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## Agricultural and Resource Economics Update

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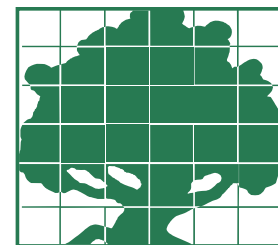
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# Agricultural and Resource Economics UPDATE



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## Labor Trajectories in California's Produce Industry

*Philip Martin and Linda Calvin*

If wages increased, California fruit and vegetable growers would have to adapt. Possible adjustments include, mechanization, imports, and labor aids.



Hand-harvesting asparagus increases labor costs. Photo courtesy of CA Asparagus Commission

The value of California's fruit, nut, and vegetable crops was \$20 billion in 2009, almost 60% of the state's farm sales of \$35 billion. California dominates U.S. production of these crops and currently accounts for about half of the U.S. fresh vegetable production and about half of total fruit production. Many of these fruits and vegetables are labor intensive; labor costs for fruit and vegetables average 42% of variable production costs. Over half of the state's hired farm workers are unauthorized, and most move on to nonagricultural employment within a decade of beginning to work in the fields. The California produce industry depends on a constant influx of new, foreign-born labor attracted by wages above those in their countries of origin, primarily Mexico. Enforcement of immigration laws or immigration reform could raise labor costs.

Enforcement of immigration laws has increased recently in two major ways. First, the U.S. government has erected fences and vehicle barriers on a third of the 2,000 mile Mexico–U.S. border to deter unauthorized entries. Second, the Immigration and Enforcement Agency that enforces immigration laws inside the United States has begun to audit more of the I-9 forms completed by newly hired workers and their employers. After these audits, employers are asked to inform workers whose data do not match government records to clear up discrepancies. Most workers instead quit, which has prompted some farm employers to invest in housing in order to hire legal

H-2A guest workers (H-2A workers must be provided with free government-inspected housing). H-2A workers must be paid at least the so-called Adverse Effect Wage Rate (AEWR), which in 2011 is \$10.31 an hour in California, higher than the state and federal minimum wages. AEWRs were established in the 1960s to prevent the presence of legal foreign workers from depressing the wages of U.S. farm workers.

Immigration reform could also raise farm labor costs by legalizing currently unauthorized farm workers and encouraging farm employers to turn to H-2A guest workers if legalized workers find nonfarm jobs, which could raise labor costs. Efforts to enact immigration reform between 2005 and 2007 failed, but in his 2011 State of the Union speech, President Obama urged Congress to try again. He said: "I know that debate will be difficult. I know it will take time. But tonight, let's agree to make that effort." This paper reviews the three most likely adjustments in the fruit and vegetable industry to higher labor costs: mechanization, imports, and labor aids.

### The Produce Industry and Trade

U.S. production of fresh-market fruit and vegetables has increased in the last two decades—up 12% for fresh fruit and 41% for fresh vegetables (Table 1 on page 2). Individual commodities, however, have fared very differently. Between 1990–92 and 2008–10, average U.S. fresh-market asparagus production declined 50%, while fresh-market

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Table 1. U.S. Fresh Fruit and Vegetable Statistics

		-----Average-----		
		1990-92	2008-09 for fruit 2008-10 for vegetables	Percent change
Production				
Fresh fruit	Million lbs	19,541	21,822	12
Fresh vegetables	Million lbs	35,335	49,811	41
Per capita consumption				
Fresh fruit	Pounds	68	76	12
Fresh vegetables	Pounds	142	169	19
Imports				
Fresh fruit	Million lbs	2,133	7,273	241
Fresh vegetables	Million lbs	3,874	12,121	213
Exports				
Fresh fruit	Million lbs	4,429	5,802	31
Fresh vegetables	Million lbs	2,949	3,931	33
Import share of consumption				
Fresh fruit	Percent	12	31	152
Fresh vegetables	Percent	11	23	109
Export share of production				
Fresh fruit	Percent	23	27	17
Fresh vegetables	Percent	8	9	13

*Note: Bananas are excluded from the fruit group. Vegetables exclude potatoes, sweet potatoes, mushrooms, dry peas, dry beans, and lentils; but include melons.*  
*Source: USDA, Economic Research Service, Fruit and Tree Nuts Yearbook, Vegetable and Melons Yearbook.*

strawberry production increased 137%. The U.S. produce industry competes with producers in many other countries with lower farm wages, and imports are increasing as a share of U.S. consumption—up 152% for fresh fruit and 109% for fresh vegetables over the past two decades. Some of these imports arrive when the United States does not produce that product (fresh cherries in December) while others compete with U.S. production, as in the case of some asparagus imports.

### Hired Farm Workers

Hired workers have long done most of the farm work on California’s fruit and vegetable farms. California has required farm employers to pay unemployment insurance taxes on the wages of workers who earn more than \$100 a quarter since 1978, making unemployment insurance data a “census” of hired workers. In 2009, California’s 17,300

agricultural establishments (usually farms) hired an average of 374,000 workers. Even if each of these establishments had three full-time operators and unpaid family workers, hired workers would have done almost 90% of the work on California farms.

Most hired workers are men born in Mexico. The U.S. Department of Labor’s National Agricultural Worker Survey (NAWS), which surveys workers employed on U.S. and California crop farms, reported that almost three-fourths were born in Mexico and a quarter were born in the United States. Over half of the workers interviewed between 2005 and 2007 were unauthorized.

Most hired workers stay in the seasonal farm workforce a decade or less. The NAWS found that 15% of crop workers were newcomers, in the U.S. farm workforce for less than a year. Those attracted to seasonal jobs on fruit and vegetable

farms are generally workers whose alternative U.S. job options are limited by lack of English-language skills, education, and other factors.

