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ALSO IN THIS ISSUE

2018 Trade War, Mitigation Payments, and California Agriculture

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The U.S. substantially increased a number of import tariffs in 2018, precipitating a trade war that was very costly to U.S. agriculture, given its dependence on international trade. The losses arose because several trading partners retaliated with import tariffs targeted at U.S. agricultural exports. The U.S. government then created the Market Facilitation Program (MFP) to compensate U.S. farmers for trade-war losses. Except for cotton and rice, California farmers were not made whole by the MFP payments. California's producers of tree nuts, dairy, and processed fruits and vegetables were the biggest losers.

President Trump launched a trade war in 2018 to pressure reforms of the Chinese economic system that facilitated unfair trade practices, including forced technology transfer, limited market access, intellectual property theft, and subsidies to state-owned enterprises. The U.S. government argued that new import tariffs would narrow the U.S. trade deficit with China and convince multinational companies to bring manufacturing jobs back home. While the United States imposed tariffs on more than $550 billion of Chinese products, China retaliated with tariffs on more than $124 billion of U.S. goods between July 2018 and August 2019. The trade war caused economic pain on both sides of the dispute and led to the diversion of trade away from China and U.S. bilateral flows. It also forced American companies to accept lower profit margins, cut wages and jobs for U.S. workers, and raised prices for U.S. consumers and companies. U.S. farmers lost billions of dollars in export sales to China due to retaliatory tariffs.

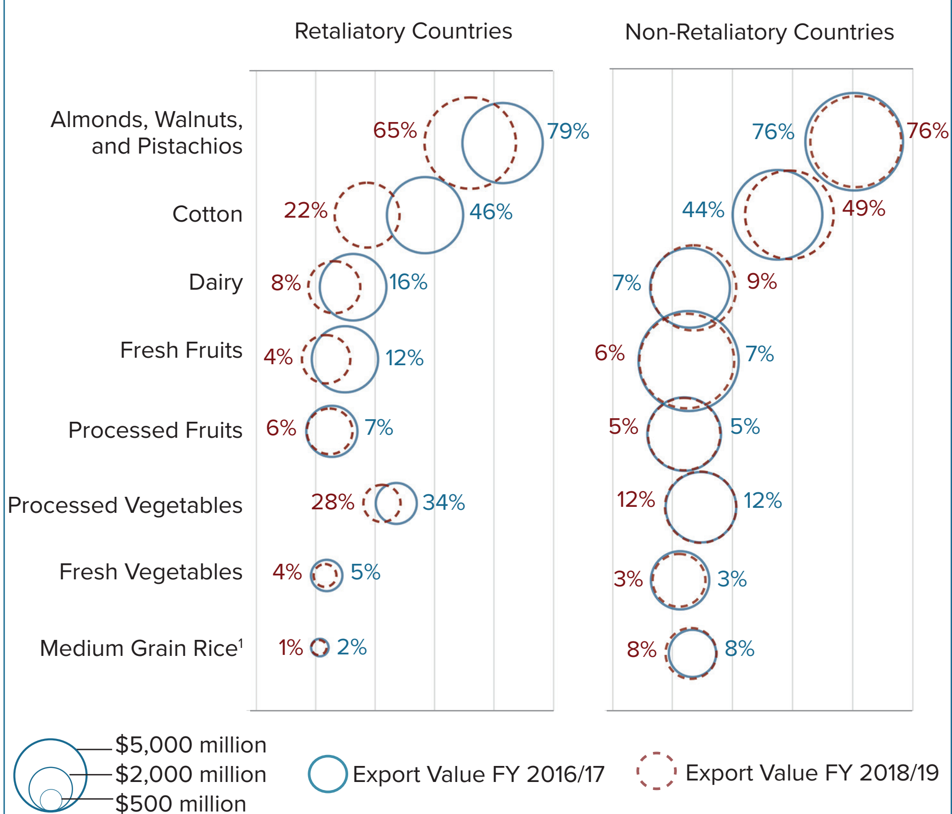
In this article, we report on research that estimates the impact of the 2018 trade war on California agriculture. We measure the lost value of exports due to the trade war and then compare the trade-war losses with the government compensation payments—under the Market Facilitation Program (MFP). We find that overall, California's losses from the trade war far exceeded the government compensation payments. The stated objective of the MFP was to provide taxpayer assistance to farmers that had been harmed by the trade war. However, in reality, the MFP program was mostly about political patronage, especially for producers of certain commodities in selected states.

The MFP was a two-year program. In this article, we refer to the 2018 MFP as MFP1 and the 2019 MFP as MFP2. The MFP1 program distributed $8.6 billion and the MFP2 upped the ante to $14.4 billion in direct payments to farmers who were considered financially harmed by trade disruptions and tariffs. Eligible commodities under MFP1 were five non-specialty crops (corn, cotton, sorghum, soybeans, and wheat), two specialty crops (fresh sweet cherries and shelled almonds), dairy, and hogs. MFP1 subsidies were calculated based on percent change in gross trade volume lost, compared to 2017. The *but for* value of trade was then estimated with a global trade simulation model.

MFP2 expanded commodity coverage and eligible commodities included: (1) 27 non-specialty crops such as grains, oilseeds, and cotton; (2) 10 specialty crops (including almonds, fresh grapes, pecans, pistachios, and walnuts); and (3) dairy and hogs. The 2019 payments for non-specialty and specialty crops were based on average county-level yields and farm planted acres. There

Figure 1. Exports of U.S. Products Before and During the Trade War[1]

Retaliated Products Relevant to California, Export Value in $ Millions, and U.S Market Share in Percent



Note: [1] Import data from the retaliatory and non-retaliatory countries used for all categories except medium grain rice. Retaliation (tariff change) identified at HS6 level. For medium grain rice, U.S. export data used for circle size and overall rice (including long grain rice) share used for vertical axis value.

