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A Dynamic Spatial Equilibrium Model of the California Alfalfa Market

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A DYNAMIC SPATIAL EQUILIBRIUM MODEL OF THE CALIFORNIA ALFALFA MARKET

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SUMMARY

A recursive, spatial equilibrium model of the California alfalfa market was constructed with the state divided into 25 regions. Statewide alfalfa demand was estimated econometrically using a simultaneous equations model, and then disaggregated using estimated livestock numbers in each region. Dynamic acreage response functions were estimated for the major producing regions which represented about 95 percent of statewide production. Equilibrium prices, trade flows, and regional consumption were calculated using a spatial equilibrium model. The model was tested by estimating parameters with data through 1982 and then generating forecasts for 1983 to 1986. Both static forecast tests using actual alfalfa acreage data and dynamic forecast tests using simulated acreage from the acreage response functions were conducted. In general, the model performed reasonably well, with average annual forecast errors ranging between 6.5 and 9.9 percent depending on the variable and forecast test (dynamic or static).

After testing the model, parameters were re-estimated with data through 1986 and a number of 99 year simulations were performed with 1986 as the base year. With exogenous variables held at their average 1983-86 levels, model results suggest that the California alfalfa market is in approximate long-run equilibrium. Large shocks to initial acreage resulted in a relatively quick return to long-run equilibrium. Response of alfalfa acreage and price to changes in various exogenous variables was relatively inelastic. Among the exogenous variables considered, alfalfa price was most sensitive to the feed cost index and price of livestock products. Alfalfa area was most sensitive to the producers' cost index in the short-run, and feed cost and livestock product prices in the long-run. Alfalfa yields have been steadily increasing over time. If they were to continue to increase at this same rate, model results suggest an 11 percent area decrease, a 51 percent production increase, and a 58 percent price decrease (in constant dollars) over the 99 year time period.

Reductions in federal water subsidies were found to have a relatively moderate impact on the aggregate California alfalfa market, but potentially significant effects in regions that rely heavily on federal water. Impacts on the California alfalfa market from reductions in federal dairy subsidies were found to be fairly small. Apparently demand is sufficiently price elastic to absorb the extra hay resulting from reduced dairy herds with only moderate price decreases which, combined with price-inelastic supply response, result in small reductions in alfalfa area. Finally, cotton price and income programs have potentially large effects on the California alfalfa market: Price and acreage could change by as much as 20 percent if cotton programs similar to those in 1954-1972 were to be re-instituted.

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A DYNAMIC SPATIAL EQUILIBRIUM MODEL OF THE CALIFORNIA ALFALFA MARKET

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. Blake and Clevenger (1984) estimated a series of monthly auto-regressive price forecasting equations, an annual alfalfa demand equation, and an annual auto-regressive acreage forecasting equation for New Mexico; they used the model to predict monthly alfalfa prices on a statewide basis. Myer and Yanagida (1984) estimated a demand function for alfalfa in 11 western states and combined it with a quarterly ARIMA model to forecast prices. Blank and Ayer (1987) constructed an econometric model for the Arizona alfalfa market, while Knapp (1987) and Konyar and Knapp (1988) provided analyses of the aggregate California market. Alfalfa is also included as a cropping activity in various programming models of regional agricultural production. These analyses are generally static and not all include demand functions for alfalfa.

In this report a dynamic spatial equilibrium model of the California alfalfa market is presented. The model combines regional alfalfa demand and acreage response functions in a spatial equilibrium model and predicts regional alfalfa acreage, prices, quantities consumed, and transportation flows. Base run results are then compared with several different policy scenarios: (1) a change in the federal dairy price support program, (2) a reduction in federal water subsidies, and (3) re-institution of a cotton acreage control program.

Descriptive Overview of the California Alfalfa Market

This section describes the major variables in the California alfalfa market from 1945 to 1986. The major sources for these data are the Federal-State Market News Service (FSMNS) and the California Crop and Livestock Reporting Service. For further details on the data sources, see Konyar and Knapp (1986).

Figure 1 shows the total area planted to alfalfa in California from 1945 through 1985. Average total area was 1.00 million acres from 1945-1953, 1.16 million acres from 1954-1977, and 1.03 million acres from 1978-1986. Konyar (1985) attributes the substantial increase in alfalfa acreage from 1954-1972 to acreage allotments

Figure 1. California Alfalfa Area

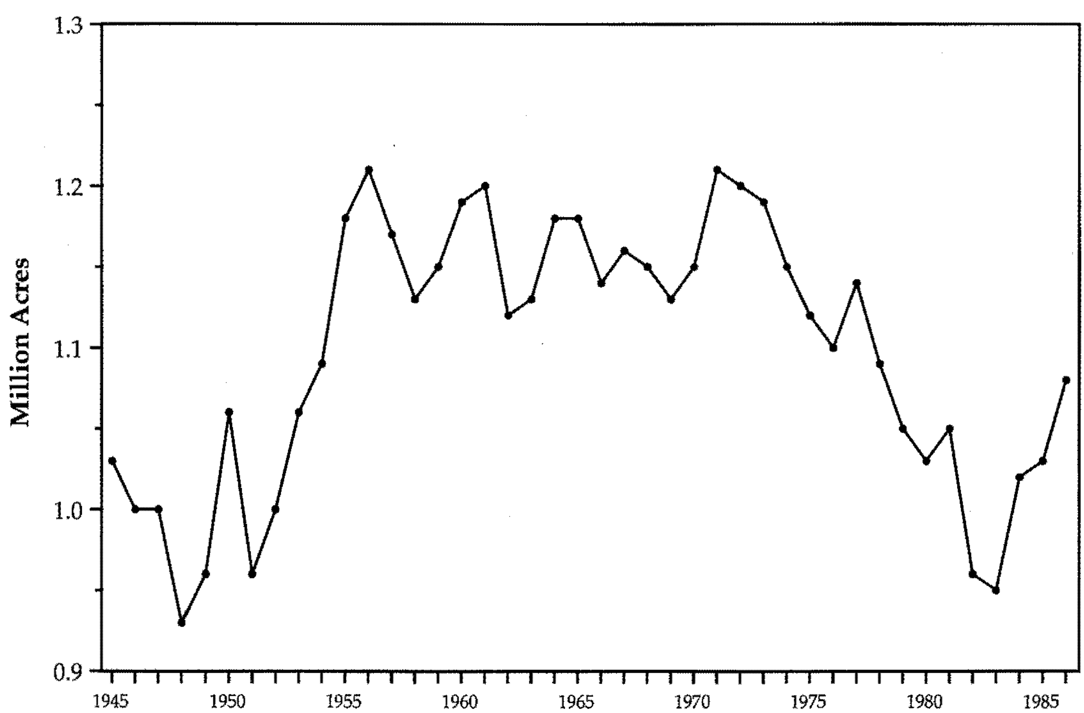
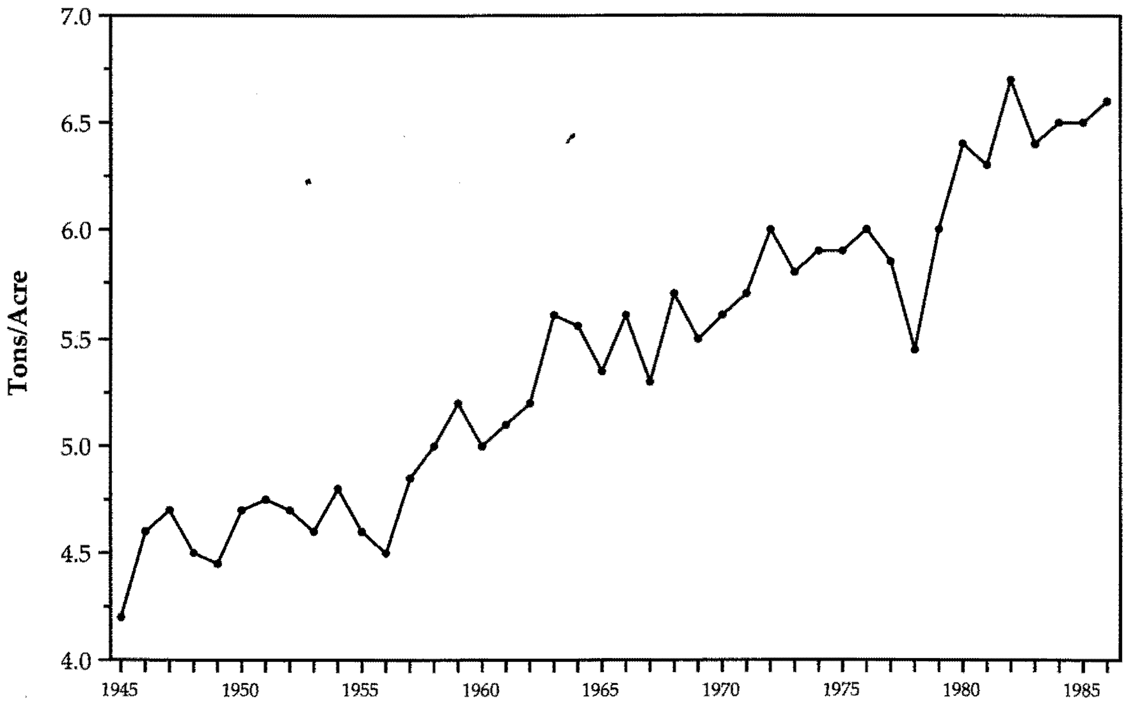


Figure 2. California Alfalfa Yields



and marketing quotas for cotton. Apparently, land was shifted out of cotton and into alfalfa production during this period. When these programs ended, more cotton was planted, and alfalfa acreage dropped.

Figure 2 illustrates the steady increase in alfalfa yields in California over time. A regression on the data in Figure 2 shows that yields have increased at the rate of .05 tons per acre per year:

$$\underset{}{ALFYLD} = \underset{(70.84)}{4.26} + \underset{(22.25)}{.054*YR} \qquad R^2 = .93$$

where ALFYLD is alfalfa yield in tons per acre, YR is year with YR = 1 for 1945, and t–statistics are given in parentheses. Annual fluctuations about the trend line are relatively small. The root mean squared percentage difference between actual and trend line yields is about 3.4 percent while the mean absolute percentage difference is 2.5 percent.

Figure 3 shows California alfalfa hay production over the same period. Production increased in the early 1950s due to increases in both area and yields. From the mid-1950s to the early 1970s production increases were due mostly to increasing yields. Since then increasing yields combined with decreasing area have maintained relatively constant production on average; however, there have been some significant year-to-year fluctuations.

Milk cows, other cattle and calves, and horses are the major users of alfalfa hay in California, with milk cows being the single largest alfalfa consumer. Figure 4 shows numbers of milk cows and all cattle and calves in California. Milk cow numbers have remained very constant over the entire time period.

Figures 5 and 6 plot the nominal and deflated prices of alfalfa hay, respectively. Nominal prices were relatively constant from 1945 until the early 1970s. After that, they increased due largely to inflation, but with substantial year-to-year variability. Deflating the nominal price with the U.S. Department of Agriculture production cost index, shows a general decline over time, at the rate of about $.40 per ton per year, with substantial year-to-year fluctuations.[1]

[1]The root mean squared percentage difference between the actual deflated price and a quadratic trend deflated price is 15 percent, while the mean absolute percentage difference is 12 percent.

