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Economic Analysis of Ethanol Production in California Using Traditional and Innovative Feedstock Supplies

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Abstract

In this article, we estimate the costs of using alternative feedstocks to produce ethanol in a 40 million–gal facility in California's San Joaquin Valley. Feedstocks include corn imported from Midwestern states and locally grown agricultural products such as corn, grapes, raisins, oranges, and other tree fruits. The estimated feedstock costs per gallon of ethanol include $0.92 for Midwestern corn, $1.21 for locally grown corn, $6.79 for grapes, $3.36 for raisins, $3.92 for citrus, and $1.42 for other tree fruit. Adjusting for coproduct values lowers the estimated net feedstock costs to $0.67/gal of ethanol for Midwestern corn, $0.96 for locally grown corn, $6.53 for grapes, and $3.30 for raisins. We also examine the potential increases in net revenue to raisin producers, made possible by having an alternative outlet available for selling surplus raisins.

Index Entries: Biofuels; renewable energy; raisins; ethanol; feedstocks.

Introduction

Prior to the winter of 2003, the primary oxygenate added to gasoline sold in California was methyl tert-butyl ether (MTBE). Since that time, refiners in California have been discontinuing the use of MTBE, while increasing their use of ethanol as an oxygenate. As MTBE use is discontinued, most of the ethanol that will be used in its place likely will be imported from other states. An economic analysis of the potential for producing

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ethanol in California is timely and appropriate, given that MTBE is being discontinued, and that California has a large agricultural industry that may benefit from increased demand for some of its products.

In the early 1980s, motivated by fuel shortages, geopolitical uncertainty, and high fuel costs, California developed the capability of producing fuel ethanol. Producers demonstrated the ability to make ethanol from local feedstocks including agricultural waste, industrial waste, and other biomass sources. Five ethanol production facilities were constructed in California during that time. Three of those facilities were closed within 10 yr, when fuel prices declined, feedstock costs rose, and subsidies for ethanol production were ended. Nonetheless, California gained valuable experience while the plants were operating. In particular, producers demonstrated that ethanol could be produced in California, provided that subsidies were available. Producers also learned that plant location and the choice of feedstocks are important firm-level decisions and that regional economics and political considerations influence the financial viability of ethanol production.

As the most productive agricultural region in the United States, it seems appropriate to reconsider the role that ethanol production might play in California. In this article, we estimate the costs of using alternative feedstocks to produce ethanol in a 40 million–gal facility in California's San Joaquin Valley. We consider seven materials that might be used as an ethanol feedstock: citrus, grapes, raisins, deciduous tree fruit (peaches, plums, and nectarines), corn, almond hulls, and whey. Any of these, except corn, can be described using one or two of the following statements: (1) it is currently produced in surplus amounts in the San Joaquin Valley (grapes and raisins), (2) it is a culled product (grapes, citrus, tree fruit), or (3) it is a byproduct (almond hulls and whey). Ethanol production from any of these sources would enhance the farm-level economics of the primary crop activity by generating new demand for culls, surplus, and byproducts that would otherwise be wasted or sold for a minimal price.

We calculate the costs of using alternative feedstocks on a per-gallon-of-ethanol basis, to enable ready comparison of the relative costs and benefits of each feedstock. We assume that ethanol producers must purchase feedstocks at the prevailing market prices of the culls, byproducts, and surplus products. Our results suggest that the cost of producing ethanol using California agricultural products or Midwestern corn is higher than the current price of ethanol. Hence, a public subsidy would be required to encourage ethanol production using any of the feedstocks we examine.

An alternative view of the ethanol question is: would crop producers be willing to sell a portion of their surplus production at a price that ethanol producers would be willing to pay in the absence of a subsidy program? That question is particularly pertinent when producers must store their surplus production for some period of time before it is sold in a primary market. The net price received by producers in those markets declines with the length of time that the surplus production is held in storage. Hence, producers might gain by selling a portion of their surplus production to ethanol producers at a price below the primary market price. We examine this possibility for the case of raisin production and storage in California's San Joaquin Valley.