Source: Global Trade Atlas by IHS Markit; authors' analysis.

were uniform county-wide payments made for eligible commodities.

To calculate MFP2 payments, the U.S. government used the maximum annual value of exports over the previous ten years as the baseline, which greatly inflated payments in 2019 compared to 2018. Under MFP2, California farmers received about $355.4 million in total, which worked out to about $31,733 per farming operation eligible for payments. The amount paid out to California was about $99.1 million for non-specialty crops, $186.3 million for specialty crops, and $70.1 million for livestock (mostly dairy and dairy products).

Compared to its share of agricultural commodities impacted by the trade war and the losses incurred, California was not a big recipient of MFP payments. We found that California losses during the first year of the trade war (2018–2019) were about $875.1 million. MFP1 and MFP2 payments amounted to $96.0 and $355.4 million, respectively for 2018 and 2019. So even if we combine the MFP compensation for two years, it is only about one-half of the California trade losses in a single year. Unlike the case for several states in the Midwest and Southern U.S., overall the farmers in California were undercompensated. However, some commodities were overpaid (e.g., rice and cotton), while others were undercompensated (e.g., nuts and dairy), and some received no compensation at all (e.g., processed vegetables and fruits).

The 2018 Trade War

The U.S. government imposed tariff increases against major trading partners in 2018. These new tariffs were implemented for a variety of stated reasons, including national security concerns and the desire to force economic policy change in foreign countries. In response to U.S. tariffs, several trading partners imposed retaliatory tariffs against products imported from the United States. These countermeasures increased the average import tariff from 7.5% to 23.5% for 6,341 products covering about $124 billion (14.4%) of the pre-trade war imports from the United States. This return to protectionism is unprecedented in recent U.S. history (at least not since the Smoot-Hawley 1930 tariffs), measured by the number of countries and products involved, as well as the magnitude of the tariff increases. The retaliatory tariffs depressed U.S. exports of targeted products and impeded the ability of U.S. producers to compete in international markets.

In relative terms, the agricultural and food industry was affected more by retaliatory tariffs than any other sector of the economy. China imposed retaliatory tariffs on almost all agricultural and food products; Canada on processed meats, and fruits, vegetables, coffee, and whiskey; Mexico on processed fruits, and pork, cheese, and vegetables; the EU on processed vegetables, and legumes, grains, fruit juice, peanut butter, and whiskey; and Turkey on tree nuts, rice, some prepared foods, whiskey, and tobacco.

We calculated that the average foreign tariff on U.S. agricultural and food products increased from 8.3% to 28.6%, targeting 908 products and encompassing more than $31.9 billion USD (37.1%) of agricultural and food exports of the United States. The impact of retaliatory tariffs was particularly significant for agricultural and food trade with China. U.S. exports of agricultural products to China decreased by 53% between 2017 and 2018.

Several of the retaliatory tariffs were ultimately lifted as a result of ongoing negotiations. In May 2019, Canada and Mexico lifted their retaliatory tariffs to clear the way for the ratification of the United States-Mexico-Canada Agreement (USMCA), as the U.S. also lifted its tariffs on steel and aluminum from Mexico and Canada. The U.S. and China reached a trade deal in January 2020 that could ease trade tensions, as China committed to significantly increase imports of bulk products such as corn and soybeans from the United States.

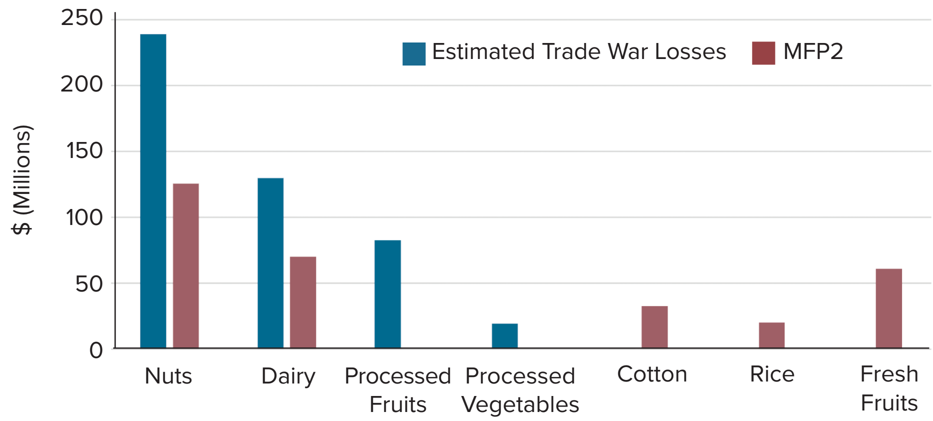
California Impacts

While the trade war had profound implications for the agricultural and food industry in the U.S. as a whole, it had even a more substantial impact on California's farmers and food processors. Research at Iowa State University found that California incurred the largest net economic welfare loss among all states, after accounting for taxpayer cost of the MFP payments. As the trade war winds down, one of the most important questions for California agriculture is what sort of export opportunities were left on the table because of the trade war?

Globally, China is one of the largest importers of agricultural products and China's agricultural imports were growing rapidly in 2018 and 2019. However, to some extent, California was closed out of this market because the retaliatory tariffs favored other exporting countries that were not subject to these tariffs. For instance, Australia (almonds, grapes, oranges, walnuts), Peru (grapes), Chile (walnuts, grapes), Egypt (oranges), and Iran (pistachios) gained from the Chinese tariffs against the United States. Before the trade war, California was the major exporter of walnuts to China, but with the retaliatory tariffs, China shifted to Chile and Australia for imported walnuts. Almost all California products exported to China experienced a significant drop in market share, with the U.S. market share for tree nuts (almonds, pistachios, and walnuts) dropping from 94% to 53%, the dairy market share falling from 9% to 3%, and so on.

