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ALSO IN THIS ISSUE

China's Retaliatory Tariffs and California Agriculture

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Agricultural exports from California have been caught up in the more general trade dispute with China. China retaliated against U.S. steel and aluminum tariffs by imposing its own tariffs on some agricultural goods from California. The financial impact of China's tariffs on California farmers will vary by commodity, but most products will only be bruised.

> "Greater damage may come from China's 15% tariff on American fruits, nuts, and sparkling wine."
>
> *Wall Street Journal*, April 2, 2018

Fear of a growing trade war between the U.S. and China has increased volatility in commodity and equity markets and sent commodity prices and the stock market down. Manufacturers and the agribusiness industries are vulnerable because China is an important market for many products. The financial markets are also exposed because China owns more U.S. government bonds than any other country.

In January 2018, the U.S. began its trade actions against China by imposing import duties on washing machines and solar panels. Less than a week later, China launched an anti-dumping and anti-subsidy investigation into imports of sorghum from the United States. The U.S. then escalated the conflict by imposing import tariffs on steel (25%) and aluminum (10%) under Section 232 of U.S. trade law, claiming national security reasons. Subsequently, the U.S. announced possible import tariffs on as much as $100 billion worth of Chinese imports, as a challenge of China's technology licensing under U.S. trade law Section 301.

China responded to the U.S. Section 232 tariffs by announcing its own tariffs on 128 U.S.-origin products. Agricultural products account for a large share of China's imports from the United States, and therefore China included a number of agricultural products on the retaliation list, including pork, fruits, wine, and nuts. Some of the targeted products are very important California exports, including almonds, walnuts, pistachios, wine, oranges, and table grapes.

There was also a response to the U.S. Section 301 threat that could lead to 25% import duties on Chinese imports of products such as soybeans, cars, aircraft, and whiskey. China's official statements justified the retaliation in order to balance the damage caused by the 232 and 301 actions.

Table 1. China Import Tariffs Announced in Response to U.S. Section 232 Tariffs

HS Code	Commodity	Former Tariff (%)	New Applied Tariff (%)
080211	Almonds, in shell	10	25
080212	Almonds, shelled	10	25
080231	Walnuts, in shell	25	40
080232	Walnuts, shelled	20	35
080251	Pistachios, in shell	5	20
080252	Pistachios, shelled	5	20
080510	Oranges, fresh or dried	11	26
080610	Grapes, fresh	13	28
220410	Sparkling Wine	14	29
220421	Wine	14	29

Source: FAS GAIN Report CH18017, 4/2/2018

Table 2. Summary Trade Statistics, 2017 Calendar Year ($1,000 US)

	a	*b*	*c*	*d*	*e*	*f*
Commodity	U.S. Exports to all Markets	PRC Imports from all Sources	U.S. Reported Exports to PRC	PRC Reported Imports from U.S.	% U.S. Exports to PRC	% PRC Imports from U.S.
Almonds	$4,343,890	$95,528	$99,239	$92,893	2.1%	97.2%
Table Grapes	$779,911	$588,026	$22,167	$51,895	6.7%	8.8%
Oranges	$630,399	$381,825	$48,460	$86,627	13.7%	22.7%
Walnuts	$1,369,023	$33,811	$32,253	$29,829	2.2%	88.2%
Pistachios	$1,415,635	$183,794	$39,783	$177,580	12.5%	96.6%
Sparkling Wine	$25,019	$75,517	$526	$237	0.9%	0.3%
Wine	$1,166,974	$2,553,576	$67,566	$75,555	6%	3.0%

Notes: PRC: People's Republic of China; Column a, c U.S. customs data. Column b, d PRC customs data. Column e = d/a. Column f = d/b.
Source: Compiled from *Trade Data Monitor*

The purpose of this article is to discuss the likely impact of China's response to the Section 232 U.S. tariffs, focusing on a small subset of the 128 targeted products (see Table 1). I address the claim in *The Wall Street Journal* (*WSJ*) quote above that significant damage (to the U.S.) may come from China's 15% tariff on American fruits, nuts, and sparkling wine. I find that China's retaliation will not have the depth of impact on California farmers that the *WSJ* implies.

Prior to the Section 232 retaliation, China's import tariffs on the products in Table 1 ranged from 5% on pistachios to 25% on walnuts in the shell. The new tariffs increase the rate on walnuts to 40%. Walnuts have a higher Chinese tariff than some of the other nuts because China is a large producer of walnuts, with an annual harvest about three times the size of the U.S. harvest. In contrast, China is a relatively small producer of almonds and pistachios.

California Agricultural Exports to China

China ranks in the top five foreign markets for California agriculture and the most important exports to China include almonds, pistachios, walnuts, wine, and dairy. Four of these products were subject to the April 2018 retaliatory tariffs, with dairy an exception. Table 2 reports summary trade statistics for the seven agricultural products in Table 1, for calendar year 2017. Pistachios exports account for the largest export value to the People's Republic of China (PRC), equal to $177.58 million in 2017 (see column d in Table 2).

A number of press reports on the retaliatory tariffs have failed to grasp the importance of the supply and demand elasticities in the export/import market. Furthermore, they have misinterpreted the trade statistics and therefore arrived at wrong conclusions. For instance, in an April 2, 2018 opinion editorial in *The Wall Street Journal* entitled "Two Can Play at Trade War," it was reported that China is the largest export market for California's nut farmers. The *WSJ* reported $530 million in pistachio exports to China and $518 million in almond exports, totaling $1.05 billion for 2016. However, China customs statistics report total imports of almonds and pistachios (from all origins) of only $279 million in that year.