Surplus raisin production occurs often in California, and the sale of surplus raisins is restricted somewhat by a federal marketing order. The high cost of storing raisins reduces the net revenue earned by farmers, and the carryover of production from one year to the next can have a depressing impact on future raisin prices. We find that between 1992 and 2001, an ethanol industry would have generated greater revenues for raisin producers in 6 of those 10 yr. We consider only the farm-level benefits of having an alternative outlet available for selling a portion of the surplus raisin production. In particular, we examine the decision to allocate surplus raisins from storage, either to the food market or to the ethanol market. We do not consider raisin production costs, because those have already been paid. We assume that the ethanol plant exists, and that its owners would be willing to purchase raisins for use as a feedstock.

Our goals in this article are (1) to estimate the costs of using alternative feedstocks to produce ethanol in a 40 million–gal facility in California's San Joaquin Valley, and (2) to demonstrate the impact of storage costs on the decision to sell surplus crops for use in ethanol production at a price below the price available in primary markets. We describe the availability and cost of the agricultural products that might be used as feedstocks for ethanol production in California. We use that information to estimate the costs of producing ethanol and to examine the impact of storage costs on crop marketing decisions.

Feedstock Availability and Costs

We examine seven feedstocks with respect to supply, seasonality, price, and ethanol yield. In particular, we describe the price/t, the gallons of ethanol produced/t, and the feedstock cost/gal of ethanol. We examine both Midwestern corn and California-grown corn, because either crop might be used for ethanol production. In addition, the analysis for Midwestern corn provides a benchmark for comparison with corn and other feedstocks produced in California. Those alternatives include grapes, raisins, oranges, other tree fruit, almond hulls, and whey.

We describe the potential ethanol yield from almond hulls and whey, but we do not consider these materials for use in the ethanol facility. The technology exists to process almond hulls and whey for ethanol, while retaining their value as animal feed, but that activity requires an additional capital investment that is beyond the scope of this study.

Oranges

We examine oranges, rather than all citrus crops, because oranges are the primary citrus crop produced in the San Joaquin Valley. We consider both Navel and Valencia oranges. The yield and total production of oranges can vary substantially from year to year. Considering both Navel and Valencia production removes much of the seasonality from supply consideration; Navel oranges are harvested during November through May, and Valencia oranges are harvested during June through October.

Currently, about 195,000 acres are planted in Navel and Valencia oranges in California, and most of that area is within the San Joaquin Valley. Oranges from Tulare and Fresno Counties accounted for 53.6 and 14.8%, respectively, of the value of California's production in 2001 *(1)*. California oranges are grown primarily for the fresh fruit industry. Between 1991 and 2000, the estimated average annual total pack was 110 million cartons, or 2.06 million t of oranges. On average, 515,000 t (about 25%) were culled from the total harvest during the packing process. Fruit culled from the fresh orange industry is diverted for juice. We consider this culled fruit segment a potential source of biomass for ethanol production.

The average price received by orange growers in the southern San Joaquin Valley for culled oranges diverted to processing for juice between 1991 and 2000 was $51/t. We use that price in our analysis. The estimated yield of ethanol is 13 gal/t of culled oranges *(2)*, resulting in an average feedstock cost of $3.92/gal of ethanol.

California-Grown Corn

During 1991 to 2000, field corn was planted on about 400,000 acres in California. About half of that area was harvested for silage for the dairy industry each year, while the other half was harvested for grain. The average grain yield was about 4.6 t of grain/acre. In our analysis, we assume that the grain production from 200,000 acres will be available for use in ethanol production.

Between 1991 and 2000, the average market price for California field corn was $108/t. That price is consistent with current prices and is used in our study. With current technology, 89 gal of ethanol can be produced/ton of corn *(3)*. Hence, we use an average feedstock cost of $1.21/gal of ethanol produced using California-grown corn.