We quantified the impact of tariff increases on foreign trade with both retaliatory and non-retaliatory countries in research for the National Bureau of Economics Research (NBER). We developed and estimated an empirical model that accounts for the reallocation of exported products across markets. We measured the reduction in trade of targeted agricultural products with retaliatory countries (i.e., trade destruction) and found some increase in trade with other non-retaliatory countries for some commodities (i.e., trade diversion).

Figure 2. MFP2 Payment vs. FY 2018 Trade Loss for California Products, $ Millions



Source: USDA FSA MFP payment data; authors' analysis

Figure 1 shows summary trade statistics for exports of agricultural products that were: 1) important to California agriculture, and 2) faced steep retaliatory tariffs. Each circle represents a two-year (July–June) cumulative value of U.S. exports. The left side of the figure shows exports to retaliatory countries and the right-side exports to non-retaliatory countries. The blue solid line circles represent exports before the trade war and the red circles show export trade values during the trade war. The size of each circle represents the value of exports. The two horizontal axes represent the share of U.S. exports in the retaliatory and the non-retaliatory countries, and the shares are shown as blue (2016/17) and red (2018/19) percentages, respectively.

With the exception of tree nuts, all of the red circles are smaller than the blue circles for exports to retaliatory countries, indicating the destruction of U.S. exports of named products to the retaliatory countries. The larger red circle for tree nuts does not indicate these products gained from the trade war. As mentioned above, in China alone, California tree nuts experienced a significant loss in market share, in a market that was growing rapidly. That is why for exports to retaliatory countries, the share for almonds, walnuts, and pistachios drops from 79% to 65% during the trade war.

China was the only country to impose retaliatory tariffs on cotton. The U.S. cotton share of imports by China fell from 46% to 22%, a swing that is not unusual in that market. Furthermore, total U.S. exports of cotton did not decline during the trade war. During this time period, U.S. cotton exports to non-retaliatory importers gained market share (from 44% to 49%), evidence of trade deflection.

The right-hand side of Figure 1 tells the story of exports to non-retaliatory countries. For the most part, the circle sizes are very similar before and during the trade war, as are the market shares. This finding means those products that suffered market share losses in the retaliatory countries did not make up for the losses by diverting lost exports to non-retaliatory countries.

The 2018/19 trade losses for California versus MFP2 payments are shown

Table 1. Government Payment vs. Net Farm Income, 2019[1], Selected States, $ Millions

States	Net Farm Income	Total Government Payment[1]	Total Government Payment as % of Net Farm Income	MFP Payment as % of Net Farm Income
	$ Millions		Percent	
California	11,071	420	4	2
Texas	5,646	1,788	32	18
Nebraska	4,158	1,122	27	21
Iowa	3,229	2,066	64	47
Illinois	2,770	1,738	63	52
Georgia	2,676	700	26	11
Florida	2,575	232	9	1
Pennsylvania	2,315	173	7	4
Kansas	2,319	1,410	61	43
North Dakota	1,762	1,056	60	41
Mississippi	1,420	599	42	23
Alabama	1,174	231	20	11
Arkansas	974	990	102	48
U.S. Overall	83,721	22,447	27	17

Note: [1] Government payment refers to federal direct farm program payments, mainly MFP payments for 2019; Data are for 2019 calendar year.

Source: USDA ERS, Farm Income and Wealth Statistics, 2020

in Figure 2. This figure reports the estimated trade losses for fiscal year 2018 (i.e., July 2018–June 2019), shown by the blue vertical bars. Losses in year two of the trade war were likely higher because some tariffs increased. These annual losses measure the net impact of the retaliatory import tariffs on California's agricultural exports, allowing for re-direction of exports to non-retaliatory countries—trade deflection. Tree nuts suffered losses of about $239 million, and the MFP payments ($126 million) were only about 52% of the loss. Similarly, dairy exports experienced losses of about $130 million, much more than the compensation amount of $70 million. Processed fruits and vegetables experienced trade war losses but received no MFP payments.

In contrast, we find that the U.S. government overestimated the true impact of the trade war on fresh fruits, rice, and cotton, and therefore overcompensated these commodities. For instance, the MFP2 payment to cotton was about 40% of the market price, which was unwarranted in our view because we find a *de minimis* loss for cotton as a result of the trade war. U.S. exports of medium grain rice actually increased during the trade war and California exports were steady. In our research, we find no evidence of a trade loss for California rice.

Table 1 shows federal government farm payments (including MFP and other farm subsidies) by state, reported as a share of net farm income for 2019. In the last column, the MFP payments are also reported as a share of net farm income. California stands out as a relatively small recipient of farm payments (4% of net farm income) and a very small recipient of MFP payments (2% of net farm income). In contrast, in a number of states, the MFP payments accounted for a very large share of net farm income, up to 52% in Illinois.

Conclusion

The U.S. government underestimated the overall economic losses incurred by California's agricultural and food producers due to the 2018 trade war. While the MFP program overcompensated some farmers, others faced substantial trade-war losses that outweighed MFP payments. Particularly, export-oriented food processors were heavily affected by retaliatory tariffs but received no compensation from the U.S. government. The unequal treatment of agricultural and food producers impacted by the 2018 trade war is a pattern also observed in other states. However, these inequalities are more pronounced in California than in any other state. California's producers focus on high value-added products and have a significant stake in reducing trade barriers everywhere, and in particular in China. The MFP payments may have jeopardized international trade arrangements because the excessive payments violated U.S. farm subsidy commitments to the World Trade Organization (WTO). Several countries are considering a challenge at the WTO in opposition to these huge payments. This dispute could cause the effects of the trade war to drag on.

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For additional information, the authors recommend:

Carter, C.A., and S. Steinbach. 2020."The Impact of Retaliatory Tariffs on Agricultural and Food Trade." National Bureau of Economic Research, w27147.