Apparently, the *WSJ* treated Hong Kong and China as one and the same. This is not the case and, in fact, Hong Kong is a much larger destination for California pistachios and almonds than is China. This means that China is not the largest foreign market for California's nuts because India and Germany are larger, even if we account for some likely black market re-exports to China through Vietnam.

The *WSJ* also singled out sparkling wine as a product that could be significantly damaged. This is doubtful, because the China market accounts for less than 1% of U.S. sparkling wine export sales (column e of Table 2) and even if that market is lost due to the tariffs, the sparkling wine will be sold elsewhere. The sparkling wine price will be unaffected because the U.S.–China trade is only worth about $237,000 per year (column d in Table 2).

Table 2 shows both reported official U.S. exports numbers to China (column c) and official Chinese import statistics (column d) for each product. These data are from the customs bureaus in each country. It is important to note that the U.S. export and Chinese import numbers do not necessarily match for each commodity, which is not surprising. For example, in 2017 the U.S. reports $22.167 million in table grape exports to China whereas China reports table grape imports from the U.S. totaling $51.895 million. In addition to table grapes, China's reported import value is higher than the corresponding U.S. export figure for oranges, pistachios, and wine (compare columns c and d).

The largest gap appears with the pistachio trade, with PRC imports from the U.S. at $177.58 million and exports from the U.S. at $39.783. These differences arise because some of the U.S.

Table 3. Hong Kong Imports and Re-Exports (2017)

		2017 ($1,000)			
		Almonds	**Table Grapes**	**Pistachios**	**Walnuts**
	Imports	$370,408	$493,834	$714,041	$40,702
	Re-Exports				
World		$215,386	$363,883	$302,386	$29,335
Vietnam		$98,000	-	$164,218	$5,995
United Arab Emirates		$34,062	-	-	$7,587
India		$32,069	-	-	$6,429
China		$26,670	$358,280	$127,125	$3,474
Pakistan		$10,382	-	-	-
Other		$14,204	$5,603	$11,044	$3,367
	Trade Balance	–$155,022	–$129,951	–$411,655	–$11,367

HS codes: Almonds 080211, 080212, Table Grapes 080610, Walnuts, 080231, 080232, Pistachios 08025

Source: Compiled from *Trade Data Monitor*

exports of table grapes, oranges, pistachios, and wine destined for China are trans-shipped through Hong Kong and this trade is not picked up by U.S. export statistics. The reason is that the U.S. reports the products as going to Hong Kong, but if Hong Kong does not further process the products and instead ships them to the PRC, then PRC import statistics report the U.S. as country of origin.

This means the most reliable estimate of the value of trade between the U.S. and China for these commodities appears in column d of Table 2, PRC imports from U.S. This is the trade value that has been targeted by the April 2 retaliatory tariffs. There is not $1.05 billion in annual almonds and pistachio trade at risk. Rather the number is $92.893 + $177.58 = $270.493 million for these nuts in 2017. In other words, the market for these two nuts is about one-third of the size implied by the *WSJ*, and so the tariff impacts will be much smaller than suggested by this leading newspaper.

Further explanation of the actual value of trade at risk due to the trade dispute comes with examination of Hong Kong re-exports. As shown in Table 3, Hong Kong, a major port, receives a large volume of California agricultural exports that are actually destined for other countries. Hong Kong operates its own customs and tariff regime separate from China. Therefore, agricultural products shipped to Hong Kong and consumed there or shipped to places other than China will not be subject to the new tariffs.

From Table 3, we see that most of the table grapes imported into Hong Kong are re-exported to China. Imports of table grapes in 2017 totaled $493.8 million, and re-exports were valued at $363.8 million (74%), mostly to China. The largest suppliers of table grapes to Hong Kong are Chile, Australia, and Peru, in that order.

Hong Kong's trade balance (re-exports minus imports) is rather large for almonds and pistachios, given that Hong Kong's population is only 7.4 million. The large negative trade balances are likely due to further processing of almonds and pistachios in Hong Kong and some smuggling of products into China.

Vietnam is a major destination for Hong Kong re-exports of almonds ($98 million) and pistachios ($164.2 million). In all likelihood, a significant share of these nuts is either processed in Vietnam and/or sent to China via the black market. There are no reliable trade export statistics from Vietnam so the smuggling cannot be easily measured. In any case, none of the unofficial re-exports ending up in China will be subject to the new tariffs.