According to the NAWS, hired crop workers earned an average \$8 an hour in 2006, just over half of what U.S. nonfarm production workers earned. The NAWS also found that crop workers were employed on U.S. farms for about two-thirds of the year. Earning half as much and working less means that the annual earnings of crop workers averaged a third of the annual income of nonfarm production workers, who earned almost \$35,000 per a year.

### Adjusting to Higher Labor Costs

What would happen to U.S. fruit and vegetable production if farm labor costs rose? Several adjustments are possible. First, farmers could change their production processes to reduce the need for hand labor by mechanizing. They could also use chemicals or precision planters to reduce the need for hand-weeding and hand-thinning of crops. Second, imports could increase if rising U.S. farm labor costs made U.S.-produced commodities less competitive. Third, farm operators could increase the productivity of farm workers by picking fields less often (and accepting lower yields) or providing workers with productivity-increasing harvesting aids, such as conveyor belts that reduce the time required to carry harvested commodities, lightweight ladders for climbing trees, or dwarf trees that reduce the need for ladders. The adjustment an individual commodity group might pursue will vary depending on the characteristics of the crop, status of mechanization or labor aid technology, and the economic conditions of the industry.

### Mechanization: Raisins

The U.S. raisin industry, centered in Fresno County, California, faces several challenges, including declining U.S. per capita consumption (down 22%

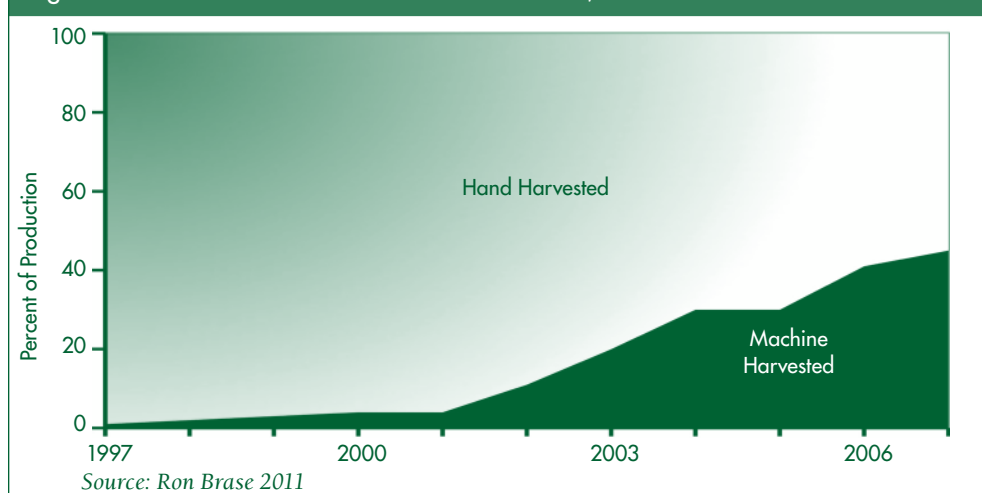
between 1990-92 and 2008-09) and increased competition in a globalizing market. The United States and Turkey are the world's largest raisin producers, accounting for over half of global supply, but Turkey is the world's largest exporter and a lower-cost producer than California. The U.S. raisin industry depends on a complicated set of state and federal marketing programs to remain competitive in export markets.

Harvesting raisin grapes was traditionally the most labor-intensive farm task in North America, with 40,000 to 50,000 workers hired each fall to cut bunches of green grapes and lay them on paper trays to dry into raisins. The key to harvest mechanization was developing grape varieties such as Selma Pete that reach maturity in early rather than late August. The canes of early maturing grape varieties can be cut in August, so that green grapes can dry into raisins on the vine—this is the dried-on-the-vine (DOV) method of harvesting. A modified wine-grape harvester shakes the dried raisin grapes off the vines. Replanting a vineyard and using DOV harvesting requires an investment but increases yields dramatically.

Before 2000, only a few growers used DOV production techniques. The price of raisins fell sharply in 2000 after a very large crop (down 56% from 1999) and in 2001 a modified mechanical wine-grape harvester was introduced to harvest DOV raisins. By 2007, an estimated 45% of California's raisins were harvested using some form of DOV mechanization (Figure 1). Complete harvest mechanization has been delayed, in part, by the large number of small raisin-grape farms, many of which have older owners who are reluctant to mechanize or perhaps replant.

Most of the 80,000 acres of raisin-type grapes removed in the past decade were older vineyards not suitable for machine harvesting. Although acreage of raisin-type grapes has declined, yield has increased, and production of

Figure 1. Hand- versus Machine-Harvested Raisins, 1997–2007



grapes for raisins in 2010 was about the same as 1990. The spread of DOV has reduced the demand for raisin harvesters to about 25,000 workers. If labor costs rose, the switch to mechanical harvesting would likely accelerate, resulting in fewer and larger raisin producers and less demand for hired labor.