Figure 3. California Alfalfa Production

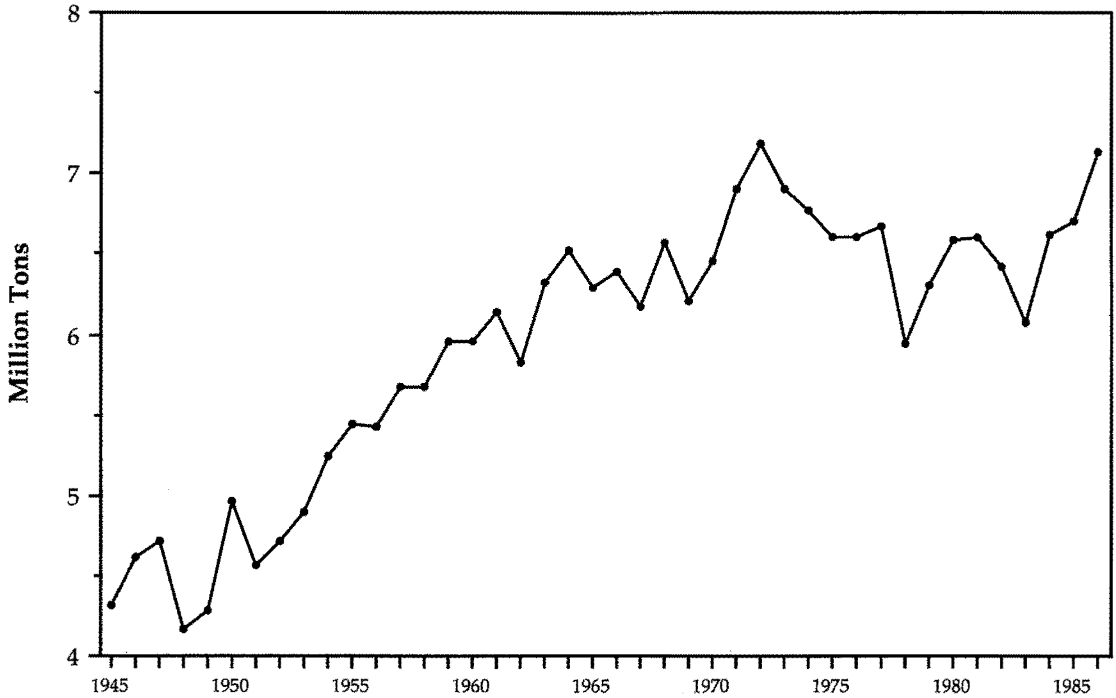


Figure 4. Number of Milk Cows and Cattle and Calves in California

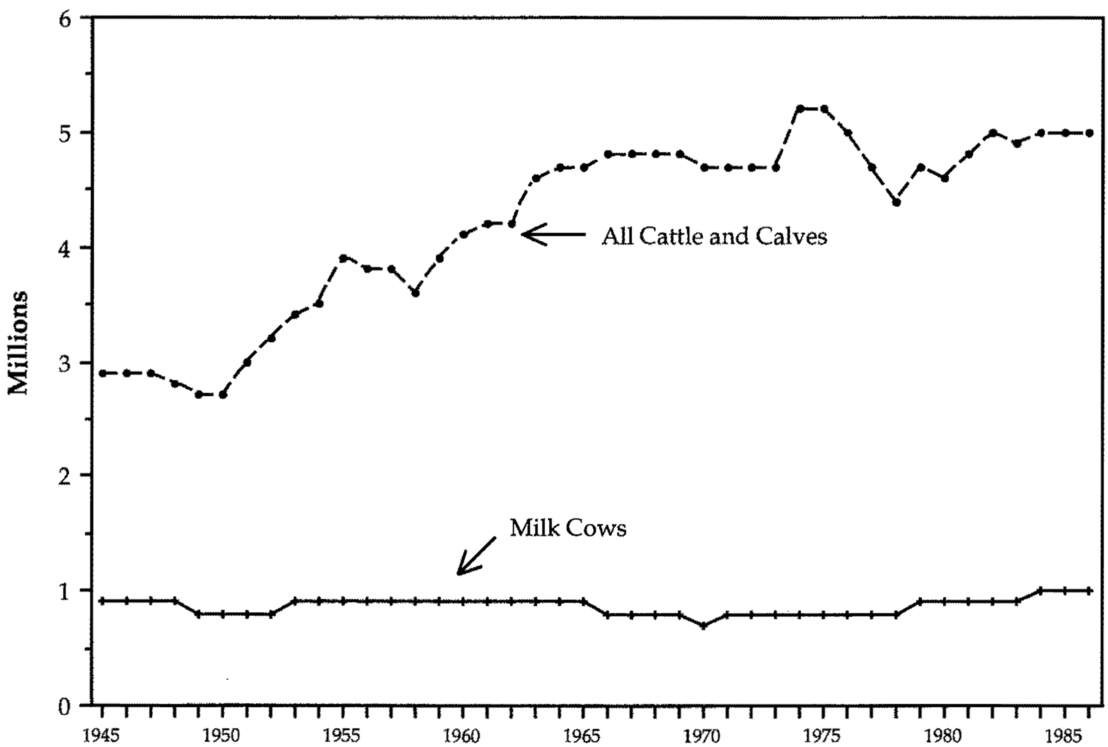


Figure 5. Average Annual Nominal Price of Alfalfa in California

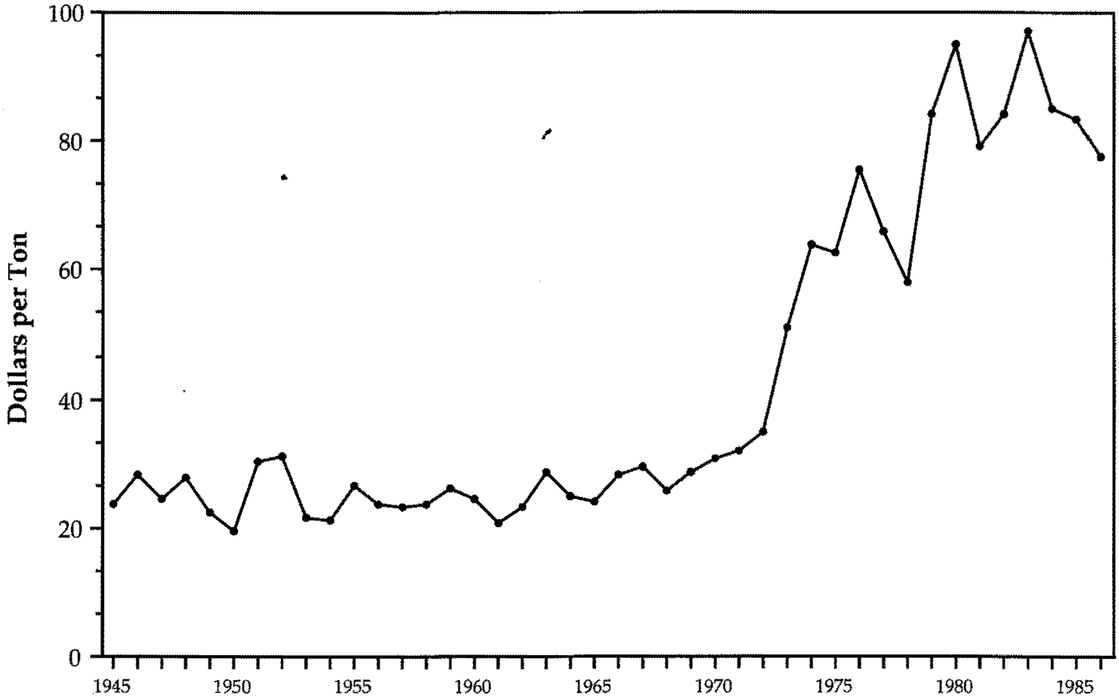
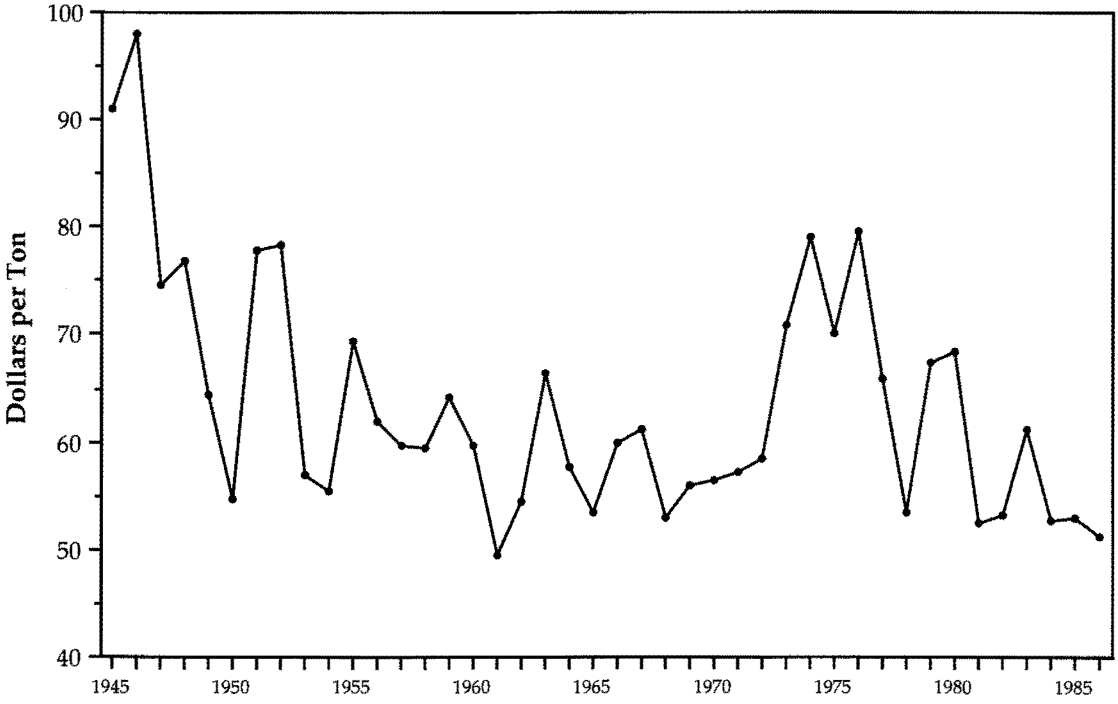


Figure 6. Average Annual Alfalfa Price in California, Deflated by the U.S. Department of Agriculture Production Cost Index (1977=100)



Model Framework

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 (see Table 1). Each region has an inverse demand curve giving regional price as a function of regional consumption. The 16 major producing regions (Table 1) also have acreage response functions that estimate acreage in year t as a function of lagged acreage and expected prices and yields. Alfalfa acreage is assumed constant in the other nine regions. Alfalfa production is calculated in each region in year t using the estimated alfalfa area and exogenously-determined yields.

Alfalfa can be shipped between regions. Transport costs are imposed on both inter- and intra-regional shipments, with out-of-state imports and exports from each region determined exogenously. The spatial equilibrium model computes equilibrium transportation flows, consumption, and prices for year t. Equilibrium prices from year t are then used in the acreage response functions to compute regional alfalfa acreage in year t + 1. This process is repeated for every year over the horizon.