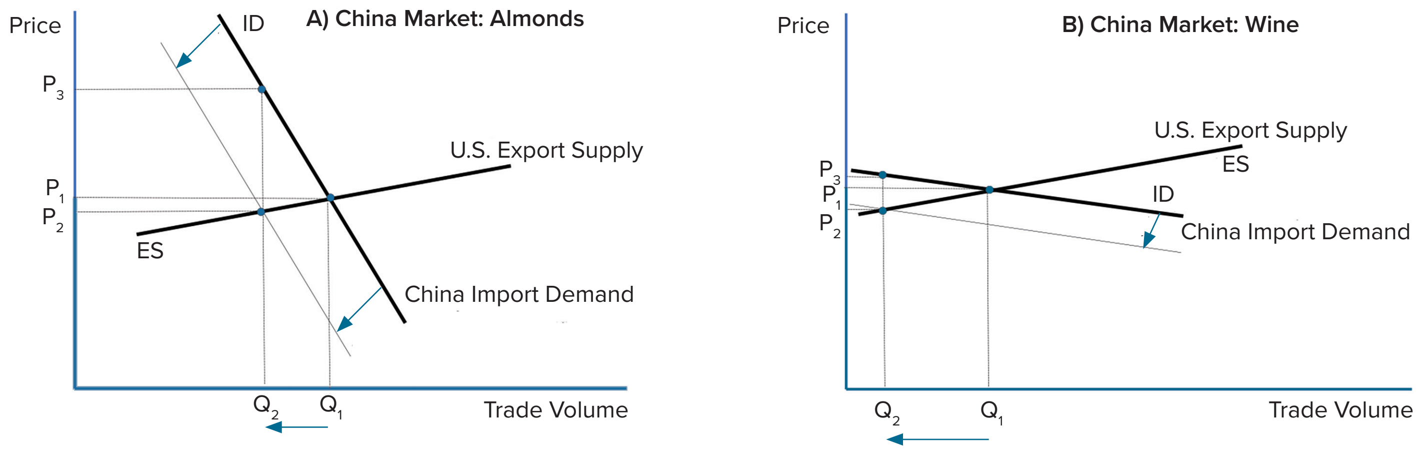
Incidence of Import Tariffs

The imposition of these import tariffs means that prices in China will be elevated and, at the same time, prices in the U.S. will be under downward pressure. Export volume from the U.S. to China will decline, holding all other factors constant. The extent of the "damage" to U.S. suppliers will depend on a number of considerations, including the relative importance of the Chinese market to U.S. suppliers, the U.S. share of China's imports, the availability of substitute products from other exporters, and the shapes of the U.S. export supply and China import demand curves.

To help us evaluate the role of these market characteristics, a stylized supply and demand model is shown in Figure 1 on page 4, representing the market for China's imports. Figure 1A could represent the almond market, characterized by a very large import market share held by U.S. exports (see column f in Table 2). The China import demand curve (ID) in Figure 1A is drawn as downward sloping and rather steep (i.e., more inelastic) because China is dependent on the U.S. supply. At the same time, the U.S. export supply curve (ES) is drawn as upward sloping but relatively flat (i.e., more elastic). ES is depicted this way because exports to China account for a very small share of overall U.S. exports (2.1%, see column e in Table 2). In other words, the U.S. is not very dependent on the Chinese market.

Prior to the tariff, the trade price is P_1 and the volume of trade is Q_1. The tariff is shown as a leftward shift in the Chinese import demand curve (ID),

Figure 1. Impact of China Import Tariffs



with the new demand curve depicted as the lighter line parallel to the original ID. As a result of the tariff, U.S. exports to China decline from Q_1 to Q_2. There is now a gap between the U.S. landed export price P_2 and the internal price in China P_3, as the tariff creates a price wedge. The incidence of the tariff is shared by U.S. sellers (who receive a lower price) and Chinese buyers (who pay a higher price). In this case, most of the price impact falls on Chinese consumers. Please note that this figure is not drawn to scale; rather than showing the exact impact of a 15% *ad valorem* tariff, the graph is drawn to represent a simpler specific tariff, with the main purpose to demonstrate the relative size and direction of price and volume effects.

Alternatively, consider Figure 1B, a similar model to Figure 1A but more representative of the wine market. In this case, China is not at all dependent on U.S. export supplies. The large wine suppliers to China are France, Italy, and Chile. Together, those three countries supplied 78% of China wine imports in 2017. As a result, China's import demand for wine is depicted as being rather flat (i.e., more elastic) in Figure 1B. In this market, an import tariff has a relatively large effect on the trade volume and a relatively small effect on the price (just the opposite of Figure 1A). In other words, U.S. wine exporters could lose a large percentage of their small export share in China without much of a price impact. In the short run, that wine will be sold elsewhere for a slightly lower price. However, in the long run, it may jeopardize the industry's attempt to build market share in a growing market.

We can use the framework in these two figures to gauge the tariff impact on the other commodities. For pistachios the import demand curve (ID) will be similar to that in Figure 1A for almonds because China imports virtually all of its pistachios from the United States. However, Iran supplies about 20% of Hong Kong's pistachio imports and could potentially divert some of this trade to China. The China import market for walnuts and table grapes will look like Figure 1B with both the ES and ID schedules flat. The market for oranges would be most unlike either Figure 1A or 1B, as both the ES and ID schedules would have some slope. California orange exporters would therefore likely experience some drop in export price and some fall in volume due to the tariff.

Conclusion

So far in the 2018 trade dispute, China has imposed tariffs on agricultural products from California that will result in a small economic impact in China and therefore are low-cost tariffs for the Chinese. The impact of the tariffs on almonds and pistachios will be mostly a higher price in China, and for wine, walnuts, and table grapes there will be little price impact but a loss of market share for California exporters. These products will be sold elsewhere. *The Wall Street Journal* reported the impacts on sparkling wine are likely to be large. Economic logic and the data do not support that conclusion. However, we recognize that the real threat is that the trade war escalates and has long-lasting reputation effects. This will hurt California agriculture because it relies on export markets, and China's imports of farm products are likely to continue to grow unless curtailed by a trade war.

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Recent Developments in the California Food and Agricultural Technology Landscape

Gordon Rausser, Ben Gordon, and James Davis

Three years ago, a global assessment of all industries revealed that food and agriculture had dramatically lagged in the adoption of digital technologies. Recent emerging trends in venture funding for innovative agricultural technologies hope to change this assessment and may well alter California's food and agriculture technology sector. This article investigates those venture-backed, California-based companies that are engaged at various points in the food and agriculture supply chain.