By-Product Use in California Dairy Feed Has Vital Sustainability Implications

Scott Somerville, Daniel A. Sumner, James Fadel, Ziyang Fu, Jarrett D. Hart, and Jennifer Heguy

Milk cow feed rations in California include a huge variety of by-product feeds that contribute a substantial share of nutrition. By-product use helps moderate feed costs, provides important income to by-product suppliers, frees Central Valley crop farm resources (land and water) for other uses, and reduces environmental consequences of waste.

Based on a 2019 survey of California dairies, 95% of San Joaquin Valley respondents fed by-products in their rations.

Photo Credit: Karen Higgins, UC Davis

Dairy farms everywhere seek economically feasible and nutritionally adequate feed rations for their cows. Feed for cows and heifers represents more than half of the cost of milk. Therefore, how dairies meet these feed challenges determines, to a large extent, the economic, social, and environmental sustainability of the dairy industry.

Processing and distribution of agricultural raw materials generate by-products that may be used as feeds. This article summarizes the current situation for the use of by-products as feed ingredients in the rations of dairy cows and heifers in California. A "by-product" is the residual material, of plant or animal origin, produced during the harvest or manufacturing process of a primary product. For example, feeds such as soybean meal or canola meal are considered feed by-products where the primary product is vegetable oil. Corn distillers' grains and corn gluten feed are by-products of corn processing for the primary products—corn sweetener and ethanol. Cotton seed and almond hulls are important by-product feeds that are from California-grown raw materials.

We show that feeding by-products, including many that are produced near California dairies, is a major feature of the California dairy farm rations and plays a significant role in processing and distribution for many California crops. We also show that, absent dairy by-product feeds, much more land and water resources would be dedicated to dairy feed production and that much more by-product biomass would enter the waste stream, generating troublesome environmental consequences.

Background

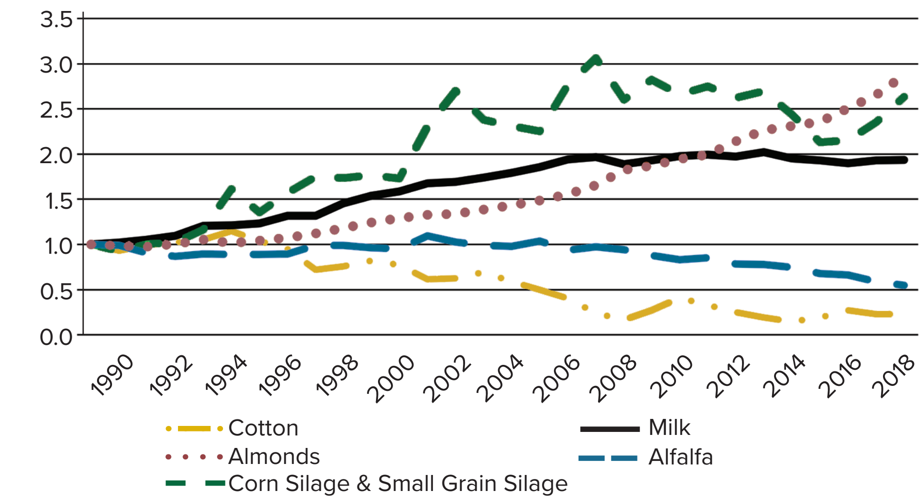
Most milk cows in California are in the San Joaquin Valley, surrounded by millions of acres of fruits, nuts, vegetables, and cotton, as well as the processing and distribution facilities that handle these crops. The wide variety of crops that generate potentially useful by-products has facilitated extensive use in feed rations, especially by the dairy industry.

Dairy farming is the largest farm industry in California measured by farm revenue, which has averaged about $7 billion in recent years. The California dairy herd is the largest in the U.S., with approximately 1.7 million dairy cows, plus replacement heifers. About 90% of cows are on farms in the Central Valley, kept in freestall barns or open lots year-round, and fed a ration of forages, cereal grains, by-product feeds, and supplements. There is very little grazing except for the 4% of cows in the organic segment, mostly in the North Coast region, where cows get a portion of their forage from pasture as required by federal regulations. California dairy is closely linked to other parts of agriculture and the California economy because much of the feed is local, and almost all the processing of California milk is local as well.

The rations fed to milk cows balance the nutrition needed to achieve a target milk production, with continued cow health, and cost. As the relative price of milk to feed falls, cows are fed more inexpensively, and milk production falls. As cow genetics, price and availability of feeds, and the price of milk change, the rations change as well. For milk cows in California, grains and oilseed meals, which supply energy and protein, are typically shipped in from the Midwest States, Plains States, and the Prairie Provinces. Local corn and other grain silages supply energy and roughage, and western alfalfa hay supplies energy, roughage, and substantial protein.

Figure 1 shows the steady growth in California milk production from 1990 through about 2007 and no growth since then. At the same time, almond area grew more slowly than milk production through about 2012. However, since then, almond area has grown by 50%, while milk production stagnated. California silage area tripled from

Figure 1. California Milk Production, and Area of Almonds, Cotton, Alfalfa Hay, and Silage (All Shown Relative to 1990)



Source: USDA, NASS.

1990 to 2008, but then lost a third of that growth by 2017 before beginning to rise again. Meanwhile, cotton area declined by more than 80% by 2009 and has been steady since, while alfalfa area was steady until 2008 and declined by half since then.

Figure 1 documents that in 2019 milk production had become double what it was 30 years ago, while alfalfa area, much of which is used to feed California cows, had fallen by half. Silage area expanded to supply feed for the milk production growth for the first two decades of the period, but has fallen over the past decade. As we shall see below, almond hulls have increasingly become a vital feed source, just as dairies provide a vital outlet for the ever-expanding quantity of hulls.