Model parameters were first estimated using data through 1982. The model was calibrated using 1982 data, and forecast tests for 1983-86 were conducted to determine model accuracy. In general, model performance was quite good, with average forecast errors for 1983-86 ranging from 6 to 10 percent. The model was then re-estimated using data through 1986 with these parameter estimates used for the base and policy runs. Model components and estimation procedures are described below.

Table 1. Model Regions[a]

Number	Name	Counties Included
1	Petaluma	Sonoma, Marin, Contra Costa, Napa
2*	Sacramento	Sacramento
3*	San Joaquin	San Joaquin
4*	Stanislaus	Stanislaus
5*	Merced	Merced
6*	Madera	Madera
7*	Fresno	Fresno
8*	Tulare	Tulare
9*	Kings	Kings
10*	Kern	Kern
11*	Los Angeles	Los Angeles
12*	San Bernardino	San Bernardino
13*	Riverside	Riverside
14	San Diego	San Diego
15	Orange	Orange
16*	Mountain	Siskiyou, Modoc, Shasta, Lassen
17	North Coast	Del Norte, Humboldt, Mendocino, Lake
18	Trinity	Trinity
19	Yuba	Yuba
20*	Sacramento Valley	Tehema, Glenn, Yolo, Butte, Colusa, Sutter
21*	Solano	Solano
22	Sierra	Plumas, Sierra, Placer, Alpine, Nevada, El Dorado, Amador, Inyo, Calaveras, Tuolumne, Mariposa, Mono
23	Central Coast	Alameda, San Mateo, Santa Clara, Santa Cruz, San Benito, Monterey
24	South Coast	San Luis Obispo, Santa Barbara, Ventura
25*	Imperial	Imperial

[a]Regions marked with * are assumed to be major producing regions and have econometrically estimated acreage response functions. Production levels are assumed constant in other regions.

Demand

The primary consumers of alfalfa in California are dairy cattle, beef cattle, and horses. Konyar (1985) estimated that in 1982, milk cows consumed 42 percent of the alfalfa; other dairy cattle, 16 percent; beef cattle, 17 percent; and horses, 24 percent.

Alfalfa consumption data are not available by region. Therefore, alfalfa demand was estimated using statewide data and then disaggregated to the model's regions. Statewide alfalfa demand is defined as:

$$(1)\quad TCONS_t = a_0 + (a_1 + a_2 PALF_t + a_3\ LPINDX_t + a_4\ FCINDX_t)\ TCAT_t$$

where $TCONS_t$ is total alfalfa consumption (10^6 tons) by horses and cattle and calves in California, $PALF_t$ is the price paid for alfalfa by livestock producers ($ per ton), $LPINDX_t$ is an index for livestock prices, $FCINDX_t$ is an index for livestock feed prices other than alfalfa, and $TCAT_t$ is the number of beef and dairy cattle in California.

Time series data on horse numbers in California is not available.[2] Therefore, horse consumption is included as part of the constant a_0 in equation (1). The expression in parentheses is alfalfa consumption per cow. From economic theory, input demand is a function of output and input prices. Accordingly, per-head alfalfa consumption is assumed 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 each year with respect to feed demand. Multiplying per-head demand by cattle numbers gives total cattle consumption. Alfalfa demand was extensively investigated in Konyar and Knapp (1986); the formulation in (1) was shown to yield excellent results when compared to existing information.[3]

The estimation procedure is a modification and extension of the analysis in Konyar and Knapp (1986). Details are given in the appendix. The estimated aggregate demand equations are:

1945-1982

$$TCONS_t = 1689 + (1.09 - .017\ PALF_t + .032\ LPINDX_t + .008\ FCINDX_t)\ TCAT_t$$

1945-1986

$$TCONS_t = 1707 + (1.085 - .014\ PALF_t + .030\ LPINDX_t + .006\ FCINDX_t)\ TCAT_t$$

Regional alfalfa demand is specified as

$$(2)\quad CONS_{it} = a_0 \frac{HORS_{it}}{THORS82} + (a_1 + a_2\ PALF_t + a_3\ LPINDX_t + a_4\ FCINDX_t)\ CAT_{it}$$

where $CONS_{it}$ is regional alfalfa consumption, $HORS_{it}$ and CAT_{it} 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 consumption as a function of prices is the same as in the statewide demand function; that is, values for the a_i coefficients are taken from the aggregate statewide demand function. Data on regional livestock numbers are given in Konyar (1985). Equation (2) is used in the spatial equilibrium model after converting it to price-dependent form and specifying values for $HORS_{it}$, $LPINDX_t$, $FCINDX_t$, and CAT_{it}.

Acreage Response

Acreage response functions were estimated for 16 of the 25 model regions. Table 2 gives 1986 alfalfa acreage, yields, and production for the 25 model regions. The 16 regions with econometrically-estimated acreage response functions account for over 95 percent of statewide alfalfa area and production in 1986. The remaining regions were assumed to have constant levels of alfalfa acreage.

A number of studies developed and estimated alfalfa acreage response functions—Blake and Clevenger (1984), Shumway (1983), Just (1974), and Konyar and Knapp (1988). Following this work, a stock adjustment model was used here to model regional alfalfa acreage

[2]Konyar (1985) and Konyar and Knapp (1986) review the several surveys of horse numbers in California. These surveys only provide data for two to three selected years of the sample period 1945-1986. The available data are used to disaggregate the statewide demand curve as described in equation (2); however, the data points are not sufficient to be used in equation (1).

[3]Konyar (1985) estimated total alfalfa consumption by horses in California as a residual after subtracting all other known uses from total alfalfa consumption in California in a particular year. The implied per-head horse consumption falls well within the range of published estimates on per-head horse consumption.

In Konyar and Knapp (1986), the econometric demand regressions were tested in part by calculating total horse consumption and per-head cattle and calf consumption from the estimated coefficients. The estimates obtained in this manner for the demand formulation in equation (1) are quite similar to the data obtained from other sources reported in Konyar (1985).

Table 2. Alfalfa Acreage, Yields and Production by Model Region, 1986[a]

Model Region	Area (acres)	Area % of state total	Yield (tons/acre)	Production (tons)	Production % of state total
1	2,170	.2	9.67	20,984	.3
2*	5,900	.6	7.00	41,300	.6
3*	56,500	5.7	6.46	364,990	5.2
4*	26,146	2.7	6.21	162,367	2.3
5*	59,200	6.0	6.94	410,848	5.8
6*	27,000	2.7	7.16	193,320	2.7
7*	80,000	8.1	8.80	704,000	10.0
8*	100,000	10.2	8.42	842,000	12.0
9*	29,033	2.9	6.31	183,198	2.6
10*	89,000	9.0	8.20	729,800	10.4
11*	8,413	.9	7.52	63,266	.9
12*	24,500	2.5	8.00	196,000	2.8
13*	41,760	4.2	8.93	372,917	5.3
14	0	0	0	0	0
15	0	0	0	0	0
16*	141,813	14.4	4.46	632,486	9.0
17	1,140	.1	5.25	5,985	.1
18	23	0	2.25	52	0
19	855	.1	5.90	5,045	.1
20*	60,593	6.2	6.04	365,982	5.2
21*	11,400	1.2	6.00	68,400	1.0
22	18,695	1.9	5.00	93,475	1.3
23	11,430	1.2	6.83	78,067	1.1
24	12,819	1.3	7.00	89,733	1.3
25*	175,868	17.9	8.06	1,417,496	20.1
Total	**984,258**	**100.0**		**7,041,709**	**100.0**

[a]Regions marked with * are assumed to be major producing regions and have econometrically estimated acreage response functions. Production levels are assumed constant in other regions.

response.[4] Desired acreage in year t was hypothesized as a function of expected alfalfa price, expected price received for competing crops, and expected production costs. After some experimentation at the aggregate, statewide level, a naive expectations model was selected. Thus, expectations for alfalfa price, price of competing crops, and production costs were assumed to equal their respective one-year lagged values. A stock adjustment equation for alfalfa acreage was specified 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:

$$(3)\quad A_t = a_0 + a_1A_{t-1} + a_2TR_{t-1} + a_3CCINDX_{t-1} + a_4PCINDX_{t-1} + e_t$$

where A is acreage of alfalfa, TR is total revenue per acre from growing alfalfa, CCINDX is an index for total revenue per acre from growing competing crops, and PCINDX is a cost of production index. The a's are the coefficients to be estimated and e_t is the error term. Competing crops in a given region were those field crops that compete with alfalfa for land in that region (see Table 3). The index was constructed by calculating total revenue per acre for each of the included crops and then computing an average weighted by the quantity produced of each. The price, acreage, and yield data were from California county agricultural commissioners' annual crop reports, and the production cost index was from the U.S. Department of Agriculture *Agricultural Statistics*. The regressions were estimated using data from 1957-1982 and from 1957-1986.

[4]More sophisticated approaches to perennial crop supply response are developed in French and Bresler (1962), French, King and Minami (1985), Hartley, Nerlove and Peters (1987), and elsewhere. However, these approaches require data on new plantings, removals, and the age-distribution of existing stocks which are not available for the California alfalfa market at either the regional or statewide level.

Table 3. Crops Used to Construct the Competing Crop Index in the Alfalfa Acreage Response Functions

Region Name	Barley	Beans	Corn	Cotton	Grain hay	Safflower	Corn silage	Grain sorghum	Sugar beets	Wheat	Sudan grass
Mountain	x				x					x	
Sacramento Valley						x					
Solano	x	x	x					x	x	x	
San Joaquin	x	x	x		x	x	x	x	x	x	
Stanislaus			x							x	
Merced	x	x		x	x			x	x	x	
Madera											
Fresno	x	x	x	x			x	x	x	x	
Tulare	x		x	x			x	x		x	
Kings	x			x		x	x		x	x	
Kern		x		x	x				x	x	
Los Angeles	x				x				x	x	
San Bernardino											x
Riverside		x		x							
Imperial				x							

Three variations 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 whose coefficient estimates were of a theoretically unexpected sign with relatively large standard errors were dropped from the regression. In regions where cotton and rice are significant crops, a dummy variable was also included to account for the changes in the government's acreage allotment program for those crops. The regressions were estimated by Ordinary Least Squares, and Durbin's h statistic was used to test for auto-correlation. If serial correlation was significant at the .05 level, the equation was re-estimated with a maximum likelihood procedure and asymptotic standard errors reported.

The regression results for 1957-1982 are shown in Table 4. 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. Elasticities of acreage response with respect to alfalfa total revenue are given in Table 5. (The revenue variable was dropped from the equations for San Joaquin and Fresno due to incorrect signs; therefore, the coefficient and associated elasticities are implicitly zero.) For the non-zero coefficients, short-run elasticities are .21 on average with a range of .02 to .67; long-run elasticities range between .16 and 4.44 with an average of 1.18.

The estimated equations were tested with an out-of-sample forecast for the years 1983 to 1986 using actual levels of the exogenous variables. The mean absolute percentage error, over the regions and years, was 8.25. A similar figure for statewide acreage forecasts over the four years is 1.5. The acreage response relations were then re-estimated for the years 1957-1986. Results were similar to those in Table 4 and are not reported. The 1986 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. The variables are:

C_i = regional alfalfa consumption (10^3 tons per year),

T_{ij} = quantity of alfalfa shipped from region i to region j

(10^3 tons per year),

where i,j = 1,...,25.

