage and prices. *TCINDX* is a transportation cost index used to adjust interregional shipment costs for alfalfa; *THORS* is the total number of horses in California; *FCINDX* is an index for prices of livestock feed other than alfalfa; *LPINDX* is an index for livestock prices; *PCINDX* is an index for cost of production; and *CCINDX* is an index for revenue from growing competing crops.

lations were reestimated using data through 1986. The exogenous variables were set at average 1984–86 values. The model then was recalibrated using the same procedure as described before. The estimated *MRKUP* value was $22/ton.

The base year is 1986 and the model is run for 99 years which is long enough for convergence to a long-run equilibrium. The base run assumes conditions as in 1984–86. Changes in initial acreage of ±50% also are considered.

With 1986 initial conditions, alfalfa acreage declines to a long-run equilibrium of 967,000 acres. Long-run equilibrium average prices paid and prices received predicted by the model are $105/ton and $85/ton, respectively. Average 1984–86 actual values are 1,043,000 acres for area, $107/ton for average price paid, and $81.97/ton for price received. Thus the model predicts a slight decrease in long-run alfalfa acreage if conditions were to remain as in 1984–86. Prices are predicted to remain relatively constant. Thus the California alfalfa market appears to be in approximate long-run equilibrium, although fluctuations about that equilibrium can be anticipated.

Market dynamics were investigated by imposing 50% increases/decreases in initial acreage levels. In both instances the market responds fairly quickly. Long-run equilibrium is reached in approximately 25 years; 90% of long-run equilibrium is reached in approximately five years.

Elasticities of alfalfa area and average prices paid with respect to various parameters are given in table 5. These elasticities show the

response of area and prices paid to changes in the exogenous variables when all endogenous variables are allowed to change. The elasticities were generated by running the model with plus and minus 20% changes in each of the indicated parameters and then computing arc elasticities.

All the elasticities in table 5 have an absolute value less than one. Increases in horse numbers (*THORS*), the feed cost index (*FCINDX*), and the livestock price index (*LPINDX*) increase area and alfalfa prices in both the short and long run. Increases in the producer cost index (*PCINDX*) and revenue of competing crops (*CCINDX*) decrease area and increase prices in both the short and long run. An increase in the transportation cost index (*TCINDX*) decreases area in the short and long run, and increases prices paid in the short and long run.

As would be expected, table 5 shows that the area response is greater in the long run than in the short run for the parameters being considered. The effects of an increase in alfalfa demand on alfalfa prices are greater in the short run than in the long run. However, a decrease in alfalfa supply due to increases in *PCINDX* and *CCINDX* implies greater long-run effects on alfalfa prices than short-run effects.

Statewide average alfalfa yields have been steadily increasing over a number of years. A time-trend regression of alfalfa yields over the period 1945–86 is

$$\text{(8)} \quad \begin{array}{c} YIELD = 4.26 + .054YEAR, \\ (.06) \quad (.0024) \end{array}$$

where *YIELD* is alfalfa yield in tons/acre, *YEAR* is year with *YEAR* = 1 for 1945, and standard errors are given in parentheses. The R^2 for this regression is .93. The estimates suggest that yields have increased at a rate of .054 tons/acre per year.

The previous runs assumed constant alfalfa yields over time. The alfalfa model was rerun with annual increases in alfalfa yields of .054 tons/acre per year but all other parameters at the base year levels. The effects of this increase in yield are quite substantial. Area decreases over time from 969,000 acres in the first forecast year to 858,000 acres in year 99. Production increases from 6.7 to 10.1 million tons/year, average price paid drops from $104/ton to $55/ton, while average price received drops from $84/ton to $35/ton. Thus, continued improvement in alfalfa yields at the historical rates could have dramatic effects on the long-run alfalfa market.

Federal Water Policy

The Reclamation Act of 1902 established the U.S. Bureau of Reclamation (USBR) in the U.S. Department of the Interior (USDI) and initiated the federal government's involvement in irrigation development. The intent of the law was to provide for and share in the cost of construction and maintenance of an irrigation infrastructure for the storage, diversion, and development of surface water for reclamation of the arid and semiarid lands in the 17 western states. The Act has been effective in that the targeted areas were transformed into some of the most productive cropland in the world.