By-Product Feeds in the California Dairy Rations

Overall, we find more than 70 distinct by-product feeds used on California dairy farms. Table 1 reports some of the California-produced by-products reported in our 2019 survey of California dairies, a follow-up with ten case study farms in the San Joaquin Valley, and California Department of Food and Agriculture (CDFA) information from 2017. Most products, and most tons of by-products, are California-produced. Some notable by-products that are shipped into California are canola meal, soybean meal, soy hulls, and dry by-products of the corn ethanol and high-fructose corn syrup industries.

The Table 1 list gives a sense of the wide range of sources. For example, rice and wheat straw are derived from farm harvesting processes. Others, such as citrus pulp, tomato pomace, and bakery waste, are derived from food manufacturing, and finally, some, such as asparagus and kiwis, are vegetables and fruits diverted from human consumption. Not all by-products are plant-based. For example, whey, an important by-product from cheese production, generally enters the human food market, but some is returned to dairies to be used as feed. Some by-products, like dried poultry litter, can only be fed to heifers, and some vegetables, like onions, are only fed to heifers and dry cows to avoid milk taint.

The share of feed costs in milk production varies depending on relative prices from about 50% to 60%. Based on CDFA data for California dairies overall for heifer, dry cows, and lactating cows combined, by-products represent about 35% of feed costs and about 35% of total dry matter fed. Based on our 2019 survey of California dairies, 95% of San Joaquin Valley respondents fed by-products in their rations.

The CDFA gathered extensive cost of production information, including detailed feed rations from more than 100 dairy farms. Almond hulls, canola meal, cottonseed, and distillers' grains were the major by-product feeds as measured by the share of dry matter in a ration. Canola meal accounts for 8% of feed costs, with cottonseed and almond hulls accounting for about 6% and 3.5%, respectively. Distillers' grains, dry and wet, account for another 4.5% of ration cost. More than 65 other by-products together account

Table 1. California-Produced By-Product Feeds and Categories

Almond hulls	Citrus, pulp and dried	Onions
Almond shells	Cottonseed,	Pomegranates
Almond skins and meal	Cottonseed meal	Raisin tailings
Apple and apple pomace	Distillers' grains, wet	Rice bran
Asparagus	Distillers' syrup	Straw, rice
Bakery waste	Fats, vegetable and animal	Straw, wheat and other grain
Beet pulp and molasses	Fish meal	Sunflower meal
Bloodmeal	Garlic	Sweet potato
Brewers' grains and yeast	Grain screenings	Tomatoes and pomace
Cabbage	Grape pomace	Whey
Carrots and carrot pulp	Kiwis	Wheat middlings
Chaff hay	Nutmeal	Vegetable juice pulp
Cherries		

Source: 2019 Survey and Case Study, and 2017 CDFA dairy cost of milk production data.

for another 13% of feed costs. Scaling up to statewide totals, these CDFA data indicate that in California in 2017, about 5.5 million tons (on a dry matter basis) of by-product feeds were included in rations for lactating and dry cows.

Table 2 shows the nutritional content of major California-produced by-products in dairy rations. Overall, California by-products supply about two-thirds of the total by-product dry matter and similar shares of total digestible nutrients. California-produced by-products supply almost one-quarter (0.67 X 0.35) of the dry matter of California dairy rations.

The San Joaquin Valley is home to about 1.5 million dairy cows and large crop production, processing, and food manufacturing industries. Low transport costs for by-products are especially important for moist, perishable by-products, which may be consumed on the same day as delivery, without further treatment to preserve the feed. For many California-produced by-products, limited alternative markets exist without further processing and transportation. When no alternative market exists, the by-product is destined for waste in the absence of a local dairy market.

Almonds represent the largest crop industry, by acreage and value, in the Central Valley and are a major economic contributor. Roughly 95% of the 2.55 million tons of almond hulls produced are used as dairy feed. As the almond industry has expanded, the quantity of hulls fed has likewise grown. Producers of almonds received a price of $4,860/ton for kernels in 2019 and $121/ton for hulls. With 2 pounds of hulls produced for every pound of kernels, hulls generate about 5% of the almond industry's revenue.

After decades of decline, cotton production has stabilized in California. About 290,000 tons of cottonseed were produced in California in 2019. About 65% of cottonseed is sold whole from the cotton ginners to Californian dairy farms. Cottonseed is a high-protein, high-energy feed that is fed with no additional processing. About 30% of cottonseed is crushed for oil and meal, and the remaining portion, less than 5%, is used as planting seed. We expect almost all cottonseed meal produced in California is sold to dairies. Cottonseed generates about 20% of cotton production revenue and cotton lint the other 80%.

Grape pomace, the mixture of seeds, stems, and skins produced after crushing, is an important by-product feed. In 2019, 4.11 million tons of grapes were crushed in California. Grape pomace accounts for about 25% of the fresh weight of grapes. For large San Joaquin Valley wineries, we estimate, based on industry interviews, that 90–95% of pomace is sold wet as dairy cattle feed. Dried grape pomace has a national market as feed. Composting of grape pomace is an option, whereas some pomace in Napa and Sonoma counties may be sent to landfills. During peak supply, wineries pay $10/ton for the collection of pomace, while at other times, wineries receive $15/ton for pomace that is stored and collected off-season.

Table 2. Nutrition Supplied to Dairy Cattle from California-Produced By-Products

	Dry Matter	Total Digestible Nutrients	Crude Protein
		(Million tons)	
Almond hulls	2.11	1.23	0.14
Corn distillers' grains*	0.53	0.42	0.16
Grape pomace**	0.30	0.10	0.04
Cottonseed and meal	0.23	0.18	0.06
Whey	0.22	0.18	0.03
Straw***	0.17	0.08	0.01
Brewers' spent grains	0.05	0.04	0.01

Notes: * Most of the corn distillers' grains are shipped into California. Shown here is 2019 California production, which is all wet distillers' grains. Production in 2020 has averaged half of 2019 production. California distilleries mostly use corn that is shipped into California.