The global economy is going through a process of digitization, but a 2015 assessment by McKinsey revealed the agriculture sector to have achieved the very lowest level of digitization. Given that global food and agriculture (FA) represents approximately a $5 trillion industry (the largest amongst all industries), this evaluation was surprising to many. One possible explanation is that the FA sector has been the recipient of historically low levels of innovative venture investment, averaging less than $500 million annually prior to 2012. Over the last few years, however, venture investors are realizing that new technological innovations in modern biology, information technology (I.T.), machine learning, artificial intelligence (A.I.), and remote sensing have the potential to drastically alter the FA landscape. Such investments have the potential to improve agricultural productivity, introduce new products, and improve supply chain efficiencies linking producers to final consumers.

Between 2012 and 2017, venture capital funding in FA technology (agtech) totaled $22.3 billion, reaching a peak of $10.1 billion in 2017, as shown in Figure 1. Across the United States, the evolution of this emerging trend is reaching far beyond Silicon Valley's early interest in agricultural biotechnology, with major investments in all segments of the FA supply chain. As with much of its history, California FA continues to be a leader in U.S. high-tech production and is the leading state by agtech investments, with $2.2 billion in 2017 (22% of total) and a total of $5.1 billion between 2012 and 2017.

Much of the significant increase in venture agtech capital addresses the challenges of incorporating robotics, information technology, and remote sensing in FA. These investments can be classified within six broad technology categories: precision agriculture, agricultural biotechnology, vertical farming, alternative animal products, decision-making tools, and supply chain management.

Figure 2 shows where each technology category touches a particular stage of the FA supply chain. Inputs, which include biophysical conditions, water, pesticides, and other inputs, are used by different farm production methods to generate raw product, which are either distributed in fresh or processed forms. These products are sold and distributed by food services, farmers' markets, traditional grocers, and internet channels direct to final consumers. It is worth noting that while four of the six areas of innovation focus on input configuration and agricultural production, supply chain management technologies comprise over half of agtech investments.

Precision Agriculture

Precision agriculture addresses variability in biophysical and climatic conditions at the field or crop level by enhancing the ability to apply inputs (e.g., water, pesticides) according to a micro-level recommendation. However, the ability to assess conditions and make treatment recommendations has outpaced application technologies. For instance, using various remote sensing and probe technologies, a thermal image of water requirements at the sub-field level is possible. However, irrigation systems

Figure 1. Agtech Investment, 2010–2017

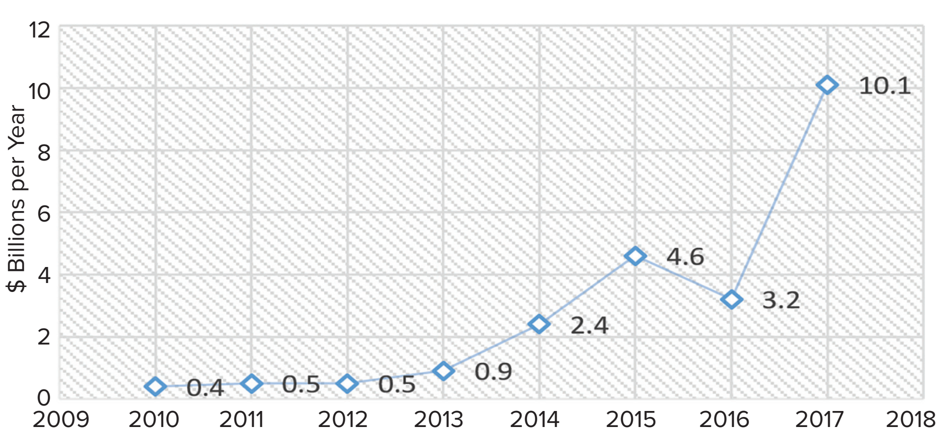
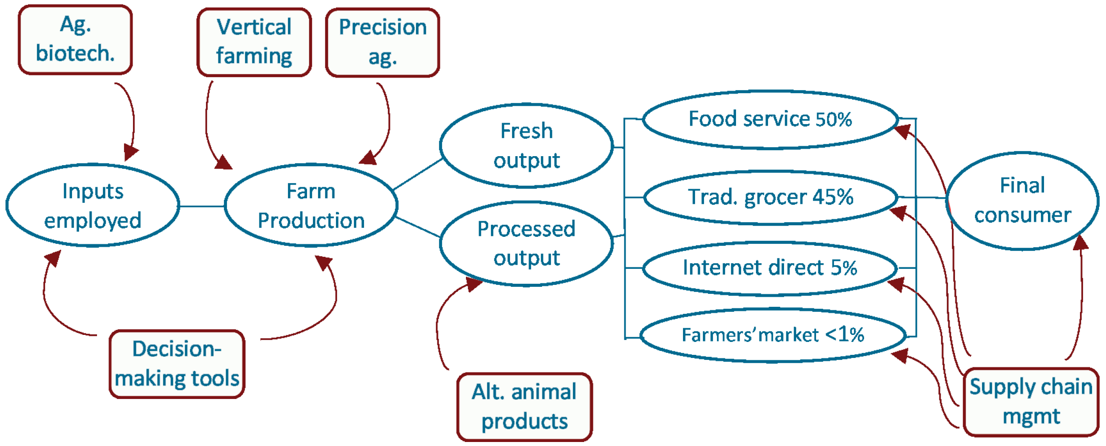


Figure 2. Supply Chain and Agtech Categories



Note: % figures are percent of U.S. sales through each distribution channel.

are not yet able to apply variable water quantities at this granular level.