The problem is to maximize

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

Table 4. **Parameter Estimates of Regional California Alfalfa Acreage Response Equations**[a]

Region Name	Intercept	Lagged Acreage	Alfalfa Rev./ Competing Crop Revenue	Alfalfa Rev./Cost of Prod. Index	Alfalfa Revenue	Dummy	Adjusted R^2
Mountain	8532.400*	0.931**		8.312			.95
	(5689.8)	(.0669)		(24.333)			
Sacramento Valley	-906.720	0.860**	3435.300			9090.900**	.94
	(8013.7)	(.067)	(2738.9)			(2500.4)	
Sacramento	-2955.400**	0.770**	2341.800**			1683.900*	.88
	(1497.2)	(.088)	(697.11)			(991.97)	
Solano	2166.345**	0.754**	1059.672				.77
	(1042.3)	(.098)	(1088.9)				
San Joaquin	41355.000**	0.347**					.22
	(7614.5)	(.121)					
Stanislaus	-2437.310	0.945**	2156.284				.93
	(3101.3)	(.065)	(1849.6)				
Merced+	18217.700	0.533**			12.001	17371.030**	.74
	(27127)	(.289)			(26.18)	(5362.8)	
Madera	-6892.380	0.955**		10.798**		4203.509**	.78
	(6780.2)	(.103)		(5.77)		(1456.2)	
Fresno+	56417.070**	0.348**				34785.650**	.98
	(8198.4)	(.081)				(3940.5)	
Tulare+	18663.020	0.485**		28.558**		23620.960**	.68
	(14879)	(.125)		(15.44)		(5415)	
Kings+	7147.114	0.627**		14.682**		7613.706**	.75
	(5545.4)	(.098)		(5.728)		(1440.9)	
Kern	-11999.400	0.744**		44.111**		11858.610**	.82
	(14446)	(.107)		(13.374)		(3597.7)	
Los Angeles+	10045.390	0.508**		4.234**			.93
	(13131)	(.177)		(2.392)			
San Bernardino+	3488.193	0.747**			4.810**		.42
	(2767.4)	(.158)			(1.621)		
Riverside+	16098.270**	0.549**	2053.674**			3349.728**	.44
	(5434.3)	(.129)	(991.45)			(977.04)	
Imperial Valley	68602.760**	0.485**	12727.070*				.34
	(25676)	(.174)	(7656)				

[a]Standard errors are in parentheses. 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 are for 1957 1982. Dummy is 1 for the years 1957-1973 in the second and third regions and it is 1 for the years 1957-1972 in the other regions.

subject to

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

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

where n is the number of regions, $B(C_i)$ is consumption benefits defined as the area under the inverse demand curve, c_{ij} are transport costs from region i to j ($ per ton), $EXPT_i$ are out-of-state exports from region i, $IMPT_i$ are 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

$$c_{ij} = c_{ij}' + MRKUP$$

where c_{ij}' is the trucking costs for alfalfa between regions and MRKUP includes loading/unloading costs, distributor's markup, and within-region transport

Table 5. Elasticity of Regional Alfalfa Acreage with Respect to Alfalfa Total Revenue Evaluated at 1982 Prices and Quantities

Region Name	Short-Run Elasticity	Long-Run Elasticity
Mountain	.02	.29
Sacramento Valley	.12	.86
Sacramento	.67	2.91
Solano	.10	.41
San Joaquin	.0	.0
Stanislaus	.13	2.36
Merced	.14	.30
Madera	.20	4.44
Fresno	.0	.0
Tulare	.22	.43
Kings	.26	.70
Kern	.37	1.44
Los Angeles	.18	.37
San Bernardino	.10	.40
Riverside	.07	.16
Imperial Valley	.13	.25

costs. Values for c'_{ij} were obtained from published distance and tariff schedules (Konyar, 1985) and are given in Table 6; $c'_{ij} = 0$ for $i = j$. The value for MRKUP was obtained using a calibration procedure described later. $QPROD_i$ was calculated as regional yield times regional alfalfa acreage. Regional yield and values for $IMPT_i$ and $EXPT_i$ were calculated from data in 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 using the acreage response functions. This procedure was then repeated for every year over the horizon.

Model Calibration/Verification

The spatial equilibrium model was first run using the 1982 demand relations and 1982 values for the exogenous 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, or MRKUP = $19.17 per ton.

A series of static forecasts were carried out for 1983-86 to test the model's accuracy. The spatial equilibrium model was run separately for each year of the period using the 1982 demand, estimated MRKUP and inter-regional transport costs adjusted for inflation, and actual levels of alfalfa production and exogenous variables.[5]

FSMNS reports California alfalfa prices (1) received by growers for individual counties based on California county agricultural commissioner data, (2) received by growers for eight to ten FSMNS producing regions depending on the year, and (3) paid in four FSMNS consuming regions. Weighted averages of prices in (1) were calculated as appropriate for comparison with the model's prices by region; weighted averages of model regional prices were calculated as appropriate for comparison with prices in (2) and (3). In Table 7, the first row gives forecast errors between model results and county-level prices, while the second and third rows compare model prices to those in FSMNS producing and consuming regions, respectively. Forecast errors were calculated as the average of the absolute value of regional percentage forecast errors weighted by the regional quantity produced. Price-received forecast errors range from 6 to 14 percent with an average error of 8 to 10 percent depending on the base of comparison.

Price-paid forecast errors are somewhat better, ranging from 3 to 11 percent with an average of 7 percent. These forecast errors are small relative to the actual regional variability in California alfalfa prices. In 1986, for example, seasonal average prices paid in FSMNS consuming regions varied from $92.17 per ton to $109.07 per ton for good quality hay. In the same year, prices received in FSMNS producing regions varied from $66.50 per ton to $92.34 per ton also for good quality hay.

[5]MRKUP was adjusted for inflation using the consumer price index and inter-regional transport costs were adjusted for inflation using an index of diesel fuel prices.

Table 6. Inter-regional Alfalfa Transport Costs, 1982[a]

Source Region	Destination Region 1	2	3	4	5	6	7	8	9	10	11	12	13
	dollars per ton												
3	15.40	7.40	0.0	9.20	13.00	7.40	18.00	18.00	18.00	18.00	28.00	31.80	31.80
4	16.80	3.60	3.60	0.0	11.60	3.60	16.40	16.40	16.40	16.40	26.80	30.60	30.60
5	18.00	10.20	10.20	11.60	0.0	10.20	15.40	15.40	15.40	15.40	23.80	29.40	28.00
6	21.60	13.00	13.00	13.00	10.20	0.0	12.20	12.20	12.20	12.20	22.60	28.00	26.80
7	22.60	14.80	14.80	14.80	12.20	14.80	0.0	11.60	11.60	11.60	17.40	26.80	25.40
8	26.80	17.40	17.40	17.40	16.40	17.40	7.40	0.0	7.40	7.40	17.40	22.60	21.60
9	23.80	16.40	16.40	15.80	14.40	16.40	9.20	9.20	0.0	9.20	19.40	23.80	22.60
10	28.00	19.80	19.80	19.40	17.40	19.80	12.20	12.20	12.20	0.0	15.40	19.80	18.60
11	33.00	33.00	33.00	26.80	23.80	33.00	18.00	18.00	18.00	18.00	0.0	13.00	14.80
12	36.80	36.80	36.80	29.40	28.00	36.80	22.60	22.60	22.60	22.60	11.60	0.0	12.20
13	40.40	35.40	35.40	35.40	33.00	35.40	28.00	28.00	28.00	28.00	17.40	13.00	0.0
16	29.40	29.40	29.40	30.60	31.80	29.40	36.80	36.80	36.80	36.80	43.00	48.20	47.00
20	14.80	15.40	15.40	16.40	18.00	15.40	23.80	23.80	23.80	23.80	33.00	36.80	36.80
21	11.60	14.40	14.40	14.80	16.80	14.40	22.60	22.60	22.60	22.60	31.80	35.40	35.40
25	43.00	38.80	38.80	37.80	36.80	38.80	31.80	31.80	31.80	31.80	22.60	16.80	18.60

Source Region	Destination Region 14	15	16	17	18	19	20	21	22	23	24	25	
	dollars per ton												
3	36.80	30.60		26.80	28.00	14.40	14.40		19.40	13.60	30.60		
4	35.40	30.60		28.00	29.40	15.80	15.80		21.60	14.80	29.40		
5	34.40	28.00		29.40	30.60	18.00	18.00		23.80	12.20	26.80		
6	33.00	26.80		31.80	31.80	19.80	19.40		25.40	15.40	25.40		
7	31.80	23.80		33.00	33.00	22.60	21.60		28.00	15.80	23.80		
8	29.40	21.60		35.40	36.80	25.40	25.40		30.60	19.80	21.60		
9	29.40	22.60		34.40	35.40	23.80	23.80		29.40	17.40	21.60		
10	26.80	18.00		36.80	37.80	28.00	28.00		31.80	21.60	17.40		
11	21.60	15.40		41.20	42.00	33.00	33.00		33.00	28.00	15.80		
12	18.00	13.60		44.00	44.00	35.40	35.40		33.00	31.80	18.00		
13	16.40	15.80		49.60	49.60	40.40	40.40		38.80	35.40	22.60		
16	53.20	47.00	0.0	30.60	19.80	22.60	23.80		33.00	31.80	44.00		
20	41.20	35.40		26.80	22.60	8.40	0.0		19.40	18.00	34.40		
21	40.40	34.40		22.60	23.80	12.20	11.60	0.0	18.60	15.40	33.00		
25	14.80	19.80		53.20	53.20	43.00	43.00		42.00	38.80	26.80	0.0	

[a] All model regions can ship to themselves. Only source regions which can ship to other regions are included. Transport costs from a region are not calculated for regions expected to be permanent importers (e.g., regions 1 and 2). Transport costs into a region are not calculated for regions expected to be permanent exporters (i.e., regions 16, 21, and 25).

Table 7. Static Forecast Tests of the Spatial Equilibrium Model[a]

	1983	1984	1985	1986	1983-86 Average
	percent				
Prices received					
County	6.0	10.4	12.4	5.8	8.6
Producing region	7.6	11.6	14.2	6.1	9.9
Prices paid	2.7	5.5	7.5	10.7	6.6

[a] Values in table are weighted mean absolute percentage errors. Actual alfalfa production figures were used.

A dynamic forecast test of the complete model (spatial equilibrium model and acreage response functions) was conducted for the period 1983-86. As before, 1982 demand and estimated MRKUP were used, along with actual values of the exogenous variables. However, alfalfa production forecasted from the acreage response relations replaced actual alfalfa production. Model results were then compared to reported prices as in the static test (see Table 8).