### Imports: Asparagus

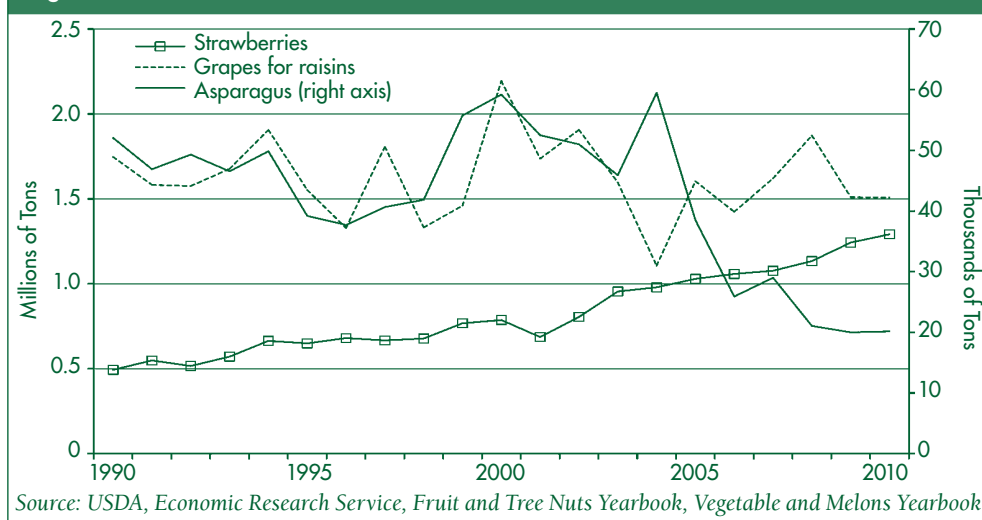
U.S. per capita consumption of fresh asparagus increased 115% since 1990, but 87% of the fresh asparagus consumed in the United States is now imported, primarily from Peru and Mexico. Some imports come into the United States during seasons when there is no domestic production, but some compete directly with U.S. production. U.S. production of fresh asparagus

fell 50% between 1990-92 and 2008-10; production in California fell 59% (Figure 2). The Food, Conservation, and Energy Act of 2007 provided funds to cushion U.S. asparagus producers from rising imports, and researchers are working on mechanical harvesters.

Harvesting fresh asparagus is labor-intensive because each spear is hand-cut individually. When the weather is warm, fields may be harvested daily rather than the more typical two or three times a week. Labor costs rather than labor availability have been the main issue for growers. Asparagus is often the first crop harvested in the spring, minimizing competition for labor from growers of other commodities.

The major issue is how to reduce harvesting costs. Selective mechanical

Figure 2. California Production, 1990–2010



harvesters could damage asparagus that is not yet mature, limiting their use, and the lack of uniform-ripening varieties restricts the use of once-over harvesters. Without a harvest mechanization break-through, imports are likely to displace more U.S. fresh asparagus production and further reduce labor demand for this crop. Asparagus may follow the path of green onions, a labor-intensive commodity only rarely grown in the United States now. Almost all green onions consumed in the United States are imported from Mexico.

### Labor Aids: Strawberries

Almost 90% of U.S. fresh-market strawberries are produced in California and all are picked by hand. Total U.S. strawberry production increased 107% between 1990-92 and 2008-10 and California production rose 135%; yields increased 73% and U.S. consumption of fresh-market strawberries doubled over this period.

Imports of *fresh* strawberries, 8% of U.S. consumption, are held down by year-round U.S. production and the difficulty of transporting fragile and perishable strawberries long distances. However, imports of *processed* strawberries, usually frozen, account for almost a third of U.S. consumption. While California strawberry growers aim for the fresh market, processing is an important residual market that is becoming less profitable with increased imports.

Strawberries are among the most labor-intensive commodities. Up to 1,000 hours of labor are required to harvest an acre, as fields are often picked several times a week over four-to-six months. Workers place strawberries into the plastic clamshells in which they are sold; the clamshells are in a cardboard flat mounted on a small wheelbarrow. In most fields, workers stop harvesting when a flat is filled, take the full flat to a truck at the end of the row to unload and receive credit for picking it, and return with an empty flat and resume picking.

A labor aid can increase worker productivity by reducing the time spent carrying full flats of berries. In the large and flat fields of Ventura County in Southern California, many growers are now using a slow-moving conveyor belt that moves down the field in front of the harvest crew. Harvesters still fill flats mounted on wheelbarrow devices, but walk fewer steps to put full trays on the belt, get an empty flat, and resume harvesting, which can reduce harvesting hours by a third or more in large fields. Adoption of the conveyor belts, which cost over \$100,000 each, has been slowed by disputes over how much harvest piece-rate wages can be reduced to reflect increased worker productivity. Growers outside Ventura County have been less likely to adopt the conveyor belt.

If labor costs rose, more growers would likely adopt conveyor belts, including versions that are more appropriate for smaller and more hilly fields. A number of research efforts aim to mechanize the harvest, including a scout and harvesting system that uses one machine to identify ripe fruit and another to harvest it; this research is, however, still in an early stage. If higher labor costs were passed on to consumers, the rapid growth in strawberry consumption might slow.

### Conclusions

The production of many major fruit and vegetable commodities is labor-intensive. Producers who hire mostly unauthorized workers face several challenges, including immigration enforcement or reforms that could raise labor costs at a time of increased trade. This paper examined the potential responses of three major California commodity groups to higher labor costs: harvest mechanization, increased imports, and more labor aids.

Early maturing raisin-grapes can be harvested mechanically, which requires replanting vineyards to achieve the maximum yield increases of the less labor-intensive system.

About half of the industry has mechanized in the last decade, reducing labor demand, but the large number of small and older producers slows adoption of the DOV technology.

Rising labor costs would likely increase fresh asparagus imports and decrease domestic production unless an economical harvester is developed, which is less likely as production declines and reduces private incentives to develop such machines. With lower production, asparagus labor demand may have already peaked.