However, in recent years, the federal government's policies concerning pricing and allocation of irrigation water have been subject to increasing criticism. The price the USBR charges its contracting water districts for the water is less than what it costs the government to provide it. The critics argue that the difference is a direct subsidy and that it adds to the federal budget burden, benefits farmers in one region of the country at the expense of farmers in other regions, and leads to further government subsidies as federal water is used in growing crops that are in surplus.

A proposed solution to the subsidy problem is to increase the price of USBR water up to its full cost. An example of this is the Irrigation Subsidy Reform Act, a bill that was introduced in 1987, which seeks to impose the full cost on federal water used on program crops. As farm subsidies persist and demand for water increases, more legislation seeking to raise the price of federal water can be expected in the future.

Alfalfa is a water-intensive crop. In some areas of California, it receives up to seven acre-feet per acre per year of irrigation water. In 1986, some 43% of alfalfa acreage in California was irrigated, fully or partially, with water from the USBR projects (USDI 1986). In 1986 the average price the USBR received for this water was $3.50 per acre-foot while the cost to the government was $20.18 per acre-foot (calculated from USDI 1988). The difference is the average subsidy with a range of $1.31–$78.54 per acre-foot. Some in Congress argue that this subsidy figure is an underestimate because in calculating the cost of constructing the water projects, the USDI has used interest rates that underestimate the government's borrowing costs (Gejdenson). Because the subsidy levels
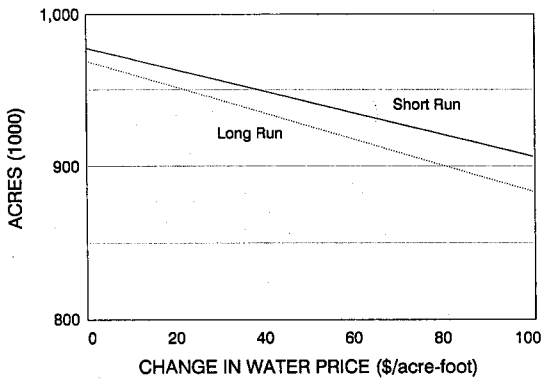
Figure 1.   Impact of water price increase on California alfalfa acreage in the short run and the long run
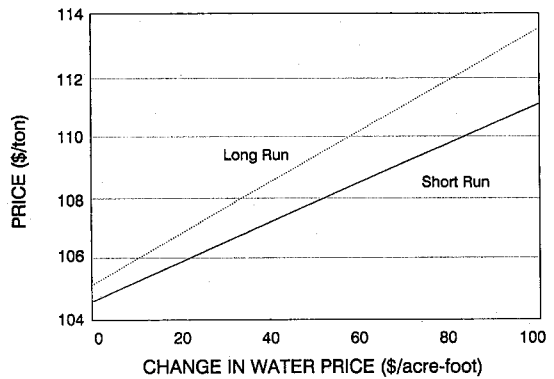

Figure 2.   Impact of water price increase on California alfalfa price in the short run and the long run

vary widely depending on the region and because the subsidy calculations are controversial, this study provides impact estimates for a range of water price increases (subsidy reductions) rather than making point estimates.

In each alfalfa-producing region, the price of USBR water was increased by amounts ranging between zero and $100 per acre-foot, at $10 intervals. The reliance on USBR water varies from region to region. To account for this, a ratio was calculated for each region which equaled the proportion of alfalfa acreage receiving its water from USBR to total alfalfa acreage in that region. The increase in water price was multiplied by the regional ratios to calculate an adjusted water-price increase in each region. The regional water-price increases were then multiplied by each region's alfalfa water-use coefficient to calculate the regional change in cost of producing alfalfa. The change in the cost of production was imposed on the model by subtracting the increase from the total alfalfa revenue in the acreage response equations. For each increase in the price of water, the equilibrium model was solved for the short and long run. The effects on California alfalfa acreage and price paid are shown in figures 1 and 2. In the short run, alfalfa acreage decreases by 6,400 acres and the price paid increases by 67¢ per ton for each $10 decrease in the USBR water subsidy. Similar figures for the long run are 8,300 acres and 84¢ per ton, respectively. As expected the long-run changes in alfalfa acreage and price are greater than the short-run responses to changes in federal water prices.