Table 8. Dynamic Forecast Test Comparing Actual and Estimated Regional Alfalfa Prices for 1983 to 1986[a]

Region/ Market[b]	1983 Actual	1983 Model	1984 Actual	1984 Model	1985 Actual	1985 Model	1986 Actual	1986 Model
	Prices Received in Model Regions							
1	103.99	116.55	84.36	109.79	87.17	95.60	74.62	85.78
2	105.00	108.98	85.00	102.31	90.00	89.89	90.00	81.61
3	110.58	108.98	84.53	102.31	87.70	89.89	84.04	81.61
4	105.00	108.98	84.00	102.31	88.90	89.55	83.60	81.41
5	115.63	100.71	95.69	99.08	96.86	87.53	90.00	80.19
6	107.00	97.54	80.00	91.00	90.00	78.97	83.00	74.98
7	96.50	97.01	85.00	90.47	77.70	77.62	83.00	74.46
8	92.50	93.67	85.00	87.17	82.40	75.27	75.00	72.74
9	98.47	95.61	80.00	89.08	74.00	76.28	75.00	73.64
10	93.19	91.91	84.06	85.43	84.70	73.25	83.00	71.52
11	110.27	98.60	95.00	92.04	103.00	78.46	85.00	75.38
12	93.36	88.39	90.85	87.00	84.60	68.72	81.93	69.46
13	88.93	86.04	90.00	76.90	63.25	63.85	74.24	66.50
14	85.19	91.73						
15								
16	93.91	90.68	81.75	85.55	79.60	76.61	78.33	73.56
17	102.87	117.61	92.63	112.17	95.25	102.32	94.04	89.16
18	95.00	108.10	95.00	102.77	82.35	93.25	84.76	83.65
19	100.00	110.57	89.99	105.21	80.00	95.60	89.99	85.08
20	97.77	111.62	80.65	106.25	83.64	90.67	76.20	83.87
21	100.00	106.34	85.00	101.41	80.00	85.85	75.00	79.86
22	95.92	72.58	84.65	88.39	85.04	51.97	77.16	84.39
23	229.41	110.92	90.24	104.22	90.09	90.89	91.54	82.52
24	106.75	102.29	104.81	95.70	96.64	81.99	91.77	77.52
25	89.45	78.71	83.00	72.38	86.00	59.48	64.62	63.85
	Prices Paid in Market Areas 1-4 and Prices Received in Market Areas 5-14							
1	114.72	116.01	109.44	109.99	105.86	96.41	92.17	86.48
2	113.61	111.62	102.71	105.65	106.53	93.49	94.90	84.10
3	132.58	126.40	116.09	120.26	114.12	107.64	109.07	92.61
4	133.28	133.96	114.61	127.74	111.89	113.54	107.41	96.89
5	89.23	78.71	83.40	72.38	80.13	59.48	66.50	63.85
6	92.78	91.91	85.67	85.43	87.01	73.25	76.34	71.52
7	90.92	94.23	77.07	87.81	84.29	75.66	71.91	73.02
8	90.13	97.14	73.98	90.59				
9					84.06	77.62		
10					89.69	77.93	84.11	74.57
11	112.04	100.71	96.40	99.08	96.78	87.53	87.89	80.19
12	120.36	108.98	100.40	102.31	98.42	89.79	92.26	81.55
13	120.36	108.98	100.40	102.31	80.11	89.89	92.34	81.61
14	118.38	111.62	94.34	106.25	96.67	90.67	90.60	83.87

[a]See text for description of computation procedures.
[b]Model regions are defined in Table 1. Market regions are defined according to FSMNS *Alfalfa Hay: California Market Summary*:

1 = Chino
2 = Tulare-Visalia-Hanford
3 = Escalon-Modesto-Turlock
4 = Petaluma
5 = Imperial Valley
6 = Kern
7 = Hanford-Corcoran-Tulare
8 = Fresno-Kern-Madera
9 = Fresno-Kern
10 = West Fresno-Madera
11 = Los Banos-Dos Palos
12 = Tracy-Patterson
13 = Stockton Delta
14 = Sacramento Valley

Table 9 reports the statistical results of the comparison. Annual average forecast errors for price received range from 6 to 14 percent with a four-year average of 9 to 10 percent, depending on the base of comparison. Annual average forecast errors for prices paid range from 2 to 12 percent with a four-year average of 6 percent. With two exceptions, the forecast errors generally increase with time. Overall, test results suggest that the model's level of accuracy is reasonable, especially when using it, not to forecast, but to analyze relative changes in the alfalfa market due to changes in agricultural and resource policies.

Table 9. Dynamic Forecast Tests of the Spatial Equilibrium Model[a]

	1983	1984	1985	1986	1983-86 Average
	percent				
Prices received					
County	6.5	10.2	12.0	7.0	8.9
Producing region	7.8	10.9	14.1	7.0	9.9
Prices paid	2.5	3.9	7.9	11.7	6.5

[a]Values are the average of the absolute percentage forecast errors in each region, weighted by the predicted quantity produced in the respective regions. Alfalfa production is calculated using alfalfa acreage response functions.

Market Structure

After the calibration/verification runs, the model was updated. Demand and acreage response relations were re-estimated using data through 1986. The exogenous variables were set at average 1984-86 values, and the model was re-calibrated using the same procedure as before. The estimated MRKUP value was $22 per ton.

Alfalfa acreage and price dynamics are illustrated in Figures 7 and 8. With 1986 as the base year, the model is run for 99 years for convergence to a long-run equilibrium. With 1986 initial conditions, alfalfa acreage declines to a long-run equilibrium of 967 thousand acres. Long-run equilibrium average prices paid and prices received predicted by the model are $105 per ton and $85 per ton, respectively. This compares to average 1984-86 actual values of 1043 thousand acres for area, $107.07 per ton for average prices paid, and $81.97 per ton for prices received. The model therefore predicts a very slight decrease in long-run alfalfa acreage if conditions were to remain as in 1984-86, with prices 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. Alfalfa shipments among regions in the long-run are given in Table 10.

Fifty percent increases/decreases in initial acreage levels were imposed. In both cases, the market responded fairly quickly with long-run equilibrium being reached in approximately 25 years; 90 percent of long-run equilibrium was reached in approximately five years. With a 50 percent increase in initial acreage, long-run equilibrium acreage was 2 percent greater than the base long-run equilibrium acreage, while average prices paid declines by a little less than 2 percent. The reverse occurred with a 50 percent decrease in initial acreage. Thus, the model appears to converge to multiple equilibria depending on the initial conditions. However, the imposed changes in initial acreage were severe, and the resultant differences in long-run equilibrium small.

Table 11 reports the elasticities of alfalfa area and average prices paid with respect to changes in various exogenous variables when all endogenous variables are allowed to change. These arc elasticities were generated by running the model with plus and minus 20 percent changes in each of the indicated exogenous variables.[6] All the elasticities in Table 11 have an absolute value less than one. Increases in horse numbers, the feed cost index, and the livestock price index increase area and alfalfa prices in both the short- and long-run. Increases in the producer cost index and cost of competing crops decrease area and increase prices in both the short- and long-run. An increase in the transportation cost index decreases area in the short- and long-run, and increases prices paid in the short- and long-run.

[6]Arc elasticities are computed here as

$$\frac{(Y_2 - Y_1)/[(Y_1 + Y_2/2)]}{(X_2 - X_1)/[(X_1 + X_2)/2]}$$

where Y_i is the value of the endogenous variable (area or price), X_i is the value of the exogenous variable, i=1 is the value at the 20 percent decrease in the exogenous variable, and i=2 is the value at the 20 percent increase in the exogenous variable.

Figure 7. Forecasted Alfalfa Area in California Under Base Conditions and Under a 50 Percent Increase and a 50 Percent Decrease in Initial Area

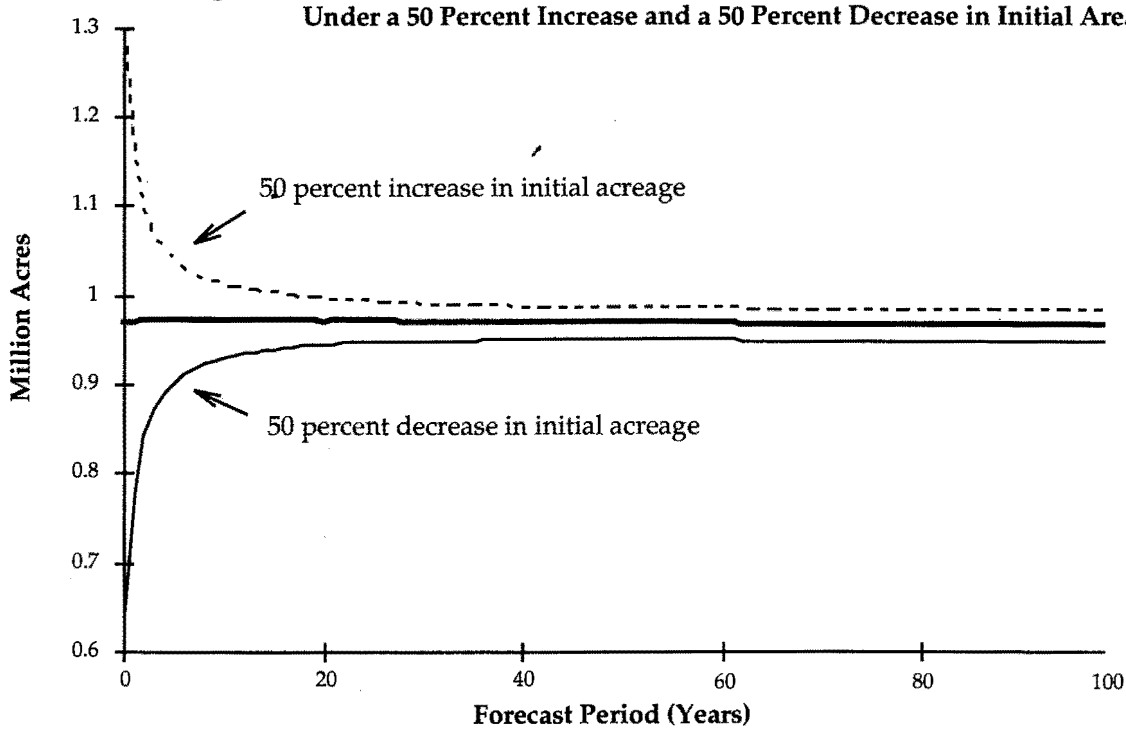


Figure 8. Forecasted Average Alfalfa Price Paid Under Base Conditions and Under a 50 Percent Increase and a 50 Percent Decrease in Initial Area