Table Grapes

In 2001, there were 88,000 acres of table grapes in California and the average production was 8.07 t/acre *(1)*. The harvest season is from May through November, and table grapes can be sold as fresh fruit or for use in making juice, concentrate, or wine. Between 1991 and 2000, an average of 680,000 t of table grapes reached the fresh fruit market, each year. The average proportion of culled fruit in the fresh market is 25.5% *(4)*. Therefore, we assume that 173,400 t of culled grapes would be available for use in ethanol production.

The average price for culled grapes diverted to other uses such as in the juice and concentrate markets during 1991 to 2000 was $161.70/t. We use that price in our analysis because it represents the value of the next-best alternative to sale in the fresh fruit market. Table grapes produced in the San Joaquin Valley and sold in California must contain a minimum sugar content of 17% *(5)*. That content implies an ethanol yield of 23.8 gal/t of grapes. This is determined by multiplying the sugar content by 100 and multiplying that result by a conversion coefficient of 1.4 gal of ethanol/t of grapes per unit of sugar (R. Murray, personal communication, 4/4/02). The estimated feedstock cost of culled table grapes becomes $6.79/gal of ethanol.

Raisins

The average annual production of raisins in California during 1991 through 2000 was 368,000 t. The Raisin Advisory Committee allocates a portion of the total production to "free tonnage" and the remainder to a "reserve pool." The reserve pool represents the potential feedstock source for ethanol production. Between 1979 and 2001, the average allocation to the reserve pool was 28% of total production. Using that proportion and the average production from 1991 through 2000 generates an expected annual reserve pool of 103,000 t of raisins. Although raisins are harvested from August through October, they can be stored for use as a feedstock in any month.

At present, there is an oversupply of raisins in California. The reserve pool for the 2000–2001 season was 203,330 t, or about 66% of total production *(6)*. Changing dynamics in international trade and market developments in the wine industry will continue to have an impact on the size of the reserve pool.

Between 1993 and 2001, growers received an average of $329/t for raisins in the reserve pool. That price fell to $250/t in 2001 *(6)*. We use the average annual price of $329/t in our analysis, while noting that raisins will be available at a lower price in the future, if the condition of excess supply continues. Hence, we consider also an alternative raisin price of $250/t. About 98 gallons of ethanol can be produced/t of raisins. Using the average reserve pool price of $32/t, the feedstock cost would be $3.36/gal of ethanol. The feedstock cost is $2.55/gal when the 2001 reserve pool price of $250/t of raisins is considered.

Deciduous Tree Fruit

We consider deciduous tree fruit production including peaches, plums, and nectarines. Between 1991 and 2000, California produced 664,000 t of tree fruit annually. The average annual cull rate is 25%, providing 166,000 t of potential ethanol feedstock. This feedstock would be available seasonally from May through October.

The prices of culled tree fruit depend on the marketing options available. Industry surveys completed in the spring of 2002 indicate that culled fruit prices range from $15 to $20/t. Hence, we use a price of $17/t in our analysis. Ethanol yields from culled fruit vary with the fruit selected. Nectarines have the highest yield 13 gal/t; peaches yield 12 gal/t; and plums generate 11 gal/t. We use the average of these estimates (12 gal/t) in our analysis. Hence, the estimated feedstock cost for culled fruit is $1.42/gal of ethanol.

Almond Hulls and Whey

Although whey and almonds are not considered feedstocks in this study, they might be recognized as potential, alternative feedstock choices. In 2002, there were 525,000 acres of bearing almond trees in California. In 2001, these alternate-bearing trees produced 450 million tons of unprocessed almonds. Almond hulls have a high sugar and protein content. Currently, they are used as a feedstock for cattle because of the protein content. For this use, almond hulls received an average market price of $73/t between 1990 and 2000.