Fresh strawberry producers are likely to use more aids to increase worker productivity or find that higher labor costs passed on to consumers would slow rapidly increasing consumption. The adjustments of fruit and vegetable producers to higher labor costs depend on factors that include the availability of mechanical alternatives, the degree of import competition, and the feasibility of aids that increase worker productivity.

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# Meeting a Growing Demand for Food and Fuel in a Sustainable Manner

David Zilberman and Gal Hochman

Production of biofuel from grains has reached a limit, resulting from concerns about food and fuel trade-offs. Several nonfood biofuel feedstocks show promise. The introduction of new feedstocks and the adoption of new biofuels by consumers will be gradual.

The recent discovery of the genome and DNA, combined with concerns about reliance on nonrenewable energy sources and climate change, have led to efforts to introduce alternative industrial processes that rely on biological processes and renewable resources. These emerging industries are sometimes referred to as the “bioeconomy” and include biofuels, biotechnology, and green-chemistry industries. The bioeconomy is expanding the range of activities that are pursued by agriculture to include the production of feedstock for energy and chemical production, in addition to the production of foods, feeds, and fiber. This paper provides an overview of recent research findings on the economics of biofuel and its relationship to the food sector and the environment.

The biofuel industry is probably the most obvious sector of the bioeconomy. It is producing ethanol from sugarcane in Brazil, from corn in the United States, and from cassava and sugar beets in Thailand and Europe. It is producing biodiesel from vegetable oil, from palm oil in Malaysia, and from rapeseed in Europe. Current biofuel production in Brazil cannot meet domestic demand as 50% of the vehicle fleet is flex-fuel cars, i.e., cars that can run on both gasoline and

ethanol. Brazil has a significant amount of land reserves that will be able to increase ethanol production capacity in the future. But currently, it is importing ethanol from the United States.

Currently, in the United States, corn ethanol is a breakeven business to biofuel refineries where revenues (including a 45 cents per gallon subsidy) cover both variable and fixed costs. The economics of the industry is strongly affected by the subsidy and mandate that reaches 14 million gallons annually. The profitability of the industry fluctuates depending on the relative price of corn versus fuel.

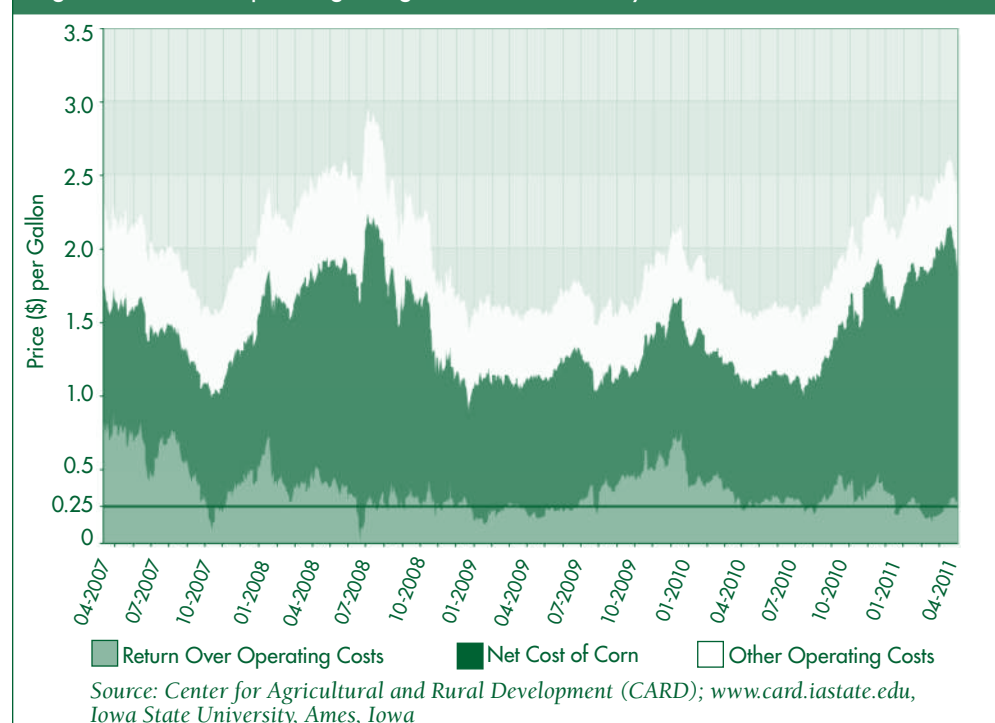
Figure 1 depicts the profitability of the industry between 2007 and 2011. The upper boundary of the white region is the price per gallon of ethanol. The cost includes the cost of corn and other operations costs, and what’s left is the return to investment. A benchmark to assess profitability is that 25 cents per gallon required to

repay the investment in five years. The 25-cents line is thus the breakeven line.

The industry was very profitable in 2006–07 where profit margins (revenue–variable costs) in some months reached 80 cents per gallon—much above the 25 cents per gallon required to repay the investment in five years. Yet, during the period of high food prices in 2008, revenues hardly covered variable costs. Because of this volatility, investors who were able to establish biorefineries during the high-margin period of 2006–07 were able to recapture their investment in two years, while investors in biorefineries that were launched during the period of relatively low biofuel prices faced financial difficulties.

While the industry’s profitability is strongly affected by the subsidy, it is very likely that it would have existed in a somewhat smaller capacity with a smaller (or no) subsidy because of the periods of high margin that make

Figure 1. Ethanol Operating Margins Based on Nearby Futures and Iowa Corn Prices



investment very lucrative and possible to recapture in a short period of time. However, the capacity of the industry has been strongly affected by the assurance provided by the biofuel mandates introduced by the U.S. Energy Independence and Security Act.

