TEMPORAL ALLOCATION ALTERNATIVES FOR SOUTHEASTERN RED DELICIOUS APPLES

L. R. Motsinger, J. E. Epperson, and W. O. Mizelle, Jr.

Abstract

This study examines the economic feasibility of storing southeastern U.S. Red Delicious apples under various circumstances. Circumstances encompassed type of storage, potential market share in the storage periods, perceived level of quality, and opportunity cost of storage. Reactive programming was used to allocate shipments throughout the harvest and storage periods. Except for apples harvested in August, storage was found to be economically feasible under all situations studied. The greatest economic benefit to producers was shown to come from the synergistic effect of storage and improvement in perceived quality.

Key words: regular cold storage, controlled atmosphere storage, marketing, producer revenue.

The Southeastern States of Georgia, South Carolina, and North Carolina have historically been major suppliers of fresh apples marketed during the first weeks of the new season which begins in August (Mathia and Beals). Both Red and Golden Delicious varieties are available to market in late August and September. Of the two varieties, Red Delicious is the most important, comprising 51 percent of total southeastern apple production (USDA, SRS(b)). Fresh Red Delicious apples from regions competing with the Southeast are generally shipped starting in late September and continue through October (USDA, AMS(a)).

The volume of apples to be marketed is generally low during most of the southeastern harvest period relative to the rest of the year. This supply situation is reflected in relatively high farm prices at the beginning of the season and declining prices as the season progresses. As the harvest season wanes, the price of apples begins to rise again. Given these temporal relationships, the marketing strategy of southeastern growers has been to harvest and market as much of the crop as possible following the earliest acceptable maturity date (Mathia and Beals).

Some storage facilities are available in the region. However, the primary purpose of these facilities has been to remove field heat from fruit and extend the period between packing and marketing during extremely heavy harvesting, packing, and selling periods.

Because of increased production from 1977-1982 and superior marketing and promotional practices, Washington has become established as a constant supplier of apples throughout the year (O'Rourke, 1983; American Fruit Grower (a and b)). This increase in production has led to increased sales of Washington apples in August and a subsequent loss of market share by southeastern growers (USDA, AMS (b)). Growers in the Southeast have been prompted to reassess their strategy of marketing only in the harvest period.

This study will examine the economics of extending the present marketing period for Red Delicious apples produced in the Southeastern United States through alternative means of storage. The objective is to determine whether growers in the Southeast can increase revenue net of storage costs by building and operating storage facilities.

Two types of storage are examined: regular cold storage and controlled atmosphere (CA) storage. Regular cold storage is a type of refrigerated storage that can preserve apples for up to 6 months. To maintain the quality of fruit, storage temperatures must be kept

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The authors are indebted to Charles Safley, Department of Economics, North Carolina State University; Desmond O'Rourke, Department of Agricultural Economics, Washington State University; and Bill Miller, Department of Agricultural Economics, University of Georgia for helpful comments and suggestions on an earlier draft. Special appreciation is extended to Deborah B. Dallas for computational assistance.

at 32 degrees Fahrenheit with a relative humidity of 90 to 95 percent (Childers). Unless the fruit is held at the proper humidity, it will lose moisture and shrivel. Regular CA and rapid CA storage are the most commonly used controlled atmosphere storage methods (*Packer*).

Regular CA storage involves filling the storage room with fruit as soon as possible after harvest, lowering the temperature to 32 degrees Fahrenheit, and reducing the oxygen level to less than 3 percent during a 3-week period. Rapid CA is different than regular CA in that the time of lowering the temperature and oxygen is reduced to 1 week or less.

METHODOLOGY

Reactive programming is used to allocate fixed supplies of southeastern Red Delicious apples to the months of the year that maximize producer revenue net of storage costs. Fixed supplies used in the model are quantities shipped in 1980, a year of record high production in the Southeast.[1] Solution of the model also requires the development of price response functions for each month for southeastern Red Delicious apples as well as the total cost of storage by month.