It may be possible to use the sugar in almond hulls for ethanol production, while leaving the protein for use by animals. Research and investments may be required to develop a suitable production process and some time and effort may be required for market development. We recommend further study of the potential use of almond hulls for ethanol production in California.

Whey is a coproduct of cheese manufacturing. In 2000, California produced an estimated 1.5 billion lb of cheese, yielding 747,000 t of dried whey. It is costly to dispose whey in municipal water systems. Hence, an alternative use for whey would enhance the economics of cheese production. Currently, whey protein is used as a food additive, a protein supplement, and an animal feed. In addition, there are a few ethanol plants in California and the Midwest that use whey as a feedstock. The current California whey production would yield approx 4.7 million gal of ethanol.

The market price of whey used as animal feed is $340/t *(7)*. As with almond hulls, it may be possible to utilize the sugar in whey for ethanol production, while enabling the protein in the byproduct to be used for animal feed. Hence, the net feedstock cost of whey in ethanol production may be less than $340/t of whey. Further research on the potential of expanding the use of whey as an ethanol feedstock would be helpful in evaluating the viability of this alternative.

Summary of Feedstock Supplies for Fuel Ethanol Production

When considering the supply and price of feedstocks, it is necessary to consider how much of each feedstock would be required to produce 40 million gal of ethanol annually, and how much of each feedstock is available throughout the year. It is not necessary that the plant use a single feedstock. In fact, further analysis could be conducted to determine optimal combinations of feedstocks based on price, seasonality, and yield. The estimated feedstock requirements and the amount of each feedstock that

Table 1
Feedstock Requirements and Availability for a 40 Million–Gal Ethanol Facility

Feedstock	Feedstock requirement (t/yr)	Feedstock available (t/yr)	Proportion of supply (%)	Ethanol (gal/t)
Culled oranges	3,076,923	515,000	17	13
Other tree fruit	3,333,333	165,916	5	12
Grapes	1,680,672	173,400	10	24
Raisins	408,163	103,000	25	98
California corn	449,438	920,000	205	89

should be available in California, given current production levels, are shown in Table 1.

Corn is the only feedstock that would be available in sufficient supply to support production of 40 million gal of ethanol, given current production levels. The current production of grain corn in California is 920,000 t, while the estimated requirement is for 449,438 t (Table 1). The proportions of supply that would be available for other feedstocks range from 5% for other tree fruit to 25% for raisins. The production, availability, and prices of feedstocks would change with farm-level and industry responses to public policies and market developments that influence the demand for ethanol production.

Ethanol Production Costs and Returns

We base our ethanol facility and production assumptions on a study conducted earlier by the California Energy Commission *(8)*. That study examined the potential for using traditional biomass sources as feedstocks for producing ethanol in California. We extend that analysis by considering nontraditional feedstock alternatives, such as California-grown corn, surplus grapes and raisins, and culled oranges and other tree fruit produced in the San Joaquin Valley. We also consider almond hulls and whey, and we use updated estimates of energy prices in our analysis.

Some of the data we use are taken from the California Energy Commission's 2001 report *(8)*. Other data sources include the California Department of Food and Agriculture; the Raisin Administrative Committee; the Renewable Fuels Association; and interviews with individuals in the tree fruit, citrus, almond, raisin, and grape industries.

We consider a new, 40 million–gal ethanol facility built in the San Joaquin Valley. Feedstocks for the facility include corn and surplus fruit products. Coproducts include dried distiller's grain (DDG), and pomace, another animal feedstock. We assume that the facility operates throughout the year, using selected combinations of feedstock materials. The seasonality of biomass availability is demonstrated in Table 2. Corn and raisins are available throughout the year, because both crops can be stored after harvest (Table 2). Oranges also are available throughout the year, because we consider two varieties that are harvested at different times of the year.