In some areas of agricultural production, this is beginning to change. For instance, Blue River Technologies developed "see and shoot," which attaches a small robot on the back of a conventional tractor to quickly detect and assess weed growth and then apply a micro-spray of herbicide at the root of the infestation. To further enhance efficiency, the technology is paired with a software program utilizing weather and climate data with remote sensing and GPS to assess the sub-fields most prone to infestations.

Agricultural Biotechnology

Investments in agricultural biotechnology, which was focused on seed modification technologies until recently, have expanded to include new methodologies of gene transfer, gene editing, genomic testing and pathogen identification, and biological imaging. These have been made possible by breakthroughs of CRISPR-Cas9, TALENs, and Zinc Fingers. TALENs and Zinc fingers are gene-editing systems similar to CRISPR that rely on DNA-binding domains to identify target sequences to cleave those sequences. These technologies range in efficiency with CRISPR the most efficient.

Thus far, the political and regulatory framework that has slowed the development of traditional genetic modification techniques has not impeded the early progress of these new technologies. One example is Caribou Biosciences, a UC Berkeley startup, which enhances genetic material of seed varieties using CRISPR-based techniques. Another example is Sostena, a UC Davis startup, which utilizes specialized hybrid breeding techniques in conjunction with their proprietary software to improve the productivity of niche crops such as cantaloupe, watermelon, and pepper.

Moreover, new applications of biotechnology are being applied to algae and mushroom-based products, and the early signs of the growing societal and regulatory acceptance of biotechnology in food products in some parts of the world should allow for greater adoption of these innovations. For example, Synthetic Genomics is developing basic research that may allow algae-based biofuels to be cost effective.

Vertical Farming

Major advances in light diodes, computer-based decision making, and plant genetics hold the promise of allowing vertical farming systems to produce high-value, organic-certified crops in or near urban centers. As a result of consumer preferences being increasingly influenced by the information (certifications) surrounding food product availability, start-up companies in this space have the ability to capture that demand for information through novel applications of vertical farming technology.

For instance, vertical farming companies in California, such as Local Roots Farm in Los Angeles or Plenty in South San Francisco, are producing organic and non-GMO certified products, attempting to capture a higher willingness to pay for these characteristics and to bypass the traditional supply chain to dramatically reduce transportation costs. Overall, these systems drastically reduce water and other input use but face significantly more energy cost than conventional farming in production (due to the need to create light). Light diodes and advances in solar and bio-energy production may increase efficiency of indoor agriculture.

Alternative Animal Products

Alternative animal products comprise a growing range of approaches to create animal-free meat using molecular biology and tissue engineering to generate plant-based meat. These technologies respond to not only environmental consequences of animal products but also to expensive cost structure of animal meat production. These available technologies utilize advances in genomic and tissue engineering to produce meat products that are converging to the taste, texture, and smell of animal meat. There are two principal methods. One uses all plant-based materials, while the other uses meat tissues combined with cyanobacteria (the only photosynthetic prokaryotes able to produce their own oxygen) to produce meat products in laboratories.

While most venture capital in this space is allocated to alternative terrestrial animal products, such as Memphis Meats and Beyond Meat, Finless Foods is producing fish. Overall, these technologies offer novel methods that may decrease marginal costs, especially in important states like California with increasing strict land and pollution standards.

These firms must also contend with consumer preferences that present challenges in acceptability, especially if there is an early "mistake" or the timing of broader market introduction happens to align with a mishap in another related sector (e.g., Mad Cow Disease occurred the year after the introduction of GMOs in Europe, and became a major target by non-GMO activists, despite the two being unrelated).

Decision-Making Tools

Going beyond the laboratory, farm-level technologies are responding to the increasing milieu of tools at a farmer's disposal. One of the key issues with the introduction of many new technologies is the ability for the farmer to incorporate them in their production systems. Dominant firms in this sector include Farmer's Edge, who utilize Variable Rate Technology to improve crop production and reduce waste, and Farmers Business Network (FNB).

FBN is leveraging modern agronomic and statistical techniques to provide farmers with the most accurate information for improved farm decision-making. For example, FBN shares chemical price data with their members to restructure the current asymmetric information between chemical suppliers and their customers.

Supply Chain Management

Supply chain management technologies promise to provide food distributors and retailers more efficient ways of inspecting, certifying, and preparing food for consumption, and providing final consumers with new levels of convenience and ease of shopping. Business-to-business relationships have also experienced