The ability of the industry to grow is constrained by the blending mandates that restrict the amount of biofuel to be 10% of the fuel in a traditional gasoline car. Altogether, the industry has the capacity to produce 15 billion gallons of corn ethanol, but it is not likely to expand much in the future because of the current mandates.

The industry could expand if the blending barrier were raised to 15%, which is not likely to cause major problems with current car fleets. But this is subject to political debate. The industry could also expand if the number of flex-fuel cars and, in particular, the gas stations that serve them, were increased.

The value of biofuel is apparent from a realistic perspective on the capacity to address climate change with other technologies. California aims to reduce emissions by 80% of the 1990 emissions level by 2050. While this target cannot be met with existing technologies, even reducing the emissions level by 60% cannot be met without biofuels that are used in power as well as transportation.

Biofuels, relative to other alternatives, are a cost-effective way to rely on biological procedures to harness solar energy. Biofuels may be needed to meet greenhouse gas (GHG) emission-reduction objectives globally. However, there is significant concern about the impact of biofuels on food prices, which is a major constraint on the growth of the first-generation biofuels originating from starches.

While the impact on food available to consumers in the United States is quite low (less than 1%), impacts on prices of corn and soybeans could be significant, depending on overall harvests as well as inventory levels. For

example, in 2008, some estimates suggest that biofuel demand contributed to a 30% increase in the price of corn. But, overall, these estimates also suggest that the impact of biofuel demand on food-price inflation is secondary to the impact of economic growth in developing countries, such as China and India.

### Biotechnology and the Food/Fuel Dilemma

The impact of biofuels on food prices could be mitigated if the use of genetically modified (GM) varieties were expanded. Thus far, GM varieties have been used mostly in the production of corn, soybeans, and rapeseed in the United States, Canada, Brazil, and Argentina. The reduction of corn and soybean prices due to the current use of GM varieties is of the same order of magnitude as the increase in food prices attributed to biofuels in 2008. The impact of GM varieties on food prices could have been much larger if GM varieties of corn and soybeans were adopted in Europe or Africa and/or if GM rice or wheat varieties were used anywhere in the world.

Expansion of the use of GM varieties could have a beneficial environmental effect as well as reduce food prices to counter the impact of biofuels. The recent report of the National Research Council suggests that, based on the U.S. experience, the use of GM varieties has significant beneficial effects on the environment by reducing the use of pesticides, runoff, and soil erosion through increased adoption of low-tillage. Sustaining these gains is at risk because of the emergence of resistance to herbicide-tolerant varieties, which suggests the need for better management of the use of GM varieties as well as the introduction of new GM traits.

Thus, expansion and better management of the use of GM varieties can mitigate the impact of biofuels on food prices and have significant beneficial environmental effects.

### Biofuels, Sugarcane, and Deforestation

While the potential of biofuel production from staple food crops, such as corn and soybeans, is limited even with the adoption of GM varieties, there is significant potential to increase the production of biofuels from sugarcane and new sources. There are concerns that expansion of sugarcane biofuels in the tropics will lead to deforestation and significant emission of GHG. But there is significant potential to increase fivefold the acreage of sugarcane for biofuel in the savannas of Brazil and in Africa, without much loss of biodiversity or, in particular, large emissions of GHGs in the transition.

It is also suggested that expansion of biofuel production will expand deforestation indirectly, especially in Brazil. Conversion of range or savannas from grazing to farming will accelerate the conversion of forests to grazing. Transition from forests to grazing have occurred in the past, but the deforestation process in the Amazon was part of a historical land-settlement process. It was supported by government policies and by expansion of infrastructure, such as railroads and highways, that enabled the shipment of products from the interlands to the coastal areas. The process of land-based expansion in Brazil in the last 100 years is similar to the process of settlement in the United States in the 19th Century and in Europe and China earlier.

The American experience suggests that, once an agricultural land base has been stabilized, there is continuous growth in productivity through further intensification. While increased profitability of soybeans or sugarcane because of biofuels may contribute to the deforestation process, deforestation will continue nevertheless as long as cheap land is available and new cattle ranching operations are profitable.

Deforestation can be controlled only by establishing and enforcing strong

environment-protection policies in the Amazon. The Brazilian government is establishing such policies, but the enforcement could be improved. However, intensification of range-management practices can significantly increase cattle production on existing land and reduce GHGs. Such intensification efforts are supported by the research agenda of the Brazilian Agricultural Research Corporation (a government national plan for climate and mitigation action), by producer responsibility movements, and by efforts to establish certification of sustainable production of cattle. The Brazilian policies have resulted in the deforestation rate slowing markedly since 2005.