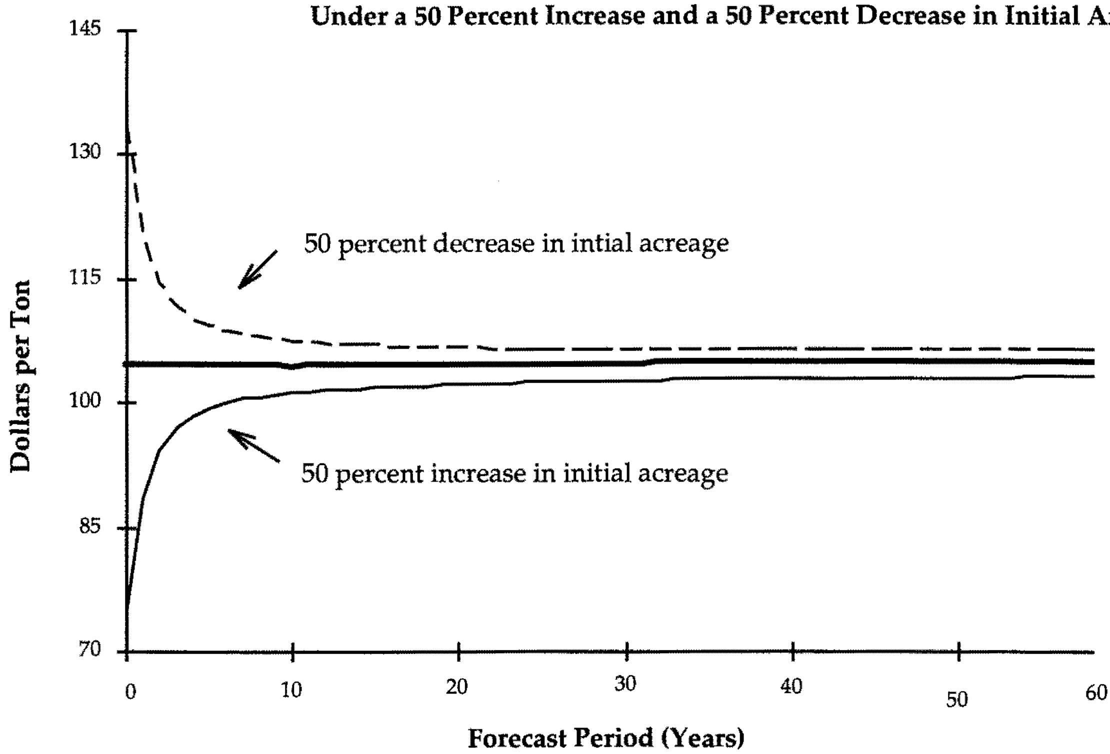


Table 10. Alfalfa Interregional Trade Flows in Long-Run Equilibrium, Base Run

Source Region: Number	Source Region: Name	Destination Region: Number	Destination Region: Name	Quantity (1000 tons/year)
7	Fresno	23	Central Coast	237
8	Tulare	2	Sacramento	125
		3	San Joaquin	32
		6	Madera	103
9	Kings	23	Central Coast	89
10	Kern	1	Petaluma	94
		2	Sacramento	5
		4	Stanislaus	173
		23	Central Coast	24
12	San Bernardino	11	Los Angeles	43
13	Riverside	11	Los Angeles	104
16	Mountain	17	North Coast	171
		18	Trinity	13
		19	Yuba	14
20	Sacramento Valley	1	Petaluma	15
		19	Yuba	32
21	Solano	1	Petaluma	12
25	Imperial	1	Petaluma	92
		11	Los Angeles	328
		14	San Diego	123
		15	Orange	55
		24	South Coast	263

As would be expected, Table 11 shows that the area response is greater in the long-run than in the short-run, but 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 than short-run effects on alfalfa prices.

The previous runs assume constant alfalfa yields over time. From the previous discussion, statewide alfalfa yields have been steadily increasing at an average rate of .054 tons per year. The alfalfa model was rerun assuming annual increases in yields of .054 tons per year, but all other exogenous variables at base levels. The effects were quite substantial. Area decreased over time from 969 thousand acres in the first forecast year to 858 thousand acres in year 99. Production increased from 6.7 to 10.1 million tons per year, average price paid dropped from $104 per ton to $55 per ton, while average price received dropped from $84 per ton to $35 per ton. Thus, continued improvements in alfalfa yields at past rates could have dramatic effects on the alfalfa market in the long-run.

Table 11. Estimated Short-Run[a] and Long-Run[b] Elasticities for Alfalfa Area and Average Price Paid in the Dynamic Spatial Equilibrium Model with Respect to Major Exogenous Variables

	Area		Average Price Paid	
Variable	Short-Run	Long-Run	Short-Run	Long-Run
TCINDX [c]	-.03	-.07	.02	.05
THORS [d]	.03	.10	.21	.15
FCINDX [e]	.08	.23	.43	.32
LPINDX [f]	.08	.21	.41	.30
PCINDX [g]	-.11	-.19	.10	.16
CCINDX [h]	-.07	-.13	.06	.11

[a]Period 2 for prices and acreage.
[b]Period 99 for acreage and prices.
[c]Transportation cost index used to adjust inter-regional shipment costs for alfalfa.
[d]Total number of horses in California.
[e]Index for livestock feed prices other than alfalfa.
[f]Index for livestock prices.
[g]Cost of production index.
[h]Index for total revenue per acre from growing competing crops.

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), initiating 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 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, federal government policies concerning pricing and allocation of water have been subject to increasing criticism. The price the USBR charges its contracting water districts is less than it costs the government to provide the water. Critics argue that the difference is a direct subsidy that adds to the federal budget burden, benefits farmers in one region of the country at the expense of other farmers, and leads to further government subsidies as federal water is used in growing crops that are in surplus. Federal water policies are also criticized for misallocation of this scarce resource due to rigid water rights laws such that the water does not always go to the highest bidder.

A proposed solution to the subsidy problem is increasing the price of USBR water to its full cost. As farm subsidies persist and demand for water increases, legislation seeking to raise the price of federal water can be expected. In this section the impact of reducing federal irrigation water subsidies (increasing the price of federal water) on the price and acreage of alfalfa hay in California is investigated.

Alfalfa is a water-intensive crop, receiving up to 7 acre-feet per acre per year of irrigation water in some areas of the state. In 1986, some 43 percent 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, the average subsidy, ranges from $1.31 to $78.54 per acre-foot. Some argue that the subsidy is generally underestimated because the USDI uses interest rates below the government's borrowing costs in calculating the cost of constructing its various projects (Gejdenson, 1988). Because the subsidy levels vary widely depending on the region and 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.[7] Because the reliance on USBR water varies from region to region, the water price increase was multiplied by the ratio of alfalfa acreage receiving USBR water to total alfalfa acreage in each region. The result was then multiplied by the respective region's alfalfa water use coefficient and subtracted from the total alfalfa revenue in the acreage response equation. The effects on California alfalfa acreage and price paid are shown in Figure 9. These estimated impacts on alfalfa acreage and prices 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 USBR water increases. In the short-run, alfalfa acreage decreased by 6.4 thousand acres and the price paid increased by 67 cents per ton for each $10 increase in the price of USBR water. Figures for the long-run are 8.3 thousand acres and 84 cents per ton, respectively.

While the statewide impacts of increases in the USBR water price on alfalfa prices and acreage are fairly small, regional impacts could be substantial. Some regions rely heavily on USBR water, and water is a significant portion of their variable costs. Regional long-run equilibrium acreage and prices paid are given in Table 12 for alternate increases in the price of USBR water. For example, in the Imperial region the $100 per acre-foot increase in the price of federal water resulted in a 21 percent decrease in the long-run acreage. (The comparable statewide figure is 9 percent.)

Federal Dairy Policy

The federal government, through its dairy support programs, plays a key role in the determination of milk price and herd size nationally. The level of price supports is established by legislation with new laws passed in response to changing conditions in the dairy industry. For example, in response to an increasing surplus of milk, the Food Security Act of 1985 mandated lowering the support price by 50 cents per cwt on January 1 of each year from 1988 through 1990 if the government's purchase of milk is forecast to exceed 5 billion pounds in the coming year. Another example is the federal dairy herd buy out program intended to reduce the size of the nation's dairy herd. Another potential impact on the nation's herd size is the anticipated approval by the Food and Drug Administration of bovine growth hormone BST, which increases milk production per cow (USDA, 1987). In this section the impact of changes in the dairy herd size

[7]These are increases from the prices of USBR water implicit in the base run.

Figure 9a. Impact of Increasing Water Prices on California Alfalfa Acreage

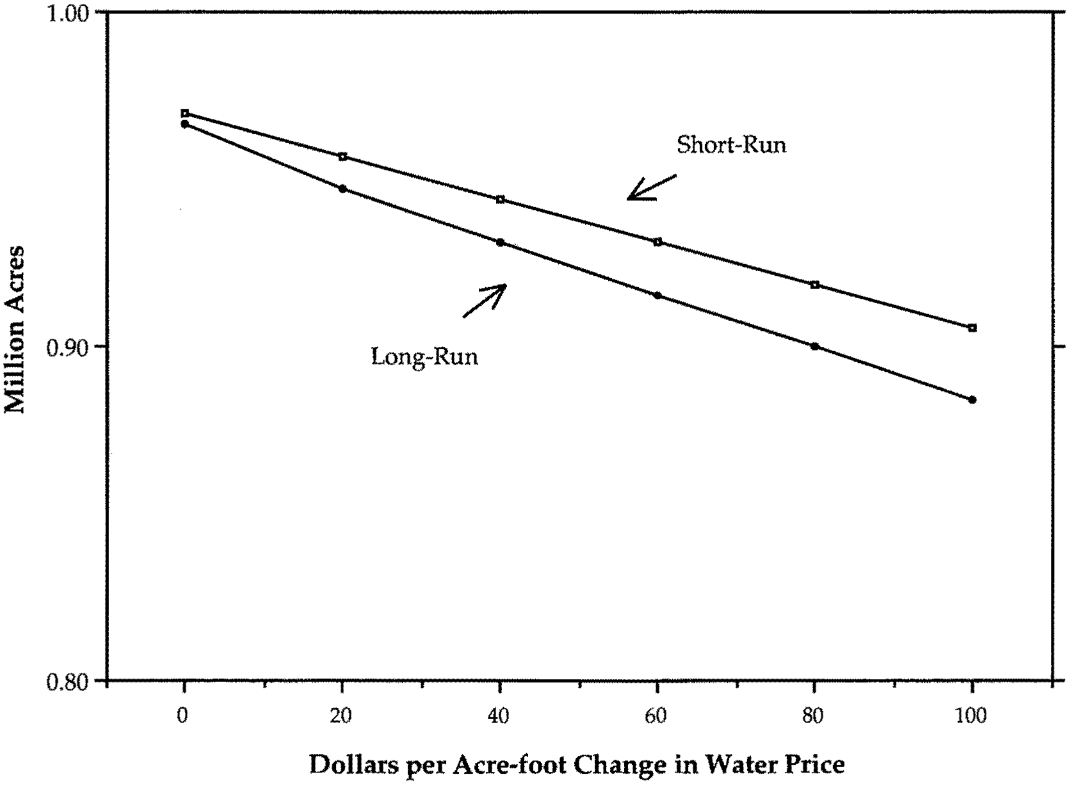


Figure 9b. Impact of Increasing Water Prices on California Prices Paid for California Alfalfa