Feasibility of regular and CA storage is examined in light of alternative circumstances. These circumstances include: two levels of perceived quality, two potential market shares in the storage period, and two levels of the opportunity cost of storage. One perceived quality level is represented by a discounted price for southeastern Red Delicious apples; the other is represented by a potential undiscounted price for southeastern Red Delicious apples which is, in fact, the price of Red Delicious apples for the rest of the United States. Potential market shares include 10 and 20 percent of the U.S. market and alternatives for the opportunity cost of storage are computed at 10 and 15 percent interest for this analysis.[2] Thus, 16 different storage situations are examined (2 types of storage X 2 levels of perceived quality X 2 potential market shares X 2 levels of the opportunity cost of storage). The economics of no storage and the economics associated with the various situations examined are compared so as to draw conclusions and make recommendations.

THE MODEL

REACT, a recent version of the reactive programming procedure developed by Tramel and Seale in the late 1950s, is used for this analysis. It accommodates solution of the temporal allocation problem in this study which encompasses a single homogeneous product, linear demand functions, fixed supplies, and storage costs (King and Gunn). Quadratic programming is also suitable for solution of the problem; however, in this case, reactive programming is easier to use since it is specifically designed to simulate the behavior of a competitive market over time and space (King and Gunn).

The formulation involves one product, M supply periods, and N demand periods where $i = 1, 2, \ldots, M$ and $j = 1, 2, \ldots, N$. Supplies, S_i, from each supply period are fixed ($S_i = K_i$, where K indicates a constant) while temporal price response relationships are defined as:

$$(1)\quad P_j = \alpha_j - \beta_j \sum_i X_{ij},$$

where: α_j and $\beta_j > 0$;

p_j = price in the j^{th} period;

$\sum_i X_{ij}$ = quantity demanded in the j^{th} period; and

X_{ij} = flows from period i to period j.

Let T_{ij} represent the unit cost of storing the product from period i to period j. Total supply (ΣS_i) must be $\geq$ total demand (ΣR_j).

Using Samuelson's concept of net social payoff as a basis for specifying the objective function, the problem can be stated as (Samuelson; Takayama and Judge): maximize

$$(2)\quad f(X) = \sum_j \alpha_j \sum_i X_{ij} - \tfrac{1}{2} \sum_j \beta_j \left(\sum_i X_{ij}\right)^2 - \sum_i \sum_j T_{ij} X_{ij}$$

[1]Based on recent tree surveys, no major increase in supplies of southeastern Red Delicious apples is expected in the near future.

[2]Selected potential market shares in the storage periods may be considered as possible goals.

subject to:

$$X_{ij} \geq 0,\ S_i = K_i, \text{ and } \Sigma S_i \geq \Sigma R_j.^3$$

This formulation ensures that storage does not occur from period i to period j if $P_j - P_i < T_{ij}$. Assumptions of the model are:

1. all units of the product are homogeneous (i.e., with regard to size, variety, and other quality factors),
2. storage is unnecessary within periods,
3. storage costs are uniform per unit of product but not necessarily proportional to time,
4. the market is perfectly competitive,
5. price response functions are linear, and
6. storage is technically feasible (Takayama and Judge; Tramel and Seale).

Price Response Data

Prices for Red Delicious apples were obtained from *National Shipping Point Trends,* a weekly publication, for the period January 1977 through December 1982 (USDA, AMS (a)). Prices for each producing state were averaged by month for a given grade (U.S. Fancy or better) to obtain U.S. prices of Red Delicious apples for each month. Since prices were reported for 40-pound cartons, prices were converted to thousand hundredweight (cwt.) units to match the units in which shipment data were reported.

Quantity data were derived from several sources and expressed in thousand cwt. A straightforward breakdown by variety for apples shipped during all months was not available. For the storage months from November to June, data from the International Apple Institute (IAI) provided accounts of movements of apples by variety. From June through October, the amount of Red Delicious apples shipped was estimated. For June and July, the factor used to estimate quantity was the ratio of Red Delicious apples in storage to total apple holdings on June 1 of each year. For the harvest months of August, September, and October, the ratio of production of Red Delicious apples to total production of all varieties shipped in each month was used to estimate the shipments of Red Delicious apples by state (USDA, AMS (a and b); USDA, SRS (a and b)).

Monthly population estimates were taken from *Population Estimates and Projections* (USDC, Bureau of Census) for 1977-1982. Disposable income was collected from the *Survey of Current Business* (USDC, Bureau of Economic Analysis) on a monthly basis from 1977-1982.