Water price changes only were considered

for alfalfa and not for the competing crops. Ignoring the effect of a water price increase on competing crop costs is likely to result in overestimation of an acreage shift out of alfalfa production. Even then, the impact of increases in the USBR water price on alfalfa prices is fairly small, even in the long run. However, large increases in the federal water price can have significant long-run impacts on alfalfa acreage. This is especially true at the regional level, as some regions rely heavily on USBR water, and water is a significant portion of the variable cost. For example, in the Imperial region a $100 per acre-foot increase in the price of federal water results in a 21% decrease in the long-run acreage. A similar figure for statewide acreage is 9%. The estimated impacts on alfalfa acreage and price should be viewed as an upper bound because no adjustment is made in the model for the possibility of farmers switching to a water-saving technology or to a different water source as the price of water increases.

Federal Cotton Program

Alfalfa competes with cotton for land in many production regions in California. Federal government cotton programs (acreage allotment and set-aside provisions) were in effect during 1954–72 with the intent of reducing cotton acreage. During the period the cotton programs were in effect, the alfalfa acreage in California was, on average, 112,000 acres higher and the price was $4.60 lower per ton than the average levels outside that period.

The cotton programs were included in the equilibrium model by assigning a value of one to the cotton dummy variable in the acreage response equations. The model then was solved for the short run and the long run. In the short run, alfalfa acreage increases by 152,000 acres, from the base year level of 969,000 acres, or 16%, and the price paid declines by $15.20, from the base year level of $104.42 per ton, or 15%. The short-run increase in acreage is similar in magnitude to the average change in the level of those variables during the 1954–72 period when the cotton programs were in effect. The predicted decrease in price is somewhat larger than the observed change in that period; however, this is probably due in part to inflation. Relative to base year levels, the long-run equilibrium acreage increases by 211,000 acres, or 22% and the price paid declines by $20.92, or 20%. In general, the cotton program seems to have a potentially large impact on the California alfalfa market.

Annual yield increases at the historical rate have significant effects on the alfalfa market. Over a 99-year period, area decreases by 11%, production increases by 51%, and average price drops by 58%.

The effect of plausible changes in federal water rates to reduce water subsidies has a moderate impact on the aggregate alfalfa market. However, there can be significant reductions in acreage in regions relying heavily on federal water if rates are raised high enough. The cotton program has significant implications for the alfalfa market. If the program existing during 1954–72 were reinstituted, alfalfa acreage would increase by 16% in the short run and 22% in the long run, according to model forecasts. Price effects are 15% and 20% declines in price paid during the short and long run, respectively.

Conclusions

A spatial equilibrium model of the California alfalfa market was constructed. The model estimates alfalfa shipments between regions and is simulated over a number of years. A number of out-of-sample forecast tests for individual components and for the entire model were made. Static forecast tests using actual acreage and exogenous variables result in a 1983–86 average error of 8.6% for regional alfalfa prices received, and 6.6% for regional prices paid. Similar values are 8.9% and 6.5% for the dynamic forecast test which uses forecasted alfalfa acreage and actual values of exogenous variables. Overall, the model has sufficient accuracy for analysis of the alfalfa acreage and price response to various outside shocks.

The results suggest that the California alfalfa market is fairly close to long-run equilibrium. Large changes in initial acreage result in a moderately quick return to long-run equilibrium. Elasticities of alfalfa price and acreage with respect to changes in various exogenous variables have absolute values less than one. For the exogenous variables considered, alfalfa price is most sensitive to the feed cost index and price of livestock products in both the short and long run. Alfalfa area is most sensitive to the producers cost index in the short run and the feed cost index in the long run.

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