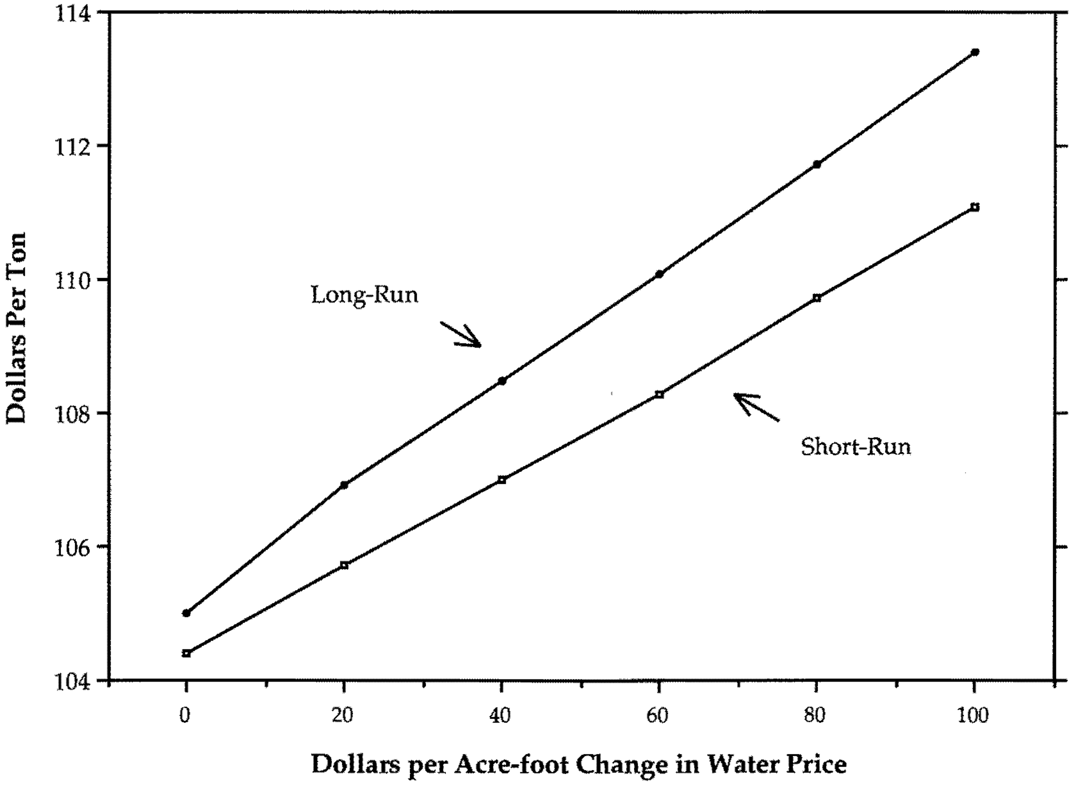


Table 12. Regional Alfalfa Area and Price Paid in Long-Run Equilibrium with Increases in the Price per Acre-Foot of USBR Water

Region number	No Increase		$30 Increase		$50 Increase	
	Area (10^6 acres)	Price paid ($/ton)	Area (10^6 acres)	Price paid ($/ton)	Area (10^6 acres)	Price paid ($/ton)
1	2.17	121.08	2.17	123.96	2.17	125.70
2	10.26	115.01	10.81	117.89	11.13	119.63
3	62.65	115.01	62.65	117.89	62.65	119.63
4	25.02	114.72	23.77	117.60	22.80	119.33
5	59.87	109.26	57.66	112.14	56.19	114.05
6	4.64	115.01	0.00	117.89	0.00	119.63
7	83.80	104.65	83.80	107.53	83.80	109.27
8	83.06	102.14	81.25	105.02	79.98	106.75
9	33.26	103.47	33.17	106.35	33.01	108.09
10	81.71	100.36	79.46	103.24	77.76	104.98
11	0.00	105.98	0.00	108.86	0.00	110.60
12	25.16	97.40	25.54	100.28	25.76	102.02
13	46.15	93.11	46.19	95.99	46.20	97.73
14	0.00	100.21	0.00	103.09	0.00	104.83
15	0.00	103.91	0.00	106.79	0.00	108.53
16	147.72	99.62	148.88	102.50	149.34	103.94
17	1.14	122.26	1.14	125.14	1.14	126.59
18	0.02	114.27	0.02	117.15	0.02	118.59
19	0.86	116.34	0.86	119.22	0.86	120.67
20	68.50	110.13	62.96	113.01	59.11	114.75
21	12.34	112.50	12.17	115.38	12.05	117.11
22	18.69	94.62	18.69	94.62	18.69	94.62
23	11.43	116.34	11.43	119.22	11.43	120.96
24	12.82	109.09	12.82	111.97	12.82	113.71
25	175.43	89.26	164.19	92.14	156.59	93.88

in California on the state's alfalfa acreage and price is investigated.

Nearly 60 percent of alfalfa output in California goes to the state's dairy industry. In each demand region, dairy herd size is varied between plus and minus 50 percent at 10 percent intervals and the model is solved for the short- and long-run. Results of a decreasing herd size are shown in Figure 10. For every 10 percent increase (decrease) in dairy herd size, the statewide short-run acreage and the price paid increases (decreases) by 3.8 thousand acres and $2.16, respectively. Figures for the long-run are 10.2 thousand acres and $1.58, respectively. Regional impacts in the long-run are given in Table 13. There do not appear to be strong differential impacts among the regions resulting from the assumed changes in dairy herd size.

Federal Cotton Program

Alfalfa competes with cotton for land in many production regions in California. During 1954-1972, federal cotton programs included acreage allotment and set-aside, with the intent of reducing cotton acreage. During this period, California alfalfa acreage was, on average, 112 thousand acres higher and the price was $4.60 lower per ton than their average levels at other times. This section discusses the impact of a reintroduction of the cotton acreage allotment and set-aside programs on the short- and long-run acreage and price of alfalfa in California.

Recall that the cotton programs were included in the model by assigning a value of one to a dummy variable in the acreage response equations for 1954-1972, and a value of zero otherwise. To simulate the reintroduction

Figure 10a. Impact of Changes in Dairy Herd Size on California Alfalfa Acreage

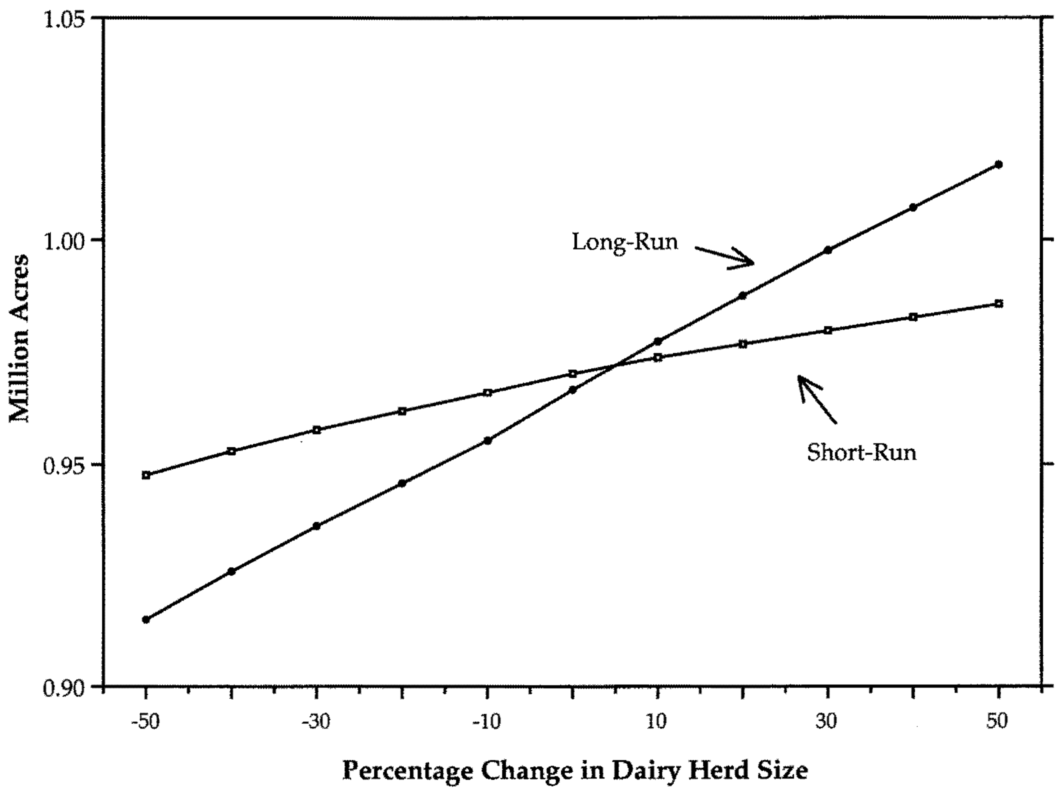


Figure 10b. Impact of Changes in Dairy Herd Size on Prices Paid for California Alfalfa

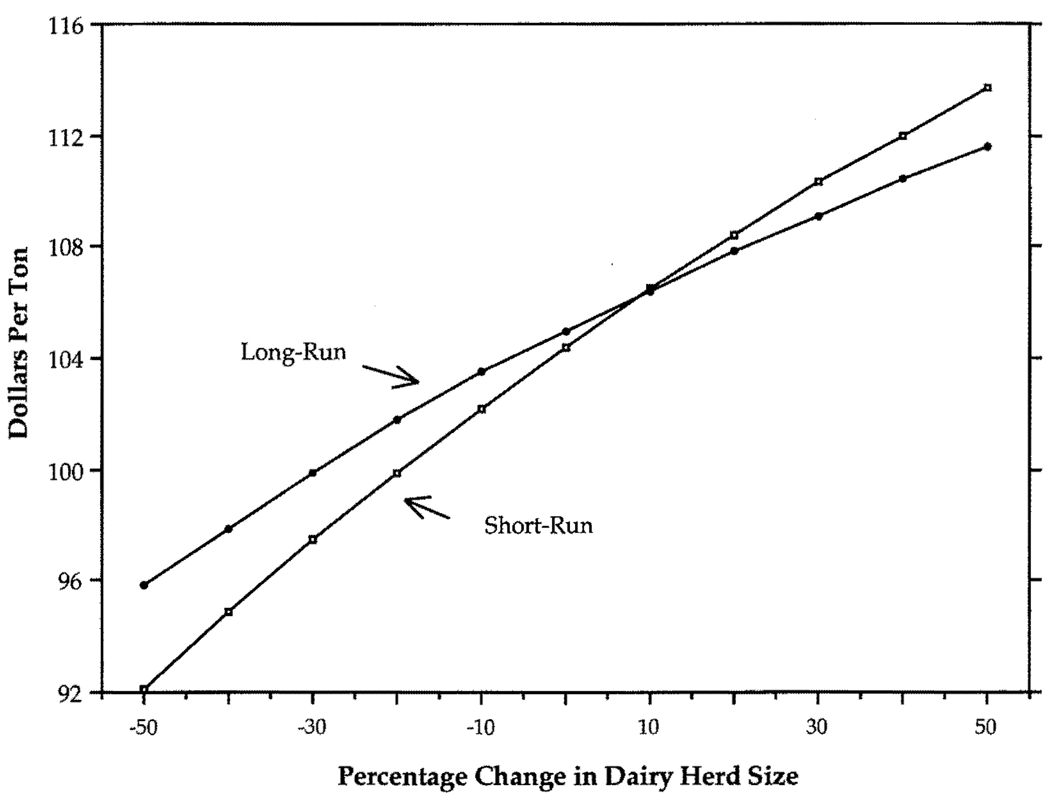


Table 13. Regional Alfalfa Area and Price Paid in Long-Run Equilibrium with Alternate-Sized Cattle Herds