Table 1. California Agtech Investments

Company name (*acquired)	Invested Capital* ($ millions)
Precision Agriculture	
Blue River Technologies*	30.8/335
Granular*	24.9/325
Abundant Robotics	12.00
TerrAvion	10.50
Hortau	76.20
PowWow	4.30
Apeel Sciences	40.00
Aqua Spy	10.80
Vinsight	1.50
Embodied	3.79
Agricultural Biotechnology	
Caribou Biosciences	44.55
TL Biolabs	4.00
Sostena	8.10
Biome Makers	2.20
Bioconsortia	27.00
Arcadia Biosciences	101/131
Marrone Bio Innovations	55/107.2
Boost Biomes	2.10
Pivot Bio	16.75
LumiGrow	19.50
Synthetic Genomics	40.00
Cibus Global	118.69
Alternative Animal Products	
Beyond Meat	104.00
Memphis Meats	20.00
Impossible Foods	389.00
Just (Hampton Creek Farms)	240.00
Soylent	72.40
Calysta	93.00
Perfect Day	26.80
Ripple Foods	109.00
Imperfect Foods	11.70
Clara Foods	1.75
Geltor	2.50
Vertical Farming	
Back to the Roots	19.31
Local Roots Farm	-
Plenty	226.00
Crop One Holdings	12.73
California Safe Soil	14.44
Edyn	4.22
Farmshelf	0.76
Iron Ox	5.00
Decision-Making Tools	
Farmers Business Network	193.90
Climate Corporation*	108.8/930
Astro Digital	20.65
Ceres Imaging	7.70
IntelinAir	5.00
PastureMap	3.10
OnFarm Systems	1.43
HeavyConnect	0.13
Harvesting Inc	-
Supply Chain Management	
Helium	38.8
Lineage Logistics	25
Haven	13.8
Source Intelligence	17.5
Aera	93.7
Elementum	67
Instacart	875
Sun Basket	108.6
Flexport	204
Aromyx	5.8
Impact Vision	1.4
Astrona	0.2
Clear Labs	36.55
Mojix	85.5
Nima	13.5
Safe Traces	8
iTradeNetwork*	-
AxleHire	4.42
Agralogics	4.18
trellisgrows.com	2.5

a dramatic landscape change with innovative supply chain technologies revolutionizing their transactions.

Companies in this segment brought in roughly 60% of the $10.1 billion of total U.S. venture funding. These companies are e-grocers, retail chains, and restaurants, which are introducing digital and automated means to conduct purchasing, distribution, and point-of-sale to end-users. This is a major shift in the magnitude and direction of funding—prior to 2015, downstream and midstream investments accounted for less than $5 billion in activity and about one-third of total agtech investments. One consequence of this shift in investment activity could well allow FA to achieve some convergence with other industrial sectors.

An example of a firm in this category is Helium, a smart sensing technology company that monitors and analyzes the temperature of refrigerators, freezers, and other potentially wasteful temperature-sensitive appliances. Companies like Helium are also at the cutting edge when it comes to integrating blockchain technology. Blockchain allows for real-time data collection across smart devices cataloguing information in the cloud to improve traceability and transparency.

With cannabis sales expected to reach $75 billion in the next 12 years, it is unsurprising to see applications of these new technologies in the cannabis industry. For example, Trellis, an Oakland-based seed-to-sale cannabis platform that uses data analytics to track the crop's performance from the plant to the dispensary. The beneficial aspects of the new technologies in this category would be the minimization of the "bureaucracy" or transaction costs within the supply chain. For example, firms can now market directly with their end-users in the case of B2B or access consumers by direct marketing. However, to leverage this potential capability these firms must also augment their skill sets. For example, Sun Basket, a firm specializing in farmer-to-consumer distribution, must incorporate in their streamlined business model the functions performed by the intermediaries they are supplanting, i.e., food safety and processing, packaging, and controlled storage.

Acquisitions

In addition to venture capital funding, a few major buyouts of early stage companies stand out. First, Monsanto purchased Climate Corps for $930 million in 2013, indicating the growing value of timely information technology in farm management. In 2017, John Deere purchased the "see and spray" technology from Blue River Technologies indicating the value of using advanced robotics in the application of pesticides and fertilizers. DuPont Pioneer acquired farm management software company Granular for $300 million, showing a continued focus on augmenting farmers' decision-making efficiencies. These three buyouts total $1.53 billion, with an average multiple of more than nine times the invested venture capital.

Finally, nine major companies recently announced major collaborative investments to develop blockchains as a way to manage global FA supply chains. While these acquisitions speak to the success of these technologies, there have been a number of noticeable failures. For example, SpoonRocket, a premade meal delivery service, shut down in 2016 after failing to raise sufficient capital. Even with a profitable product on the market and $13.5 million in venture funding, SpoonRocket was unable to overcome the cost of capital-intensive on-demand services.

Conclusion

Major challenges remain in finding complementarity between the diverse set of new innovations. For instance, the range of precision agriculture technologies still require the creation of decision rules. While a software program may recommend a certain treatment schedule, a final decision must still be made. New tools may aid this decision, but risk and uncertainty considerations will remain. In addition, farmers will need to sift through a growing set of technologies and companies to decide which ones are best suited for their operation, market, and biophysical conditions.

However, the rate of technological change further complicates the adoption process that is critical for bringing current technologies to scale. Given the rapid expected evolution, many farmers may decide to delay adoption of current technologies, especially those requiring significant upfront investment costs. In a forthcoming *ARE Update* article, we will investigate the incentives for adoption of these technologies across the supply chain.

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For additional information, the authors recommend:

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Cost of California's 2015 Drought Water Conservation Mandate

Mehdi Nemati, Steven Buck, and David Sunding

As a result of the 2015 drought mandate, we calculate the consumer welfare losses to be $203 million in Northern California and $794 million in Southern California under observed reductions. Many urban water agencies complained that the mandated targets were arbitrary and likely to be more costly than an optimal policy. We find support for this view. In particular, we calculate that an efficient mandate would have resulted in a savings of nearly $180 million for California households.

The recent California drought was one of the most extreme on record, characterized by low precipitation and high temperatures. In response, Governor Jerry Brown mandated a 25% reduction in urban water use effective between June 2015 and February 2016. The California State Water Resources Control Board (SWRCB), was the agency responsible for implementing the order. The final regulation, however, set the highest percentage reductions on utilities with the highest water use. Under the SWRCB's adopted regulation, only urban water utilities serving more than 3,000 customers or delivering more than 3,000 acre-feet (AF) of water per year were required to reduce their customers' water consumption, with restrictions ranging from 4% to 36% of baseline usage.