** About 500 thousand tons of additional cottonseed is shipped in to California.

***Dry matter, total digestible nutrients, and crude protein analysis based on wheat straw

Source: Calculations based on 2019 author Survey and Case Study and 2017 CDFA dairy cost of milk production data.

If California By-Product Feed Supply Was Reduced

Based on nutritional requirements and costs of by-products and substitute feeds, we estimate that if no by-products were available, average ration costs would rise by about 20%. The implication is about 10% higher production costs and therefore less milk production in California. With no by-products, rations would include more alfalfa hay and corn grain, but less corn silage. We estimate that in this extreme scenario, 1 million acres and 4 million acre-feet of water would be required for new alfalfa hay production. In addition, 4 million more tons of corn grain would need to be shipped into California.

Reduction in supply of by-products could occur if processing industries faced regulations that caused the cost of processing and transporting by-products to rise or if the local processing industries declined. Alternatively, an increase of other demands could make by-products non-competitive as dairy feeds.

Most by-products are individually a small share of dairy rations. Therefore, if a single by-product became unavailable, there would be little change in dairy economics or resource use statewide. Some individual by-products, such as brewers' spent grains, may have important impacts locally.

A few by-products have important statewide impacts individually. For example, given an elastic long-run demand for California dairy products, we project that removing availability of almond hulls would reduce milk production in California by more than 2% because hulls alone comprise almost 3% of dairy production costs.

Increased quantities of other feeds would be used to replace the nutritional contribution of almond hulls in dairy rations. Corn silage is the forage that would likely replace almond hulls in the ration. To replace the total digestible nutrients lost from almond hulls with corn silage, grown in the San Joaquin Valley, an additional 181,000 acres and 665,000 acre-feet of irrigation water would be required. The implied increase is about 44% of the current allocation of land and water to corn silage production.

If Dairies Cut Back in Demand for California-Produced By-Products

For most processing industries, revenue from the by-product is such a small factor in the economics of the industry that reducing demand from dairies causes only small economic changes. For example, revenue from sales of brewers' spent grains is a negligible share of the revenue of the beer industry. However, loss of dairies as an outlet may have important environmental consequences as breweries struggle to find alternative places to dispose 55,000 tons (on a dry matter basis) of spent grains. These spent grains would generate 29,000 metric tons of carbon dioxide equivalent annually upon decomposition in landfills, which is equivalent to the energy use of about 5,000 passenger vehicles.

Because almond hulls account for only 5% of revenue from almond production, direct revenue impact of less demand for hulls is small. Few alternative markets now exist for almond hulls. However, in 2020, there were indications of potential future demand for pelletized almond hulls in the Chinese feed market.

Since about 20% of cotton revenues are from cottonseed, the economic implications of reduced demand for seed are significant. Given very elastic world demand for California cotton, if demand for cottonseed from California dairies declined, the price of cottonseed would fall, California cotton production would decline, and cotton industry revenue may decline substantially.

Final Remarks

Use of by-product feeds is a crucial component of the sustainability of the California dairy industry. Reduction in access to by-products would raise dairy costs and reduce the economic viability of the industry. A major implication of by-product use is to reduce the environmental and resource pressures on crop land and especially irrigation water in the San Joaquin Valley. Absent access to by-product feeds, more acres of silage and alfalfa hay would cause even more stress on these limited resources, especially groundwater. Finally, if California dairies were not available to make use of by-products, more would end up as waste. These biological materials would have environmental consequences of local and statewide importance, including additional methane emissions.

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For additional information, the authors recommend:

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Guacamole from Mexico Fuels Surge of Avocado Imports

Hoy F. Carman

This article looks at factors associated with recent rapid growth in demand for processed avocados, including adaptation and adoption of High-Pressure Processing (HPP) technology. California producer- and importer-funded research and promotion programs have changed avocados' image to that of a healthy super-food. Expanded imports from Mexico have improved year-round availability of fresh and processed products, and guacamole's popularity.

Strong increases in U.S. consumption of processed avocado products have been largely overlooked, while popular attention has focused on the demand for fresh avocados. The major reason for this gap in knowledge is a lack of reliable statistics on avocado processing and U.S. sales of processed avocado products. Despite the significant data issues associated with measurement of processed avocado sales and consumption, there is an important story to be told. Avocados are a healthy, nutrient-loaded food product and U.S. consumption has grown rapidly. Processed avocado imports from Mexico have recently accelerated and their continued growth has important implications for U.S. producers, consumers, and the Mexican avocado industry. Sound economic reasons support Mexico's dominance in supplying processed avocado products to the U.S. market, and the underlying factors fueling recent growth of processed avocado imports are expected to continue.

Processed Avocado Imports

Avocados have evolved from a seasonal specialty to a year-round staple in both the supermarket produce aisle and consumer diets. U.S. fresh avocado consumption increased from 1.47 pounds per capita in 1989 to 8.07 pounds in 2019, with Mexico accounting for most of the increased supplies. At the same time, U.S.-processed avocado imports increased from a minuscule 0.01 pounds per capita in 1989 to almost 0.75 pounds in 2019, with Mexican product dominating imports. The processed import share of total U.S. avocado consumption increased from less than 0.5% (product weight) in 1989 to 8.5% in 2019.

Figure 1 shows the growth in processed avocado imports from 1989 through 2019. Growth was slow and steady through 2016, and then accelerated from 2017 through 2019. Processed avocado imports first exceeded 50 million pounds in 2000. It took another 11 years of growth to exceed 100 million pounds in 2011. With explosive growth beginning in 2017, it took only three years to add almost 100 million more pounds of processed imports.