Table 2
Seasonality of Biomass Availability

Feedstock	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Culled oranges	•---	----	----	----	----	----	----	----	----	----	----	---•
Other tree fruit					•---	----	----	----	----	----	---•	
Grapes					•---	----	----	----	----	----	---•	
Raisins	•---	----	----	----	----	----	----	----	----	----	----	---•
California corn	•---	----	----	----	----	----	----	----	----	----	----	---•
Midwestern corn	•---	----	----	----	----	----	----	----	----	----	----	---•

Table 3
Estimated Variable Costs of Operating
a 40 Million–Gal Ethanol Facility

Item/reference	Estimated Cost in Dollars ($/gal of ethanol)
Natural gas *(11,12)* [a]	0.190
Electricity *(9)*	0.060
Water/sewage *(10)*	0.026
Maintenance *(10)*	0.003
Management and labor *(9)*	0.090
Processing materials *(10)*	0.110
Total variable costs	0.479

[a] Note that if the DG produced when using corn as a feedstock is dried, the natural gas cost rises to $0.310/gal and the total variable cost becomes $0.599/gal. The cost of natural gas was calculated using the following tariff structure for large commercial customers of the Pacific Gas & Electric Company *(11)*: summer rates (April 1–October 31): $0.77888 per therm for the first 4000 therms, $0.68719 per therm for additional therms; winter rates (November 1–March 31): $0.84189 per therm for the first 4000 therms, $0.72810 per therm for additional therms.

Other tree fruit and grapes are considered to be available only from May through October.

Fixed Costs

The estimated cost of constructing a 40 million–gal ethanol facility in the San Joaquin Valley is $55 million *(9)*. Amortizing that investment over an expected useful life of 20 yr at a discount rate of 5% generates an amortized expense of $4.41 million/yr. Dividing that cost by the expected annual production of 40 million gal generates an average amortized cost of $0.11/gal of ethanol.

Variable Costs of Plant Operation

The estimated variable costs of operating a 40 million–gal ethanol plant excluding the cost of feedstock materials are shown in Table 3. These costs were compiled using data from the California Energy Commission *(10)*, Pacific Gas and Electric *(11)*, Yancey *(9)*, and Northwestern Corporation *(12)*. The largest components of variable cost, excluding the feedstock, are the costs of natural gas and processing materials. The sum of all components is $0.479/gal of ethanol (Table 3). The estimated variable cost is $0.599/gal of ethanol if the DG is dried, when using corn as the feedstock.

Table 4
Estimated Costs of Producing Ethanol from Selected Feedstocks for a 40 Million–Gal Facility ($/gal of ethanol)

Feedstock	Feedstock cost per unit of ethanol	Credit for coproducts	Net feedstock cost	Total variable cost[a]	Total cost[b]
Culled oranges	3.92	NA[c]	3.92	4.40	4.51
Other tree fruit	1.42	NA[c]	1.42	1.90	2.01
Grapes	6.79	0.26	6.53	7.01	7.12
Raisins (high price)	3.36	0.06	3.30	3.78	3.89
Raisins (low price)	2.55	0.06	2.49	2.97	3.08
California corn	1.21	0.26	0.96	1.44[d]	1.55[d]
Midwestern corn	0.92	0.26	0.67	1.15[d]	1.26[d]

[a] Total variable cost includes the net feedstock cost plus the estimated variable cost of $0.479/gal of ethanol, from Table 3.
[b] Total cost includes the total variable cost plus the estimated fixed cost of $0.11/gal of ethanol.
[c] NA, not available.
[d] This estimate pertains to the case in which the DG is not dried. The total variable cost and the total cost will be higher by $0.12/gal if the DG is dried.

These estimates are somewhat higher than the estimated variable cost of $0.392/gal for a 40 million–gal dry-mill plant provided by Whims *(13)* and the average cash operating cost of $0.417/gal for dry mills reported in a survey of ethanol producers for 1998 *(14)*. The difference is owing primarily to the higher cost of natural gas in California at the time we prepared our estimates. The prices of natural gas we use are explained in Table 3.