Estimation of Price Response Functions

Ordinary Least Squares (OLS) was used to estimate the price response function for Red Delicious apples. The general form of the relationship for Red Delicious apples by month, and year is:

$$(3)\ P = f(Q, POP, I, P_{t-1}, \underline{D})$$

where P is the nominal price per thousand cwt., Q is the quantity in thousand cwt., I is nominal income per capita, POP is population in hundred thousand people, P_{t-1} is the nominal price per thousand cwt. lagged 1 month, and $\underline{D}$ is a vector of dummy variables.[4] Dummy variables were added to equation (3) to allow price to vary by month and year (intercept shifters) and to allow the relationship between P and Q to vary by month (slope shifters). Independent variables included in the final equation were Q, POP, P_{t-1}, and $\underline{D}$ where $\underline{D}$ encompassed monthly slope shifters for Q. All coefficients in the final equation were significant and had correct signs; all except those for POP and three of the dummy variables were significant at the 0.01 level. The R^2 for the estimated price response equation was 0.67.

Because no data were available on the price response for southeastern apples except at harvest, some assumptions were made to obtain monthly price response functions in nonharvest periods. Using shipment data from the USDA, southeastern shipments averaged 45 percent of total United States shipments in August, 43 percent in September, and 10.4 percent in October from 1977-1981 (USDA, AMS(b)). The slopes of the southeastern price

[3]This formulation is depicted since reactive programming requires price dependent response functions as given in equation (1) (King and Gunn). Quadratic programming can accommodate either price or quantity dependent demand functions (Takayama and Judge). For a detailed description of the iterative solution procedure of the reactive programming algorithm see Tramel and Seale, Tramel, or King and Gunn.

[4]The time dummy variables account for changes in the price index. Nevertheless, estimations represented by equation (3) were also accomplished using deflated prices and income, yielding inferior fits.

TABLE 1. MONTHLY PRICE RESPONSE FUNCTIONS FOR UNITED STATES AND SOUTHEASTERN RED DELICIOUS APPLES; 1977-1981

Market month	United States		Southeast[a]		
	Intercept	Slope	Intercept	Ten percent market share slope	Twenty percent market share slope
	dollars per 1,000 cwt.				
August	30,437.90	−8.32	22,922.90	−18.49	−18.49
September	28,712.54	−4.25	21,197.54	− 9.88	− 9.88
October	26,181.24	−3.61	18,666.24	−34.75	−34.75
November	25,617.24	−2.04	18,102.24	−20.41	−10.21
December	26,000.81	−2.06	18,485.81	−20.55	−10.28
January	25,896.84	−2.55	18,381.84	−25.47	−12.74
February	25,670.14	−1.85	18,155.14	−18.50	− 9.25
March	26,731.68	−1.79	19,216.68	−17.88	− 8.94
April	27,207.52	−2.74	19,692.52	−27.40	−13.70
May	27,139.02	−2.17	19,624.02	−21.65	−10.82
June	27,978.92	−2.67	20,463.92	−26.68	−13.34
July	28,861.38	−2.36	21,346.38	−23.61	−11.81

Note: Quantities used in estimation were in units of 1,000 cwt.
[a]Southeastern slope values do not change within the harvest months of August, September, and October (as shown) since actual market shares of 45.0, 43.0, and 10.4 percent, respectively, were used.

response functions for the harvest periods were assumed to be the slopes of the United States price response functions divided by the percentages of southeastern Red Delicious apples shipped during the harvest periods. During the storage periods two potential market shares were used, 10 and 20 percent, to obtain slopes for southeastern Red Delicious apple functions in the nonharvest months. The procedure used in this analysis to obtain price response functions for southeastern Red Delicious apples, given potential alternative market shares, was similar to that used by Mathia and Brooker.[5] Monthly price dependent functions for the United States and southeastern Red Delicious apples are presented in Table 1 with southeastern price response coefficients presented by potential market share.