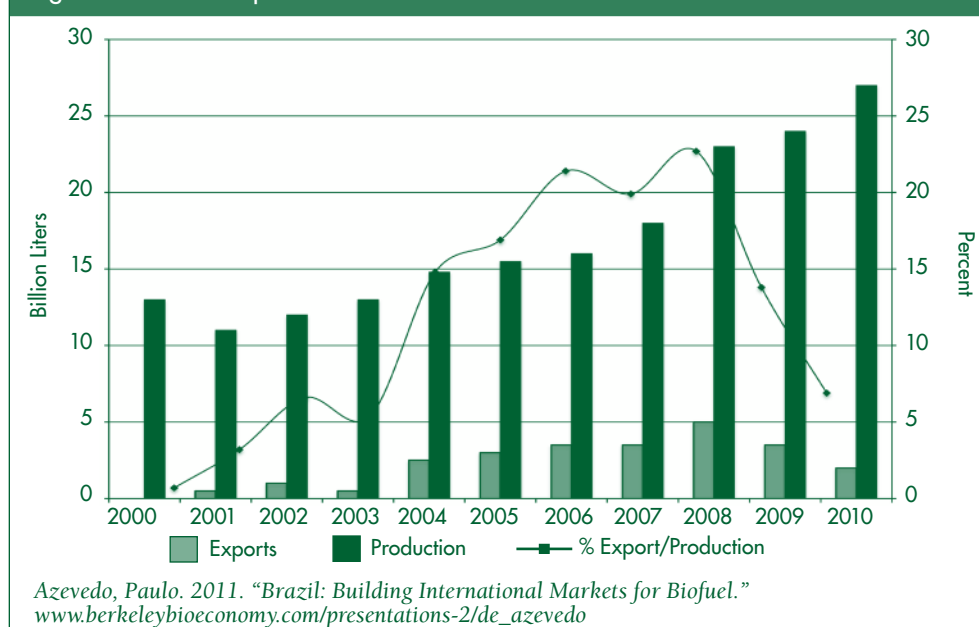
### Alternative Feedstocks for Biofuels

In addition to the expansion of sugarcane ethanol production, the growth of the production of biofuels without significant food-price effects would be made possible by the introduction of second-generation biofuels that can be grown on lands that are not used for food crops, but have the rainfall and other attributes to support biofuel production.

The challenge is to reduce the cost of this new type of biofuel significantly so that it can be competitive. Government mandates can provide a base for the industry, but breakthroughs in research and development (R&D) are crucial for its expansion. The feed crops for this industry could include grasses, such as miscanthus and switchgrass, for ethanol, as well as plants, such as *Jatropha*, for biodiesel. Some industrial forests could be converted for the production of biofuels.

Municipal waste is another important source of biofuel for both transportation and power. The economics of this feedstock stems from the cost of landfills and waste disposal that will be saved by the conversion of waste to energy, in addition to the revenue from the energy generation

Figure 2. Ethanol Exports in Brazil



as well as other byproducts that can be captured in the process.

Algae are another feedstock for the production of biodiesel. The economics of algae as a source of biofuel is dependent on combining revenue from energy generation with revenue generated by the coproduction of high-value byproducts (fine chemicals, such as beta carotene). However, the market for many of these byproducts is very limited, which restricts the capacity to produce biofuels from algae economically. The future of algae as a source of biofuel will depend on its capacity to reduce the cost of biofuels.

Agave that is used to produce tequila has a large potential to be a feedstock to produce liquid fuel. Currently, the production of liquid fuel from agave is very expensive but, with technological innovation, production of byproducts, and the direct combustion of leaves to produce energy, agave may become a more viable source of alternative energy.

At present, biofuel mandates have been the dominant driver of the expansion of biofuels throughout the world, and several studies suggest that they contribute to at least a 10% reduction in the price of fuel. A continued rise in the price of oil

combined with technological progress will lead to expansion in biofuel production beyond what is dictated by mandates. The growth of biofuels will also be dependent on the impact on food prices and support in financial incentives for GHG reduction.

While it is assumed that consumers will pay for biofuels in proportion to its energy content, there is growing evidence that the demand and the price paid for biofuel are affected by factors other than energy content. There is evidence of large differences in consumers' willingness to pay for ethanol in Brazil. Some factors are associated with willingness to pay a higher premium (more than 10%) for ethanol, including young age (<25), college education, living in regions that produce ethanol, and environmental preferences. Other characteristics are associated with willingness to pay more for gasoline, including older age, living in states that import ethanol, driving frequently, or driving expensive cars. Because of these differences, even in Brazil, the adoption of ethanol will be gradual and prices will vary among regions.

Indeed, the adoption of ethanol in Brazil is an ongoing process. Figure 2 depicts the production, export, and





Biofuels can play an important role in reducing GHG emissions and increasing fuel security. Yet, production of biofuel from grains has reached a limit, resulting from concerns about food and fuel trade-offs.

the export/production ratio of biofuels in Brazil during the last 10 years. While ethanol production in Brazil has increased by 18% annually on average over the last eight years, the share of exports in production, which reached 23% in 2008, has declined and is less than 10% in 2011. The growth of the domestic consumption of ethanol in Brazil has been associated with the gradual adoption of flex-fuel engines and investment in infrastructure to market ethanol-intensive fuels, which led to consumption beyond the mandates in some regions.

International buyers of Brazilian ethanol differ in their preferences. Some buyers from Japan and the European Union require more comprehensive information related to sustainability attributes of biofuels, while the demand for Brazilian ethanol in the United States/Caribbean is derived from short-term relative-price opportunities. One of the challenges is to develop credible certification programs for sustainable biofuels that would open doors to the

adoption of biofuels in certain countries in Europe as well as in Japan, and increase the premiums, as some consumers will be willing to pay for sustainable ethanol in those countries.

There is evidence that U.S. consumers tend to pay a premium for ethanol compared to gasoline. Farmers and other individuals who are concerned with food security or the environment are more likely to pay a premium for biofuel. The existence of a large segment of the population with a preference for biofuel over gasoline reduces the overall economic cost of moderate biofuel mandates. The targeting of the sales of biofuels to regions with a high willingness to pay for these products will increase their profitability and enhance the growth of the industry.