The estimated feedstock costs for the materials we examine range from $0.92/gal for Midwestern corn to $6.79/gal for grapes (Table 4). We adjust these costs for the value of coproducts generated when using grapes, raisins, or corn, and we express the adjustments on a per-gallon-of-ethanol basis. The coproduct values include $0.26/gal of ethanol for grape residue sold to the concentrate market, $0.06/gal of ethanol for raisin pomace, and $0.26/gal of ethanol for DDG *. The adjusted, net feedstock costs range from $0.67/gal of ethanol for Midwestern corn to $6.53/gal for grapes (Table 4). The total variable cost of ethanol production, which includes the net feedstock cost and the nonfeedstock variable costs, ranges from $1.15/gal for Midwestern corn to $7.01/gal for grapes (Table 4). The total cost includes an additional $0.11/gal for all feedstocks. The costs shown for corn in Table 4 pertain to the case in which DG is not dried. An additional $0.12/gal of ethanol must be added to the total variable cost and total cost if the DG is dried.

* The market price for DDG has ranged between $80 and $100/t in recent years *(13,15)*. Assuming that 6.5 lb of DDG is generated per gallon of ethanol produced *(15,16)*, the estimated coproduct value is $0.26/gal of ethanol using the conservative price of $80/t of DDG.

Transportation Costs

We assume that the ethanol production facility will be located to minimize the cost of transporting feedstock materials. Studies suggest that distances greater than 40–50 miles become unprofitable for utilizing agricultural waste as biomass feedstock *(15)*. In our analysis, we assume that the cost of transportation to the ethanol facility is zero, because our goal is to compare production costs for alternative feedstock materials. The assumption regarding zero transportation costs may be realistic in cases in which small ethanol production facilities are located near a large source of a byproduct, such as an almond-processing plant. In our analysis, the price of each feedstock is based on the postharvest price at the initial point of sale, such as a packinghouse or a processing facility.

Lower transportation costs could ultimately make California-produced ethanol competitive with imported supplies. Ethanol imported from the Midwest is splash-blended at fuel distribution centers. Ethanol plants using California feedstock materials might be located near the distribution centers, to minimize the cost of transporting ethanol before it is blended with gasoline.

Ethanol Prices and Net Returns

Ethanol prices vary, over time, with changes in ethanol and corn production decisions, political statements from Washington regarding fuel policy, and expectations regarding the potential adoption of a national renewable fuels standard. These factors and others have caused moderate volatility in ethanol prices in recent years. Over the longer term, ethanol prices have been less volatile. For example, from January 1995 through May 2002, the average price of ethanol delivered to San Francisco ranged from $0.90 to $1.85/gal, with a mean value of $1.20/gal *(16)*.

The net returns from producing ethanol are estimated by subtracting the adjusted production costs from the expected total revenue. We use a price of $1.20/gal of ethanol to represent a "base-case" scenario. Given that price, the estimated net returns range from a negative $5.92 ($1.20–$7.12)/gal using California grapes to a negative $0.06 ($1.20–$1.26)/gal, using Midwestern corn.

Storage Cost Analysis

The negative values of the estimated net returns suggest that surplus California agricultural products may not be viable ethanol feedstocks. However, this conclusion is not satisfying when one considers that current surplus conditions generate high storage and product transformation costs. For example, the cost of storing raisins is $11.00/t per month, and there were more than 200,000 t of raisins in storage at the end of the 2001 production season. Oranges and grapes that are either surplus or culled are stored as juice or concentrate for later use in the food and beverage industry.

Storage costs reduce the net revenue received by farmers when they sell their produce in primary markets. Hence, producers might gain net revenue by selling a portion of their surplus production in a secondary market, such as that for ethanol, rather than paying substantial storage costs while waiting for the sale of their produce in a primary market. This problem can be viewed as one of determining the net revenue maximizing strategy for allocating surplus production between storage and a secondary market. We examine this problem for the case of raisin production and marketing in California's San Joaquin Valley. We assume that surplus production can be stored for later sale in the primary market, or sold for use in ethanol production.