We quantify the welfare consequences of these restrictions for residential consumers in Northern and Southern California. We compare our predicted welfare losses, which assume perfect implementation, to estimates of actual welfare losses based on observed conservation reductions. Finally, we contrast these estimates to welfare losses under the efficient rationing regime.

Methods

We evaluate welfare losses in the residential sector using a measure of consumers' willingness to pay (WTP) to avoid water supply restriction, which is similar to other recent work. Economists define welfare loss of a shortage as the difference between what consumers are willing to pay for the rationed commodity minus the marginal cost of supply. Figure 1 depicts a simple example with a linear demand curve.

We also assume a constant elasticity of demand and estimate the single family residential water demand elasticities for each urban water utility. Average welfare loss resulting from a supply restriction in each water utility service area is a function of the elasticity of demand in the service area, the initial water price prior to the supply restriction in the water utility, and the marginal cost of service in the water utility.

The residential demand estimation uses utility-level panel data on average monthly water consumption and annual price, between January 2004 and December 2009, for single family residential consumers in California. The results of the residential water demand estimation indicate that the price elasticity of water demand in an urban water utility with a median household income of $65,000 would be –0.19—meaning a 10% increase in rates would induce only about a 2% reduction in usage. Moving forward, we use results from this specification to estimate elasticities for the welfare loss calculations.

Welfare Analysis

Welfare losses resulting from restrictions on residential water consumption in Northern and Southern California are quantified using consumption data from the year 2013 (the baseline period) encompassing 53 urban water utilities in California. Data are from the SWRCB, which calculates an estimate of residential water consumption by month for approximately 400 water utilities in California.

For a baseline, we assume restrictions based on the SWRCB utility-level conservation standards. Under the

Figure 1. Depiction of Welfare Losses Under Linear Demand, Non-Marginal Pricing, and a Flat Marginal Cost Curve

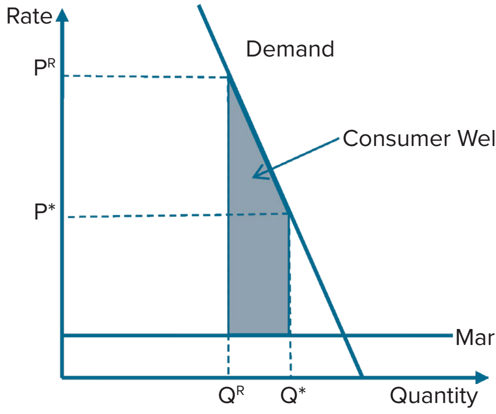


Table 1. Welfare Losses Under Uniform Restriction (25%) and Utility-Specific Restrictions from the SWRCB Conservation Program

Conservation Scenario	SWRCB Conservation Program	Observed Conservation	Conservation Under Efficient Rationing Regime
Panel A: Northern California Utilities			
Total Loss ($ millions)	$106	$203	$38
[95% Bootstrapped C.I.]	$100–$109]	[$182–$233]	[$35–$45]
Average Loss ($/AF)	$6,107	$6,082	$2,653
[95% Bootstrapped C.I.]	[$5,773–$6,263]	[$5,473–$7,015]	[$2,451–$3,086]
Household WTP($/Month)	$24	$49	$9
% Increases in Expenditures	44%	99%	18%
Panel B: Southern California Utilities			
Total Loss ($ millions)	$873	$794	$766
[95% Bootstrapped C.I.]	[$673–$1,885]	[$633–$1,429]	[$599–$1,833]
Average Loss ($/AF)	$2,680	$2,534	$2,306
[95% Bootstrapped C.I.]	[$2,066–$5,785]	[$2,019–$4,561]	[$1,802–$5,516]
Household WTP ($/month)	$29	$27	$26
% Increases in Expenditures	36%	33%	31%

Note: CI–Confidence Intervals; AF–Acre Feet; WTP–Willingness to Pay

SWRCB conservation program, water utilities are assigned to reduce their total consumption from June 2015 through February 2016 at rates between 4% and 36% based on historical consumption levels. Utilities in Northern California are generally in lower tiers of the SWRCB conservation program with a weighted average restriction of 16.2%. Utilities in Southern California have a weighted average restriction of 22.5%.

Estimated Welfare Losses Under Perfect Compliance

Table 1 presents the results of estimated welfare loss calculations under perfect compliance with the SWRCB conservation program. Larger total losses in Southern California relative to Northern California are due to the larger population. In Northern California, the SWRCB conservation program indicates average welfare losses per acre-foot of $6,107. In Southern California, average welfare loss per acre-foot of restriction is $2,680 under the SWRCB conservation program. The second and fourth rows of Table 1 indicate the 95% confidence interval for each estimate.

Our data also allow us to express welfare effects in terms of household WTP. The fifth row of each panel illustrates the average household's WTP to avoid the drought conservation mandate is $24 per month in Northern California and $29 per month in Southern California. Overall, these households' WTP are sizeable when compared to baseline household water expenditures. As evidence, the last row of both panels illustrates households' WTP measure in terms of the percentage increase in expenditures on the volumetric rate component of monthly water bills.

Households in Northern California have a WTP in terms of a percentage increase in monthly water bills of 44%. On average, households in Southern California would have been willing to increase water expenditures by 36% to avoid their mandated conservation programs. Overall, the anticipated welfare losses under perfect compliance with the SWRCB conservation program suggest aggregate losses of $106 million for the 27 agencies we consider in Northern California and $873 million for the 26 agencies in Southern California.