A null hypothesis was formulated which states that there is no difference in domestic monthly average prices of Red Delicious apples by source (Southeast versus rest of the United States) during the harvest periods of August, September, and October for 1977-1981. A "t" test was applied and found to be highly significant. Therefore, the null hypothesis was rejected. Since the difference appeared highly significant, the intercept of the United States price response function was discounted by the average difference in price during the harvest periods for 1977-1981. This difference amounted to $7,515 per thousand cwt. or $3 per bushel.[6]

Cost of Storage

Cost of storage was based on the 1974 study by Lee and Jack. Individual components of variable and fixed costs were factored by the appropriate prices paid index (buildings, wages, interest, other machinery and implements and taxes) to account for changes in cost due to macroeconomic forces (USDA, SRS(c)). The average southeastern price of electricity for each year was used while average U.S. price for LP gas for each year was used for 1977-1982. The efficiency of refrigeration equipment was assumed to be the same as for the 1974 study.[7] Total cost, excluding opportunity cost, for the first month of storage in a 100,000 carton storage facility was $1,952 per thousand cwt. for CA and $1,718 per thousand cwt. for regular storage. Each subsequent month of CA storage incurs an additional cost of $118 per thousand cwt.

[5]Other approaches for deriving monthly price response functions for southeastern Red Delicious apples require direct estimation of a price response function for the harvest periods and projection of the relationships in some manner to the storage periods or a mix of direct estimation for southeastern Red Delicious apples in the harvest periods and the approach described in the text. The procedure used in this study seemed more straightforward and consistent than these alternatives.

[6]There is some suspicion that the prices of southeastern apples and the prices of apples for the rest of the United States begin to diverge in the latter part of the southeastern harvest season. The data were not conclusive regarding such suspicion; thus, this issue was not addressed in the analysis.

[7]Reportedly, increased insulation has reduced electricity usage less than 10 percent since 1974, Extension Food Science, University of Georgia.

Table 2. Producer Revenue, Net of Storage Cost, by Market Share, Type of Storage, Price, and Opportunity Cost of Storage, Southeastern Grown Red Delicious Apples

Item	Net gain in producer revenue	
	10 percent OC	15 percent OC
	(mil. $)	
10 percent market share		
Regular storage		
Discounted price	24.87	24.72
Undiscounted price	37.28	36.93
CA storage		
Discounted price	25.65	25.39
Undiscounted price	37.77	37.16
20 percent market share		
Regular storage		
Discounted price	25.92	25.74
Undiscounted price	38.25	37.82
CA storage		
Discounted price	26.46	26.16
Undiscounted price	38.48	37.78

Note: OC is opportunity cost. Discounted price is for southeastern apples while undiscounted price is for the rest of the United States.

and each subsequent month of regular storage incurs an additional cost of $71 per thousand cwt. Opportunity costs of storage were calculated using prices given by estimated price response equations using estimated shipments from 1980 of 377.8, 1,053.5, and 271.54 thousand cwt. for the harvest months of August, September, and October, respectively.

RESULTS

Results of the analysis are summarized in tables 2-4. Additional tables, derived from Table 2, are used to show the effects of storage of southeastern Red Delicious apples on producer revenue by situation examined, tables 5-8.

Table 3. Optimum Shipping Patterns for Southeastern Grown Red Delicious Apples with Regular Storage by Market Share, Opportunity Cost of Storage, and Price

Item	Shipping month							
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar
	(1,000 cwt.)							
10 percent market share								
10 percent OC of storage								
Discounted price	378	710	123	96	106	74	82	136
Undiscounted price	378	741	130	100	104	69	68	112
15 percent OC of storage								
Discounted price	378	723	124	97	105	72	76	127
Undiscounted price	378	770	136	104	103	64	55	92
20 percent market share								
10 percent OC of storage								
Discounted price	378	632	98	116	137	88	81	174
Undiscounted price	378	668	109	128	138	81	57	144
15 percent OC of storage								
Discounted price	378	645	102	120	136	84	69	169
Undiscounted price	378	703	116	142	141	76	37	110

Note: OC is opportunity cost. Discounted price is for southeastern apples while undiscounted price is for the rest of the United States.