## Conclusion

Biofuels can play an important role in reducing GHG emissions and increasing fuel security. Yet, production of biofuel from grains has reached a limit, resulting from concerns about food and fuel trade-offs. The adoption of agricultural biotechnology will allow sustaining and even expanding production of agricultural biofuel production from food crops. However, substantial growth will require increased production of sugarcane-based biofuels and the introduction of second-generation products, which rely on feedstock that would not infringe much on food production. Some of these new products (e.g., biofuels from waste products) are more economically viable than others, but all require further R&D.

The expansion of the use of biofuels may require modification of the car fleet to increase the share of flex-fuel cars, and it also will require modification of the fuel supply chain to provide more access to biofuel products. Ideally, further R&D will result in new biofuel products that can be mixed with gasoline to reduce the cost of adjustment to biofuels. Both the introduction

of new feedstocks and the adoption of new biofuels by consumers will be gradual. The understanding of regional differences in the cost of production of, and willingness to pay for, biofuels should guide efforts to market biofuels and enhance their economic viability.

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### For additional information, the authors recommend:

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# Water and Jobs: The Role of Irrigation Water Deliveries on Agricultural Employment

David L. Sunding, Kate Foreman, and Maximilian Auffhammer

Decreased irrigation water deliveries from the federal and state water projects are shown to have a significant negative impact on agricultural employment in California's Central Valley.



Movable pipe sprinklers are used to irrigate a lettuce field in California. The importance of irrigation water for agricultural employment has spawned much debate in recent years.

The past several years have been tumultuous ones for California water agencies and farmers who rely on water exports from the Delta. Since 2005, water exports from the Delta have been reduced by drought and environmental restrictions. The loss of water supply has had economic consequences for farmers and those who make their living as farm workers. In this paper, we present the results of a statistical test of the hypothesis

that higher deliveries to water districts in a given county lead to higher employment, provide estimates of the size of this effect, and characterize the uncertainty around the estimates. Based on this analysis, we estimate that water delivery reductions in 2009 caused a loss of approximately 5,000 farm jobs in the San Joaquin Valley relative to the year 2005.

## Approach

When seeking to identify a relationship, such as the one between Delta water exports and farm jobs, it is important to control for the influence of confounding variables. This principle can be illustrated using a simple example: total production of a commodity, such as a crop, in a market-based society is the sum of each farm's production. Profit-maximizing farms decide on the optimal output by setting marginal cost equal to marginal revenue, which is equal to price if the market is competitive. Therefore, a variable beyond their control, the market price, as well as other exogenous factors (e.g., prices of inputs such as the wage rate) determine the optimal use of inputs to produce the optimal amount and mix of crops.

Total demand for farm labor at a given farm therefore depends on the prices of outputs, the wage rate, the prices of other inputs, and other exogenous factors, such as weather and water deliveries. If employment is significantly more sensitive to wages and input prices than to water deliveries, the effect of wage variations may swamp the smaller, but still significant, effects of variations in water deliveries in terms of total employment. In order to detect

the weaker signal, one needs to control econometrically for other confounding factors, either directly or via a fixed effects strategy, to be able to extract the effect of smaller factors from the noise caused by large confounding factors.

In the present case, the coefficient of interest is the effect of a change in Delta water deliveries on changes in employment. In order to arrive at such a coefficient, one should statistically compare employment in areas receiving water deliveries, which vary from year to year, to employment in areas, which do not receive such deliveries as a control group.

Counties differ in characteristics, which do not vary across time (e.g., soil characteristics, physical location). Further, there are certain factors that affect all counties contemporaneously (e.g., changes in relevant exchange rates, global commodity prices, oil price shocks, wages, and prices of other inputs). One has to account for this fact statistically in order to prevent these effects from confounding the estimated impact of water deliveries on employment. Further, there may be other factors varying at the county level over time, which are correlated with water deliveries and, if not controlled for directly, may contaminate the estimated effect of deliveries on employment.

Economists and statisticians have developed now-standard methods for performing such analyses. Known generally as panel estimation techniques, they involve creating a set of fixed effects to screen out factors that vary across regions (counties in this instance) and among years. The researcher estimates a model that includes the variable of interest together

Table 1. Summary Statistics on Employment and Delta Exports by County

County	Total Employment ------(1,000 Jobs)-----	Farm Employment	Acres Harvested (1,000 acres)	Total Delta Deliveries (1,000 acre-feet)
Fresno	338	31	1,252	1,093
Kern	254	17	834	1,011
Kings	41	5	516	305
Merced	74	10	522	150
San Joaquin	208	14	521	40
Stanislaus	163	12	422	88
Tulare	141	19	763	5

with the time- and location-specific fixed effects. What remains after removing the influence of the fixed effects is the influence of the variable of interest, in this case Delta export deliveries by county. Factors which influence employment and are correlated with deliveries which differ across time and space need to be controlled for explicitly, not via a simple fixed effect.

Failing to control for the confounders through a fixed effects strategy will lead to biased and/or inefficient (i.e., imprecisely estimated) coefficients. One could estimate this equation on a sample containing just the counties receiving deliveries or a sample of counties receiving deliveries and include counties that do not receive deliveries as a control group. We show that the estimation results are robust to using either sample. In the first sample, the identifying source of variation is within county time series variation. For the larger sample, it is within county variation relative to the control group county variation, which identifies the coefficient of interest.

### Data

The data used in the analysis are comprised of an annual panel data set covering the years 1980 to 2000. Counties used in the analysis, which receive irrigation water from either the Central Valley Water Project (CVP) or State Water Project (SWP) are the following: Fresno, Kern, Kings,

Merced, San Joaquin, Stanislaus and Tulare. Six California counties that do not receive Delta water deliveries were used as a control group to capture the effects of general changes in the agricultural economy: Madera, Imperial, Monterey, Sutter, Yolo and Yuba. The data period covered by the analysis evidences significant variation both in employment and water deliveries. It also includes one of the largest droughts in recent memory—the drought of 1987–1992.