Raisin production and marketing in California are conducted within the framework of a federal marketing order. Each year, the Raisin Advisory Committee determines the quantity and value of raisins that are allocated for sale in the "free market," and the quantity and value of raisins held in "reserve." Approximately 240,000 t of raisins are allocated annually to the free market, while 60,000 t are targeted for the reserve (*[6]*; M. Pello, personal communication, 3/6/03). Between 1991 and 2000, total raisin production in California ranged between 240,000 and 437,000 t. The amount of raisins allocated to the free market remained consistent during those years, whereas the amount allocated to the reserve pool ranged from 0 t in 1998 to 205,000 t in 2001.

Conceptual Framework

Raisin growers receive a lower price for raisins sold from the reserve pool than from the free market, in part because storing raisins in reserve generates a storage cost. The monthly allocation of raisins from reserves is determined by the Raisin Advisory Committee. When it is possible to sell raisins for use in ethanol production, the committee might increase its net revenue by selling a portion of the reserve pool in that market. The net returns obtained from selling raisins in both the food and ethanol markets can be described as follows:

$$\text{Net returns} = \sum_{m=0}^{\tilde{m}} \left(P_F - cm\right) Q_{F_m} + P_E Q_E \tag{1}$$

in which P_F is the price of raisins in the food market (\$/t), P_E is the price of raisins in the ethanol market (\$/t), c is the per-unit cost of storage (\$/t, per month), m is the month in storage, $\tilde{m}$ is the month in which net price in the food market equals the price in the ethanol market, Q_{F_m} is the quantity of raisins sold in the food market (t/mo), and Q_E is the quantity of raisins sold in the ethanol market (t/mo).

By construction of the model,

$$Q_E = \left(R - \sum_{m=0}^{\tilde{m}} Q_{F_m}\right) \tag{2}$$

In this model, the reserve quantity, R, is determined by the marketing order. We assume that the monthly allocation, Q_{F_m}, is determined by the Raisin Advisory Committee. Hence, neither the reserve pool nor the monthly reserve allocation to food markets is a choice variable. The per-unit cost of storage, c, also is determined outside of the model.

The Raisin Advisory Committee can maximize net revenue by storing raisins for the food market only while net price in the food market ($P_F - c\tilde{m}$) is greater than the price in the ethanol market (P_E). The net price in the food market declines as the number of months in storage increases. We use $\tilde{m}$ to represent the month in which the net price in the food market becomes equal to the price in the ethanol market (i.e., $P_F - c\tilde{m} = P_E$). The empirical value of $\tilde{m}$ is determined by the relationship of the fixed parameters P_F, P_E, and c. In particular,

$$\tilde{m} = \frac{P_F - P_E}{c} \tag{3}$$

The number of months, $\tilde{m}$, will be larger in years when P_F is relatively high, and smaller in years when P_E is relatively high.

Empirical Analysis

We have examined reserve pool prices and quantities for the years 1992 through 2001 to determine when the opportunity of selling raisins for ethanol production might have generated greater net revenues for raisin growers. We work with the assumption that 5000 t of raisins will be sold from the reserve pool every month (M. Pello, personal communication, 3/6/03). At this rate, the expected reserve pool of 60,000 t would be sold within 1 yr. The raisin marketing order requires that all raisins in the reserve pool be sold or discharged from the pool within 18 mo. This characteristic of the marketing order provides an economic incentive for developing viable market alternatives, particularly in years when production greatly exceeds the amount of raisins that can be sold in the food market. In addition, food market prices can be influenced substantially by large annual harvests and by maintaining large, nonmarketable reserve pools.

Based on an ethanol price of \$1.20/gal, the fixed and variable ethanol production costs of \$0.529/gal (this includes the credit of \$0.06/gal for the coproduct), and an ethanol yield of 98 gal/t of raisins, we determined that ethanol producers could afford to pay up to \$66/t of raisins sold for use in producing ethanol. Hence, the empirical information we use includes the following: P_F is the price of raisins in the food market[†]; P_E is the price of raisins for ethanol production, \$66/t; and c is the storage cost, \$11.00/t, per month.