The stair step pattern of growth in processed imports appears to be partially due to the addition of new processing capacity and establishment of new plants in Mexico over time, as well as increased market penetration for processed products. New avocado processing capacity is lumpy, even though the product mix can be flexible. The description of an avocado processing plant recently brought online in Mexico is illustrative. The plant has 190 employees operating two product lines with two high-pressure processing (HPP) machines, four packaging machines, and a capacity of 55,000 pounds of processed product per day. This plant, operating five days per week for 50 weeks can add 13.75 million pounds annually to processed avocado supply and exports.

U.S.-processed avocado imports are comparatively large when measured against total California avocado production. California produced an annual average crop of about 290 million pounds of fresh avocados for the five years from 2015 through 2019. Processed avocado imports totaled 246.6 million pounds (product weight) in 2019, but were certainly much higher in terms of the fresh-product equivalent. Research sponsored by the California Avocado Commission (CAC) indicates that the average yield of edible product for Hass avocado sizes 36 through 84 is 70%. One

Figure 1. Annual U.S.-Processed Avocado Imports, Million Pounds Product Weight, 1989–2019

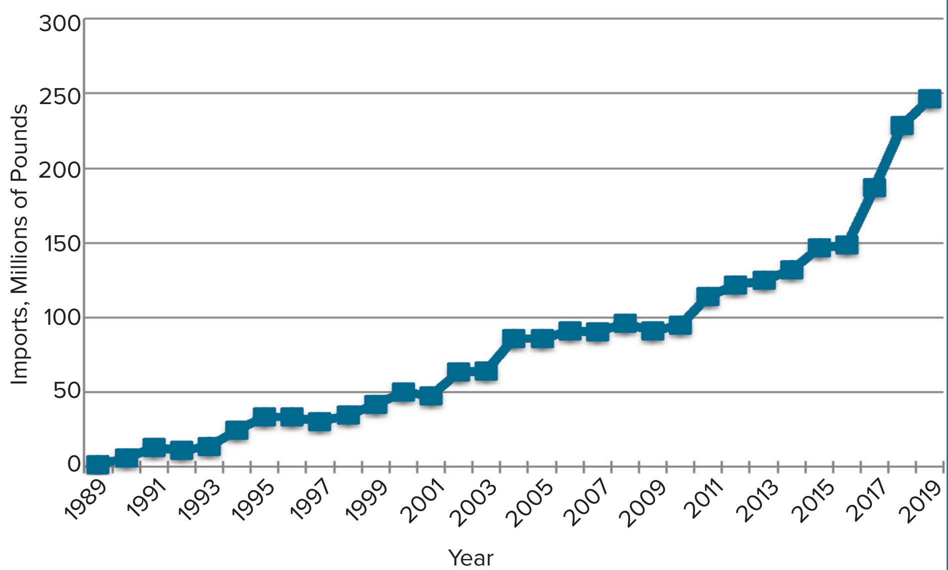
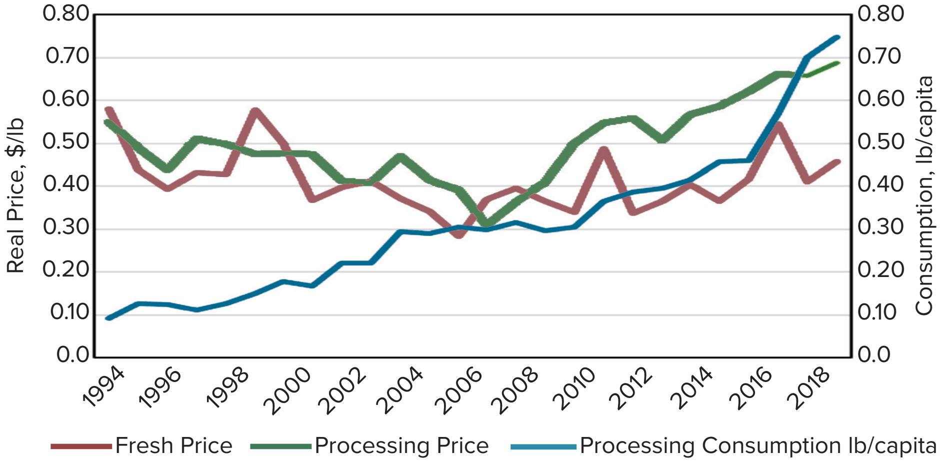


Figure 2. U.S.-Processed Avocado Imports with Real (1982–84 = 100) Port of Entry Processed Prices and Real Fresh F.O.B. Prices, 1994–2019



pound of processed avocado is thus equivalent to about 1.43 pounds of fresh avocados. A further complication is that some processed products such as guacamole contain other ingredients. Overall, it is likely that 2019 processed avocado imports required some 350 million pounds of fresh avocados. This amount exceeds the recent 5-year average California production by almost 20% and not all of the imported product was included in the processed import data. Some of the shortcomings in processed avocado data are discussed below.

Processed Avocado Data Issues

There are two reasons for shortcomings in U.S-processed avocado consumption data. First, the USDA and California did not report processed utilization of the California avocado crop because of confidentiality requirements. Thus, even though Calavo processed as much as 20 million pounds of guacamole and other avocado-based items annually in its Santa Paula, California plant from 1974 until it was closed in 2003, all of California's production was reported as fresh sales and consumption. Second, after the California plant closure in 2003, the U.S. became dependent on imports for almost all of its processed avocado needs. While the U.S. reports quantity and value of processed avocado imports, the data are incomplete because several processed avocado products are not reported separately. For example, frozen avocados (without additives) are reported in a category that includes all frozen fruits.

Mexican Avocado Processing

It is no accident that Mexico accounts for nearly all of the supply of processed avocado products in the U.S. market. It is the world's largest avocado producer, with year-round production and with labor readily available at lower wage rates than in the United States. In addition, U.S. markets are readily accessible to Mexican producing areas, major U.S. avocado marketing firms have significant investments in the Mexican avocado sector, its planted acreage continues to expand significantly, and it is the world's low-cost producer. Mexico has all of the necessary inputs for continued expansion. California's largest avocado processor's move to Mexico in 2003 was dictated by Mexico's clear advantage in comparative costs of production for avocados.