The employment data at the county level are publicly available, and were obtained from the Bureau of Economic Analysis (BEA). For the employment data series, farm workers are defined to include anyone who works in the direct production of agricultural commodities, including crops and livestock (SIC codes 01 – 02). Government water delivery data include both state deliveries from the SWP and federal deliveries from the CVP. The state water delivery data come from the California Department of Water Resources’ Bulletin 132 and the Kern County Water Agency. The federal water deliveries data are from the Bureau of Reclamation.

A Geographic Information System was used to allocate water deliveries to counties. We first took the intersection of the boundaries of each of the water districts and counties, and then calculated the acreage of the district-county intersection and divided that by the acreage of each of the districts.

We multiplied this ratio by the water deliveries in each water district and summed the share of water deliveries in the district-county intersection over counties. Thus, water deliveries are allocated to the county level according to the share of acres of each water district that falls within each county. Annual deliveries are reported in acre-feet. The data set also includes harvested acres for all crops by county. These data come from the Agricultural Commissioners’ Offices of Fresno, Imperial, Kern, Kings, Madera, Merced, Monterey, San Joaquin, Stanislaus, Sutter, Tulare, Yolo and Yuba counties for the years 1980 through 2000.

Table 1 displays average employment and water deliveries by county from 1980–2000. Fresno has the highest number of total employed workers and the highest number of employed farm workers, while Kings has the lowest in both categories. Merced has the highest percentage of employed workers in farming (13.5%), while San Joaquin has the lowest (6.7%). Fresno also has the largest area harvested (1,252,000 acres) while Stanislaus has the smallest (422,000 acres). Fresno has the highest average level of federal and state water deliveries from the Delta (1,093,000 acre-feet) and Tulare has the lowest (5,000 acre-feet). Kings has the highest Delta-deliveries-to-farm-worker ratio at 61 acre-feet per worker, and Tulare has the lowest at 0.3 acre-feet per farm worker. These large differences across counties show the importance of controlling for unobservable differences across counties via county-level fixed effects.

### Results

Controlling for shocks affecting each county in a given year via year fixed effects, the influence of a one acre-foot drop in Delta exports on county employment is 0.00240 and is statistically different from zero at the 5% level. This coefficient implies that 417

additional acre-feet of deliveries are consistent with about one additional job in the county. To better control for the influence of macroeconomic trends in the agricultural sector, we estimate the same model but expand the sample to include control counties that do not receive deliveries from the Delta. In this model, the coefficient drops slightly to 0.00225 and is statistically significant at the 1% level. This more conservative estimate implies that 444 additional acre-feet of deliveries are consistent with about one additional job in agriculture.

The Bureau of Economic Analysis (BEA) shifted to reporting sectoral employment based on the Standard Industrial Classification (SIC) to reports based on the NAICS classification. The BEA provides a concordance to match industry descriptions between the two coding systems. We extend the sample to include the years 2001-2007 for which we have both deliveries data at the county level as well as employment data from the same source (BEA), albeit collected under the North American Industry Classification System (NAICS).

As we control for year fixed effects in our preferred specification, if there are year-to-year differences in employment that are due to the new classification, our method controls for these differences. The results are robust to including the NAICS data for the additional years, as the coefficient on Delta deliveries in the sample including the control counties is 0.00222, which is nearly identical to the coefficient estimated using the SIC-based data through 2000.

In order to calculate the job impacts of a reduction in Delta exports to the San Joaquin Valley, we use the year 2005 deliveries to each county as a baseline and calculate the predicted jobs in each county using the estimated coefficients. We then calculate the predicted number of jobs in each county from the deliveries coefficient based on the 2009 level of deliveries. The

estimated drop in direct farm employment is 4,965 jobs, which is equivalent

*This more conservative estimate implies that 444 additional acre-feet of deliveries are consistent with about one additional job in agriculture.*

to a 4.6% decrease. The 99% confidence interval around this estimate of jobs lost does not include “no jobs lost,” meaning there is less than one chance in one hundred that reductions in Delta exports did not decrease direct farm employment in the San Joaquin Valley in 2009 relative to 2005.

Our county-level model therefore is consistent with economically and statistically significant losses in employment in the agricultural production sector. While the model does not formally test the mechanism of how this occurs, one would expect that acreage planted to crops would decrease if deliveries are short, which would lead to lower labor requirements to service this smaller area. We therefore test whether deliveries are correlated with total acreage cropped in the seven counties in our sample receiving deliveries.

As one would expect, there is a strong and statistically detectable relationship between deliveries and area cropped in our sample. The model specifications are the same as those used for farm employment, only that we use total area cropped in acres as the left hand side variable. The estimated effect of Delta deliveries on farm acreage suggests that each additional 36.49 acre-feet of deliveries from the Delta are consistent with one additional acre cropped. This relationship is robust across specifications and always significantly different from zero at the 1% level of significance. This finding suggests that Delta exports affect cultivation (and fallowing) in a detectable and significant way.

## Conclusions

There has been a lively debate surrounding the importance of irrigation water for agricultural employment. Using data on actual agricultural employment and deliveries from 1980–2007, we find that the number supported by the data is close to 5,000 jobs lost—due to water-delivery reductions in the Central Valley between 2005–2009, which is roughly a 5% decrease in direct agricultural employment in the Central Valley counties receiving deliveries. Our analysis suggests that the employment effects come from decreases in area planted in years with lower deliveries.

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