Table 4. Optimum Shipping Patterns for Southeastern Grown Red Delicious Apples with Controlled Atmosphere Storage by Market Share, Opportunity Cost of Storage, and Price

Item	Shipping month											
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
	(1,000 cwt.)											
10 percent market share												
10 percent OC of storage												
Discounted price	378	653	104	54	62	37	29	77	59	63	74	113
Undiscounted price	378	704	119	68	71	40	25	67	49	44	54	85
15 percent OC of storage												
Discounted price	378	675	107	60	66	39	28	73	55	55	66	102
Undiscounted price	378	753	130	82	80	43	23	58	39	26	35	85
20 percent market share												
10 percent OC of storage												
Discounted price	378	591	86	48	65	28	0	86	75	69	103	174
Undiscounted price	378	650	103	84	88	38	0	74	59	38	68	124
15 percent OC of storage												
Discounted price	378	616	90	63	75	32	0	81	69	56	88	154
Undiscounted price	378	705	116	118	112	48	0	64	44	8	35	76

Note: OC is opportunity cost. Discounted price is for southeastern apples while undiscounted price is for the rest of the United States.

Table 5. Improvement in Net Producer Revenue Attributable to Storage by Market Share, Type of Storage, Price, and Opportunity Cost of Storage; Southeastern Grown Red Delicious Apples

Item	Net gain in producer revenue			
	10 percent OC		15 percent OC	
	(mil. $)	(pct.)	(mil. $)	(pct.)
10 percent market share				
Regular storage				
Discounted price	5.0	25.0	4.8	24.3
Undiscounted price	17.4	87.4	17.0	85.7
CA storage				
Discounted price	5.8	29.0	5.5	27.7
Undiscounted price	17.9	89.9	17.3	86.8
20 percent market share				
Regular storage				
Discounted price	6.0	30.3	5.8	29.4
Undiscounted price	18.4	92.3	17.9	90.1
CA storage				
Discounted price	6.6	33.0	6.3	31.5
Undiscounted price	18.6	93.5	17.9	89.9

Note: OC is opportunity cost. Discounted price is for southeastern apples while undiscounted price is for the rest of the United States.

Table 6. Improvement in Net Producer Revenue from Controlled Atmosphere Storage Relative to Regular Storage by Market Share, Type of Storage, Price, and Opportunity Cost of Storage, Southeastern Grown Red Delicious Apples

Item	Improvement in net producer revenue			
	10 percent OC		15 percent OC	
	(1,000$)	(pct.)	(1,000$)	(pct.)
10 percent market share				
Discounted price	717.8	2.9	664.2	2.7
Undiscounted price	487.2	1.3	230.8	0.6
20 percent market share				
Discounted price	541.1	2.1	425.2	1.7
Undiscounted price	236.3	0.6	−32.8	−0.1

Note: OC is opportunity cost. Discounted price is for southeastern apples while undiscounted price is for the rest of the United States.

Table 7. Improvement in Net Producer Revenue from an Increase in Potential Market Share from Ten to Twenty Percent in the Storage Period by Type of Storage, Price, and Opportunity Cost of Storage; Southeastern Grown Red Delicious Apples

Item	Improvement in net producer revenue			
	10 percent OC		15 percent OC	
	(1,000$)	(pct.)	(1,000$)	(pct.)
Regular storage				
Discounted price	1,043.7	4.2	1,015.4	4.1
Undiscounted price	963.4	2.6	889.7	2.4
CA storage				
Discounted price	813.1	3.2	776.4	3.0
Undiscounted price	712.5	1.9	626.1	1.7

Note: OC is opportunity cost. Discounted price is for southeastern apples while undiscounted price is for the rest of the United States.

Optimal shipping patterns are presented in tables 3 and 4. All quantities harvested in August were shipped in August. Quantities harvested in September and October were distributed throughout the storage periods—September through March for regular storage and September through July for CA storage.[8]

Improvement in producer revenue, net of storage cost, from storage is presented in Table 5. The least improvement in net producer revenue attributable to storage was $4.8 million or 24.3 percent which corresponds to a situation encompassing a potential 10 percent share of the market in the storage period, regular storage, discounted price (price of southeastern Red Delicious apples), and an opportunity cost of storage at 15 percent interest. The most improvement in net producer revenue from storage was $18.6 million or 93.5 percent which is the case involving a potential 20 percent share of the market in the storage period, CA storage, undiscounted price (price of nonsoutheastern Red Delicious apples), and an opportunity cost of storage at 10 percent interest.