The UN's Food and Agriculture Organization (FAO) reported that 14 firms processed Mexican avocados in 2013. Included were a combination of Mexican, U.S.-based, and international firms. Mexico's dominance in supplying processed avocados to the U.S market has increased steadily over time. During the four years from 2011 through 2014, Mexico accounted for 93.4%, with Peru a distant second at 4.9%. During 2019, the Mexican-sourced share of U.S.-processed avocado products increased to 97.9%, while Peru's share declined to 1.1%.

U.S.-Processed Avocado Demand

The channels of distribution differ for fresh and processed avocados. The California Avocado Commission (CAC) estimates that for fresh avocados, 70% of annual sales are directly to consumers and 30% are through food service channels. The ratios are reversed for processed avocados. Convenience, together with dependability of supply, uniform quality, and consistent taste are important product attributes for food service firms.

Examination and comparison of real price and consumption data for processed avocado imports provide some clues to the nature of demand for processed avocado products. While imports of processed avocados increased from less than 0.1 pounds per capita in 1994 to 0.75 pounds per capita in 2019, processed consumption remains far below U.S. fresh avocado consumption of 8.07 pounds per capita in 2019. Annual U.S. per capita processed avocado imports are shown in Figure 2, together with port of entry processed prices and weighted annual fresh avocado prices. Average annual fresh avocado prices consist of a quantity weighted average of California and Florida f.o.b. prices and all fresh avocado imports at port of entry. As noted earlier, the incomplete per capita processed import data are product weight rather than fresh equivalent. Despite these shortcomings in measurement, the increasing pattern of processed imports is similar to per capita fresh avocado consumption.

While the overall pattern of fresh and processed avocado prices are similar over the period from 1994 through 2019, with real prices reaching lows in 2006 and 2007, the relationship between the two series does not meet expectations for close substitutes until after 2008.

That is, if fresh and processed avocados are close substitutes, we would expect fresh and processed prices to show similar adjustments over time—but with processed prices above fresh prices to reflect processing costs and equivalence.

The pattern of comparative prices prior to 2008 could be due to a combination of factors including, (1) fresh and processed avocados were not regarded as close substitutes in many applications due to processing methods used, (2) demand factors differ in at-home and institutional outlets, (3) annual averages may not capture differing seasonal patterns of supply and demand, and (4) avocados utilized for processing may not be suitable for fresh market sales.

Factors Associated with Increased Demand

Existing data, while incomplete, show a significant increase in processed avocado imports and consumption over time. Several factors contributed to increased U.S. imports of fresh and processed avocados. These included:

- Nutrition and health research funded by the CAC;
- The phased opening of the U.S. market to fresh Mexican avocados;
- Approval of the Hass Avocado Promotion, Research, and Information Order that supports research and promotion programs for all fresh Hass avocados marketed in the U.S.;
- Growth of Mexican and Hispanic restaurants and menu items;
- Increasing availability of avocado imports from Mexico, Chile, and Peru;
- Active involvement of U.S.-based firms with extensive experience in avocado packing and processing.

Economic analysis of the growth of consumer demand attributes an important role to Hass Avocado Board research and promotion programs. A crucial factor for increasing processed avocado demand was the development and adoption of HPP for avocado products beginning in 1996.

High-Pressure Processing of Avocados Fueled Growth

Avocado processing has traditionally posed a number of food safety issues since unprocessed or minimally processed ready-to-eat (RTE) avocados have a relatively high risk of microbial contamination from pathogens such as Salmonella, E. Coli, and Listeria. Traditional approaches for assuring safe-to-eat avocado products used through the 1990s were accompanied by food quality and taste issues. Heat pasteurization tended to reduce avocado quality, while additives and preservatives produced flavor issues in the final product. Due to these limitations, processed avocados were regarded as clearly inferior to the fresh product in most menu applications.

The development and application of HPP for avocado products beginning in 1996 provided a solution for serious quality and taste problems. HPP is a cold pasteurization technique in which a product, already sealed in its final package, is introduced into a vessel and subjected to a high level of isostatic pressure transmitted by water to inactivate the bacteria, virus, yeasts, molds, and parasites that might be present, extending the product's shelf life and enhancing food safety. HPP also maintains the sensorial and nutritional properties of fresh avocados throughout their shelf life. Frozen HPP products can have a shelf life of up to two years.

The availability and growth of HPP processing capacity has been an important factor in the expansion of processed avocado sales, as is the convenience of having a dependable supply of high-quality inputs for food service menu items. Texas-based Fresherized Foods, which pioneered the use of HPP of avocados for production of guacamole to supply its restaurants, began commercialization of HPP slowly in 1996 and then ramped up as HPP technology and equipment improved. By 2008 Fresherized Foods was operating two processing facilities in Mexico, one in Peru, and one in Chile. The largest Fresherized Foods plant, located in Mexico, had a capacity of nearly 1 million pounds of guacamole and fresh avocado pulp per week, using seven HPP machines and 1,400 employees.

Concluding Comments

The increased U.S. demand for processed avocados from 2016 through 2019 is impressive. This recent rate of growth is likely to pause, however, because of processed avocados' dependence on food service channels and institutional outlets that have been curtailed due to the coronavirus. First quarter 2020 processed avocado imports increased 10.6%, from 61.78 million pounds in 2019 to 68.53 million pounds, achieving an all-time high. Then, with coronavirus shutdowns, second quarter volumes decreased 13.9%, from 54.54 million pounds in 2019 to 46.97 million pounds in 2020. Processed avocado imports and consumption are unlikely to fully recover until the epidemic is controlled, when it is reasonable to expect growth to resume.

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