Welfare Losses Under Observed Compliance

Interestingly, water agencies did not exactly meet their conservation targets, with some agencies under-complying and others exceeding their targets. In fact, recorded consumption for utilities in Northern California shows that 23 of 24 utilities exceeded the required cutbacks. On average, utilities in Northern California reduced water usage by 7% more than was required.

By contrast, only 8 of 25 utilities in Southern California met their conservation standard, and 9 of 17 missed their standards by more than 5%. On average, utilities in Southern California reduced their water usage by approximately 3% less than required.

Figure 2 shows the pattern of compliance for Northern and Southern California by plotting the mandated percent reductions versus observed percent reductions for each utility included in the welfare analysis. The 45 degree line defines perfect compliance; points above it indicate utilities that exceeded their conservation mandate, while those below it did not comply. The difference in compliance between Northern and Southern California is striking, though it is difficult to attribute to a single factor.

A natural driver of compliance may be the value on water, with customers who place a high value of water agreeing to conserve less. However, many utilities with large anticipated losses managed to comply with their targets, suggesting that other factors are at play. Another important feature of the drought mandate was that individual utilities could determine how they wanted to achieve the targets. Differences in compliance may be attributed to each utility's method for achieving the standards. While individual utilities had flexibility regarding how to meet the standards, the SWRCB program also defined a

$10,000 daily fine for not meeting the assigned targets.

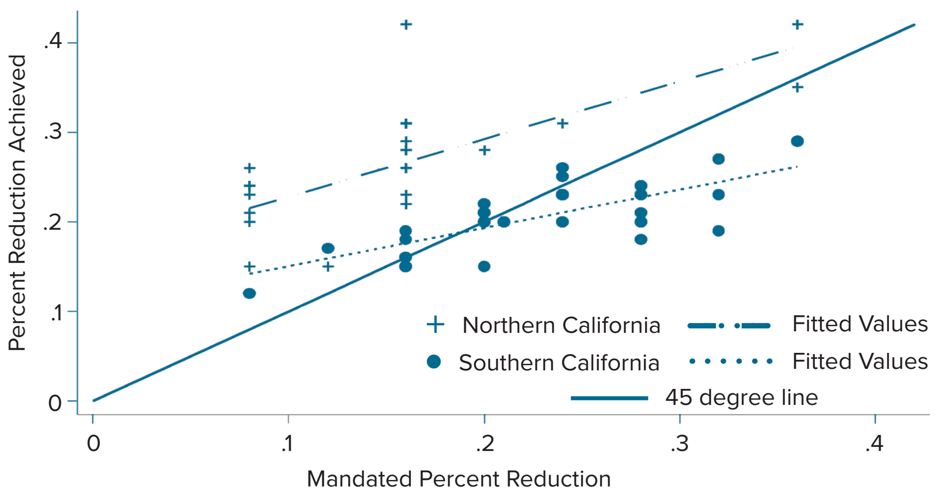
Many water districts offered rebate programs to encourage conservation during the drought. For example, city utilities, such as Menlo Park in Northern California, had attractive rebate programs during the mandate period for lawn replacement and offered a subsidized consultation on how to design drought-tolerant landscaping. These efforts included television and print advertising, as well as public information announcements available in social media.

In terms of actual welfare losses under observed imperfect compliance, in Northern California, estimates of average welfare losses per acre-foot by utility range from $2,998 to $15,710. In Southern California, estimates range from $890 to $6,638. A puzzling result is that utilities in Northern California, which have more inelastic demands than utilities in Southern California, tended to exceed their conservation standards, while those in Southern California tended to miss their standards.

Putting these numbers in perspective, the per household, per month results depend strongly on the household's utility and suggest that households in Northern California would have been willing to pay between $12 and $468 per month to avoid the observed conservation efforts in a non-drought period. In Southern California, the results suggest that households would have been willing to pay between $5 and $177 per month, depending on utility.

Finally, we calculate welfare results for an efficient mandate that achieves the same aggregate level of observed reductions. The final column of Table 1 presents these results. Welfare losses under observed reductions are comparable to the efficient rationing regime in Southern California. In Northern California, there were significant inefficiencies. Overall, the efficient drought mandate would have reduced welfare losses by 18% relative to observed water conservation. This result suggests that the SWRCB staff could more effectively incorporate economic information into future drought conservation targets.

Figure 2. Scatter Plot Showing Distribution of Mandated and Observed Percentage Reductions at Agency-Level for Northern and Southern California



Conclusion

The estimated aggregate cost of the mandate for the 53 utilities considered in terms of lost consumer welfare resulting from observed reductions is an estimated $997 million. The cost is $203 million in Northern California and $794 million in Southern California. These findings imply that Northern California households have a WTP of $49 per month to avoid the observed reductions in water use. Households in Southern California have a WTP of $27 per month to avoid the reductions in use resulting from the mandate.

The pattern of compliance with the SWRCB's conservation program presents a puzzle. Northern and Southern California households reduced their water usage by a similar percentage: 23.3% in the Bay Area of Northern California and 21.4% in Southern California. However, conservation targets in the Bay Area were significantly lower than in Southern California in both absolute and percentage terms. On average, consumers in Northern California over-complied with the conservation mandate, while those in Southern California slightly under-complied. Future research may help to explain patterns of actual conservation during a drought and may shed light on whether the state should consider larger reductions in non-residential sectors.

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