Improvement in net producer revenue from CA storage over regular storage is depicted in Table 6. There was actually a loss of $32.8 thousand (0.1 percent) involving a potential 20 percent market share, undiscounted price, and an opportunity cost of storage at 15 percent. The greatest gain was $717.8 thousand (2.9 percent) which is associated with a potential 10 percent market share, discounted price, and an opportunity cost of storage at 10 percent.[9]

Improvement in net producer revenue from a change in potential market share from 10 to 20 percent during the storage period is shown in Table 7. The least gain was $626.1 thousand (1.7 percent) which pertains to CA storage, undiscounted price, and an opportunity cost of storage at 15 percent. The largest improvement was $1,043.7 thousand (4.2 percent) which corresponds to regular storage, discounted price, and an opportunity cost of storage at 10 percent.

[8]Red Delicious apples must be in CA storage for at least 90 days in order to be identified as CA apples in states which ship large volumes of CA apples such as Washington, Michigan, and New York. Early release from storage simply means that the apples cannot be labeled CA. The purpose of the 90-day limit is to discourage possible false impressions in the sale of old apples from regular storage.

[9]There is some evidence that CA apples command a premium price relative to apples from regular storage (O'Rourke, 1974). However, the alleged price difference may be due to quality related factors rather than type of storage. Possible price differences for apples by type of storage were not addressed in this study.

Gain in net producer revenue from improved quality is presented in Table 8. The increase in net producer revenue shown in Table 8 is based on discounted versus undiscounted prices for Red Delicious apples. Discounted prices for southeastern Red Delicious apples and undiscounted prices for the rest of the United States reflect a generally perceived quality difference. As depicted in Table 8, the advantage of improved quality or perhaps perceived quality was rather uniform across situations examined. If the quality of southeastern Red Delicious apples was perceived the same as the rest of the United States, the improvement in net producer revenue would have been nearly 50 percent or from $11.6 to $12.4 million.

TABLE 8. IMPROVEMENT IN NET PRODUCER REVENUE FROM IMPROVED QUALITY OF SOUTHEASTERN GROWN RED DELICIOUS APPLES BY MARKET SHARE, TYPE OF STORAGE, AND OPPORTUNITY COST OF STORAGE

Item	Improvement in net producer revenue			
	10 percent OC		15 percent OC	
	(mil. $)	(pct.)	(mil. $)	(pct.)
10 percent market share				
Regular storage	12.4	49.9	12.2	49.4
CA storage	12.1	47.2	11.8	46.4
20 percent market share				
Regular storage	12.3	47.6	12.1	46.9
CA storage	12.0	45.4	11.6	44.4

Note: OC is opportunity cost.

CONCLUSIONS AND RECOMMENDATIONS

It is clear from the analysis that storage of southeastern Red Delicious apples can be economically feasible with the exception of apples harvested in August. As would be expected, the feasibility varies according to circumstances. CA storage apparently is more economically attractive than regular storage but not by a wide margin. Further, this margin seems to disappear with an increasing opportunity cost of storage. Increased potential market share in the storage periods appears to enhance the economic feasibility of storage.

Though the focus of the study was to determine the economic merits of storage for southeastern producers of Red Delicious apples, improved quality has been shown to possibly impact even more positively. If producers could improve the perceived level of quality of southeastern Red Delicious apples to that generally perceived for the rest of the United States, the economic rewards to southeastern producers could apparently be quite substantial.

The greatest economic gain to southeastern producers of Red Delicious apples will likely come from improved quality, followed by storage for delayed shipments. However, the synergistic effect of both improved quality and storage should yield even higher economic rewards to southeastern producers.[10]

Based on the findings of this study, it is recommended that a southeastern regional apple commission be formed to help provide the resources needed to successfully compete in the United States apple market over the periods of feasible storage. Perhaps through the amalgamation of state apple commissions into a regional commission, many of the deficiencies in market strategy can be eliminated.

Improving quality should perhaps begin with required state and federal inspections of all apples. O'Rourke (1978) in a study of the Washington apple industry noted that U.S. Extra Fancy Washington apples received a dollar or more per carton premium over U.S. Fancy apples. Another important involvement of the commission should perhaps be research and promotion. This will require grower assessments by the commission to finance research for enhanced quality and year-round promotional activities. Continued research on market potential should also be considered important.

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[10]Analyses encompassing a combination of regular and CA storage provided slightly higher net producer revenues than depicted in the text.

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