Region number	20% decrease in cattle numbers: Area (10^6 acres)	20% decrease in cattle numbers: Price paid ($/ton)	Base level of cattle numbers: Area (10^6 acres)	Base level of cattle numbers: Price paid ($/ton)	20% increase in cattle numbers: Area (10^6 acres)	20% increase in cattle numbers: Price paid ($/ton)
1	2.17	118.04	2.17	121.08	2.17	123.79
2	9.56	111.97	10.26	115.01	10.82	117.43
3	62.65	111.97	62.65	115.01	62.65	117.43
4	22.92	111.68	25.02	114.72	26.90	117.43
5	58.72	105.81	59.87	109.26	60.92	112.41
6	0.00	111.97	4.64	115.01	11.03	117.43
7	83.80	101.61	83.80	104.65	83.80	107.36
8	82.15	99.10	83.06	102.14	83.79	104.55
9	31.58	100.43	33.26	103.47	34.75	106.18
10	78.43	97.32	81.71	100.36	84.63	103.07
11	0.00	102.94	0.00	105.98	0.00	108.70
12	24.77	94.36	25.16	97.40	25.51	100.11
13	45.92	90.07	46.15	93.11	46.35	95.82
14	0.00	97.17	0.00	100.21	0.00	102.92
15	0.00	100.87	0.00	103.91	0.00	106.62
16	145.83	96.58	147.72	99.62	149.43	102.33
17	1.14	119.22	1.14	122.26	1.14	124.98
18	0.02	111.23	0.02	114.27	0.02	116.98
19	0.86	113.30	0.86	116.34	0.86	119.06
20	66.11	107.09	68.50	110.13	70.64	112.84
21	12.27	109.46	12.34	112.50	12.40	115.21
22	18.69	88.50	18.69	94.62	18.69	99.97
23	11.43	113.30	11.43	116.34	11.43	119.06
24	12.82	106.05	12.82	109.09	12.82	111.80
25	173.71	86.22	175.43	89.26	176.96	91.97

of the programs, therefore, the dummy variable is set equal to one in 1986 and thereafter, bringing the value of large positive coefficient estimates back into the model. In the short-run, alfalfa acreage increased by 152 thousand acres above the base year level of 970 thousand acres (16 percent) and the price paid declined by $15.20 from the base level of $104.42 per ton (15 percent). This short-run increase in acreage is similar in magnitude to the average change in acreage during the 1954-1972 period when the cotton programs were in effect. However, the predicted decrease in price is somewhat larger than the observed change during that period, due in part to inflationary differences between the two periods. Relative to base year levels, the long-run equilibrium acreage increased by 211 thousand acres (22 percent) and the price paid declined by $20.92 (20 percent). In summary, the cotton programs have potential to make a large impact on California's alfalfa market.

Conclusions

A spatial equilibrium model of the California alfalfa market was constructed that estimates alfalfa shipments among regions and simulates values of endogenous variables over a number of years. Out-of-sample forecast tests for individual components and for the entire model were made. Static forecast tests using actual values of acreage and exogenous variables resulted in 1983-86 average errors of 9 to 10 percent for regional alfalfa prices received depending on the source of comparison, and 7 percent for regional prices paid. Values of 9 to 10 and 6 percent, respectively were reported for the dynamic forecast test which used forecasted rather than actual alfalfa acreage. Overall, the tests determined that the model was sufficiently accurate to analyze the economics of the alfalfa market and its response to changing policies.

Results suggest that the California alfalfa market is fairly close to long-run equilibrium. Large changes in acreage starting values resulted in a moderately quick return to long-run equilibrium. Elasticities of alfalfa price and acreage with respect to changes in various exogenous variables had 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 feed cost and price of livestock products in the long-run. Annual yield increases continued at the historical rate of .054 tons per acre per year have significant effects on the alfalfa market. Over a 99 year period, area decreased by 11 percent, production increased by 51 percent, and average price paid dropped by 58 percent.

The effect of plausible changes in federal water rates to reduce subsidies had only a moderate impact on the statewide alfalfa market. However, there would be significant reductions in acreage in regions relying heavily on federal water if rates were raised substantially.

Reduction in the size of California's dairy herds due to changes in federal programs or in technology would have fairly small impacts on the California alfalfa market. Apparently demand is sufficiently price-elastic to absorb the extra hay resulting from reduced dairy herds with only moderate price decreases. These moderate price decreases combined with price-inelastic supply response result in small reductions in acreage.[8]

Changes in the cotton program had significant implications for the alfalfa market. If the program existing during 1954-1972 were re-instituted, alfalfa acreage would increase by 16 percent in the short-run and 22 percent in the long-run, according to model forecasts. Prices paid would decline 15 percent and 20 percent during the short- and long-run, respectively.

[8]The weighted average elasticity of alfalfa acreage with respect to alfalfa total revenue per acre is .64 in the long-run, where the weights are regional quantity produced and the evaluation is carried out at 1982 levels of acreage and total revenue.

APPENDIX

CALIFORNIA ALFALFA DEMAND

Konyar and Knapp (1986) extensively analyzed demand for California alfalfa hay. In this study, we extended this analysis to a simultaneous equations model. The new model consists of equations for alfalfa demand, net imports, carryovers, yields, and a closing identity. Estimation of demand in the context of a simultaneous model provides improved estimates over those from the previous research.

Statewide alfalfa demand is defined as:

$$TCONS_t = a_0 + (a_1 + a_2\,PALF_t + a_3\,LPINDX_t + a_4\,FCINDX_t)\,TCAT_t \qquad (A1)$$

where $TCONS_t$ is annual alfalfa consumption (million tons) in California, $PALF_t$ is the price paid for alfalfa by livestock producers ($ per ton), $LPINDX_t$ is an index for livestock prices, $FCINDX_t$ is an index for livestock feed prices other than alfalfa, and $TCAT_t$ is the number of beef and dairy cattle in California. The interpretation and motivation for (A1) is given in the main text.

Alfalfa is both imported from other states and exported to other countries from California, although these flows are relatively small compared to the overall market in the state. Imports tend to be baled hay and hay cubes, while exports are typically in the form of hay cubes, meal, and pellets. Alfalfa imports generally exceed exports so that net imports of alfalfa to California are generally positive. From economic theory, imports of a commodity into a region depend on transport costs and the price differential between regions for that commodity. Net imports into a region increase when the price in the region increases, when the price in other regions decreases, or when transport costs decrease. Based on these considerations, and after some experimentation, the net import function was specified as:

$$NETIMP_t = b_0 + b_1(PALF_t/TCINDX_t) + b_2\,(APIOWS_t/TCINDX_t) + e_{2t} \qquad (A2)$$

where $NETIMP_t$ are net imports of alfalfa to California (million tons), $APIOWS_t$ is an index for alfalfa prices in other western states, $TCINDX_t$ is a transportation cost index, and e_{2t} is an error term. The index $APIOWS_t$ is calculated as a weighted average of alfalfa prices in Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming where the weights are quantities produced and the data source is USDA *Agricultural Statistics*. The transportation cost index $TCINDX_t$ was computed from an energy cost index and an index for wages in the transportation industry using data from the *Statistical Abstract of the United States*. In general, net imports of alfalfa to California increase as California alfalfa prices increase, alfalfa prices in other western states decrease, or transport costs decrease.

Carryover stocks are also included as an endogenous variable in the model. Alfalfa supplies in year t depend, in part, on carryovers into year t. Carryovers out of year t depend on quantity produced and carryin to year t. Since quantity produced depends on price, carryover is determined simultaneously with price and consumption. The alfalfa carryover stock function is specified as:

$$STK_{t+1} = c_0 + c_1\,QPROD_t + c_2\,STK_t + e_{3t} \qquad (A3)$$

where $QPROD_t$ is California alfalfa production in year t (million tons), STK_t is May carryover stocks in year t, and e_{3t} is an error term. This specification is based on the flexible accelerator model in Labys (1973). In general, carryout stocks are expected to increase as production and carryin stocks increase.

Alfalfa growers can respond to changes in current prices by changing the levels of variable inputs such as water and fertilizer, and by increasing the number of cuttings during the year. Thus yields are potentially determined simultaneously with alfalfa prices. Alfalfa yields exhibit a strongly increasing trend over time due to technological change. Yields may also be affected by the aggregate land area devoted to the crop since increases in aggregate alfalfa acreage will tend to result in increased use of land less suited for alfalfa production than was previous alfalfa acreage. Various specifications were tried for the yield equation; the specification below was chosen as the best based on R^2 values, correct signs, and significance of the coefficients:

$$YLD_t = d_0 + d_{1t} + d_2\,AREA_t + d_3\,(PALF_t/CPI_t) + d_4\,(PCINDX_t/CPI_t) + e_{4t} \qquad (A4)$$

where $AREA_t$ is total alfalfa area in California in year t, $PALF_t$ is alfalfa price in year t, $PCINDX_t$ is a USDA production cost index, and CPI_t is the consumer price index used to deflate $PALF_t$ and $PCINDX_t$.

The model is closed by:

$$TCONS_t = QPROD_t + NETIMP_t - (STK_{t+1} - STK_t) \quad (A5)$$

and

$$QPROD_t = YLD_t * AREA_t \quad (A6)$$

where all variables have been defined previously.

Data sources for the model in equations (A1) through (A6) are described in Konyar and Knapp (1986) except as noted above. Because data are available for statewide average prices received by alfalfa growers, but annual average prices paid for alfalfa by livestock producers are available only for selected milk-producing regions, prices received are used instead of prices paid for the initial econometric estimation. The alfalfa hay demand function (A1) was estimated using two-stage least squares. The estimated equations are:

1945-1982 Sample Period

$$\underset{(3.89)^{***}}{TCONS_t = 1689} + (\underset{(5.25)^{***}}{.71} - \underset{(-2.27)^{**}}{.0168\, PALF_t} + \underset{(2.98)^{***}}{.0322\ LPINDX_t} + \underset{(1.68)^{*}}{.0077\, FCINDX_t})\, TCAT_t$$

$R^2 = .80 \quad DW = 2.04$

1945-1986 Sample Period

$$\underset{(4.01)^{***}}{TCONS_t = 1707} + (\underset{(5.53)^{***}}{.73} - \underset{(-1.92)^{**}}{.014\, PALF_t} + \underset{(2.85)^{***}}{.0303\ LPINDX_t} + \underset{(1.38)^{*}}{.0063\, FCINDX_t})\, TCAT_t$$

$R^2 = .83 \quad DW = 1.78$

where t-statistics are in parentheses, * indicates significance at the 10 percent level or better, ** indicates significance at the 5 percent level or better, and *** indicates significance at the 1 percent level or better.

Estimated coefficients have the correct signs and all are significant at the 10 percent level or better; most are significant at the 1 percent level. The root mean squared percentage errors for price forecasts over the sample period were 17 percent and 19 percent for the 1982 and 1986 regressions, respectively. Out-of-sample price forecast errors for the 1982 regression range from -3 percent to 15 percent for 1983-86 with an average of 5.4 percent. The forecast error generally increases with time.

The alfalfa price elasticities for the 1982 and 1986 demand functions are -1.02 and -.84, respectively, when evaluated at 1982 prices and quantities.

The demand functions were converted to a prices-paid basis using a markup value. The markup was calculated as the difference between a statewide index for prices-paid and prices-received in 1982 for the 1982 demand function and in 1984-86 for the 1986 demand function. The resulting demand functions are reported in the text.

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