[†] The average prices of raisins sold from reserves (\$/t) during the years considered in this analysis are as follows: 1991: \$238; 1992: \$281; 1993: \$192; 1994: \$152; 1995: \$432; 1996: zero; 1997: \$357; 1998: none; 1999: zero; 2000: \$250. In 1996 and 1999, farmers received no credit for raisins sold from reserves, while in 1998, the crop was reduced by weather conditions, and no raisins were held in reserve (M. Pello, personal communication, 3/6/03).

Table 5
Potential Benefits of Fuel Ethanol Production on Raisin Industry

Year	Raisins to ethanol (t)	Ethanol (million gal)	Additional revenue (thousand $)
1992	10,485	1.03	689
1993	30,535	3.00	1780
1994	47,614	4.70	3007
1996	38,094	3.73	2505
1999	45,000	4.41	2959
2000	104,165	10.21	6686

We determined the month, $\tilde{m}$, according to Eq. 3, in which c = \$11/t, per month, P_E = \$66/t, and Q_{F_m} = 5,000 t/mo. We determined the return to raisins in the ethanol market based on a price of \$1.20/gal ethanol, associated ethanol production costs of \$0.529, and an ethanol yield from raisins of 98 gal/t.

Results of Analysis

Based on the net revenue maximizing strategy, we conclude that between 1992 and 2001, the raisin industry would have benefited from an ethanol industry in 6 out of 10 yr. The additional net revenue in the beneficial years ranges from \$0.689 million dollars in 1992 to \$6.686 million in 2000 (Table 5). Preliminary market information from the 2002 harvest suggests that similar benefits might have been generated in that year.

Conclusion and Policy Implications

We have described the economic feasibility of utilizing surplus and cull citrus, grapes, raisins, tree fruit, California-grown corn, and Midwestern corn as fuel ethanol feedstocks. The cost of production exceeded the price of ethanol for all of the feedstocks we considered. However, in the case of raisins, oranges, and grapes, surplus production could generate additional storage costs. Those costs provide an incentive for considering the sale of surplus or culled production to an ethanol producer at a price less than the market price of the surplus or culled product. For example, in the case of raisins, a fuel ethanol industry might provide higher net revenues to farmers who could sell raisins from the reserve pool for ethanol production, rather than storing them until they are released for sale in the fresh market or discarded, as required by the raisin marketing order.

We estimated that the ethanol producer would be willing to pay \$66/t for raisins. That price will increase or decrease with changes in ethanol prices. At a price of \$66/t, raisin growers would not choose to grow raisins for the ethanol market. However, raisin growers could benefit from having the ethanol market as an alternative diversion when reserve pool prices are low, or when the amount of raisins held in reserve is large. We showed that raisin producers in the San Joaquin Valley would have gained net revenue by selling raisins from storage for ethanol production in 6 of the 10 yr during 1992 and 2001.

One implication of our work is that an ethanol industry in the San Joaquin Valley might provide an economic benefit to raisin growers and producers of other agricultural products that need to be stored before they are sold. A second implication is that a broader range of potential market outlets may reduce uncertainty regarding net revenue, by alleviating some of the downside exposure to the high cost of maintaining reserve stocks.

Future work in this area might include extending our analysis to the grape concentrate and orange juice markets. That research would enhance our understanding of the potential economic impacts of developing an ethanol industry in the San Joaquin Valley. Given that the net returns from the production of ethanol are negative for all of the locally grown feedstocks we considered, private firms will not choose to produce ethanol in California without a public subsidy. The amount of public funds required to support ethanol production can be reduced if alternative marketing opportunities are identified that allow producers to obtain feedstock materials from farmers at prices that are lower than those in primary markets for surplus and culled products.

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