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ALSO IN THIS ISSUE

"Containergeddon" and California Agriculture

Colin A. Carter, Sandro Steinbach, and Xiting Zhuang

We analyze the effects of the 2021 supply chain gridlock and resulting shipping container shortage on California agriculture. Due to exporters' difficulty obtaining empty shipping containers, the value of California's containerized agricultural exports fell by an estimated $2.1 billion, about 17%, from May to September 2021. Indeed, we find that the financial damages suffered by California agriculture from the supply chain disruptions exceed the industry's losses from the 2018 U.S.-China trade war. The lost farm exports mirror the fact that California ports are among the least efficient in the world. As a result, some importers now view California as an unreliable supplier of agricultural products due to inferior port infrastructure.

The Covid-19 lockdown raised U.S. household savings to historical levels. Savings increased from an average of 8% of disposable income in 2019 to 16% in 2020, reaching as high as 34% in April 2020. Amplified by government stimulus payments, the extra savings led to an increase in U.S. consumer spending. The resulting demand shock was partially met with imported goods from Asia, growing the 2021 U.S. goods trade imbalance with China by 15% for the first three quarters of 2021, compared with the same period in 2020.

Most goods from Asia arrive via containers, and before Covid-19, California ports typically handled around 40% of U.S. containerized imports. However, California ports became overwhelmed with the recent growth in imports. U.S. ports outside California handled more than 1.4 million additional loaded import containers (up 23%) from May to September 2021, compared to the average for the same five-month period from 2017–2019. In contrast, California ports moved only about 0.7 million additional loaded import containers (up 16%) during the same time period.

The Covid-related boost in imports resulted in increased demand for empty shipping containers in Asia, and freight rates from Asia to the United States rose so fast that more and more containers were being shipped back to Asia empty, as opposed to carrying U.S. export products. The empty containers were more valuable in Asia, as they could be quickly loaded and sent back to the United States, earning a much higher freight rate compared to the backhaul rate from California to Asia. This meant that outbound cargo from California was impacted due to a shortage of containers for loading, creating lost export opportunities for California farmers.

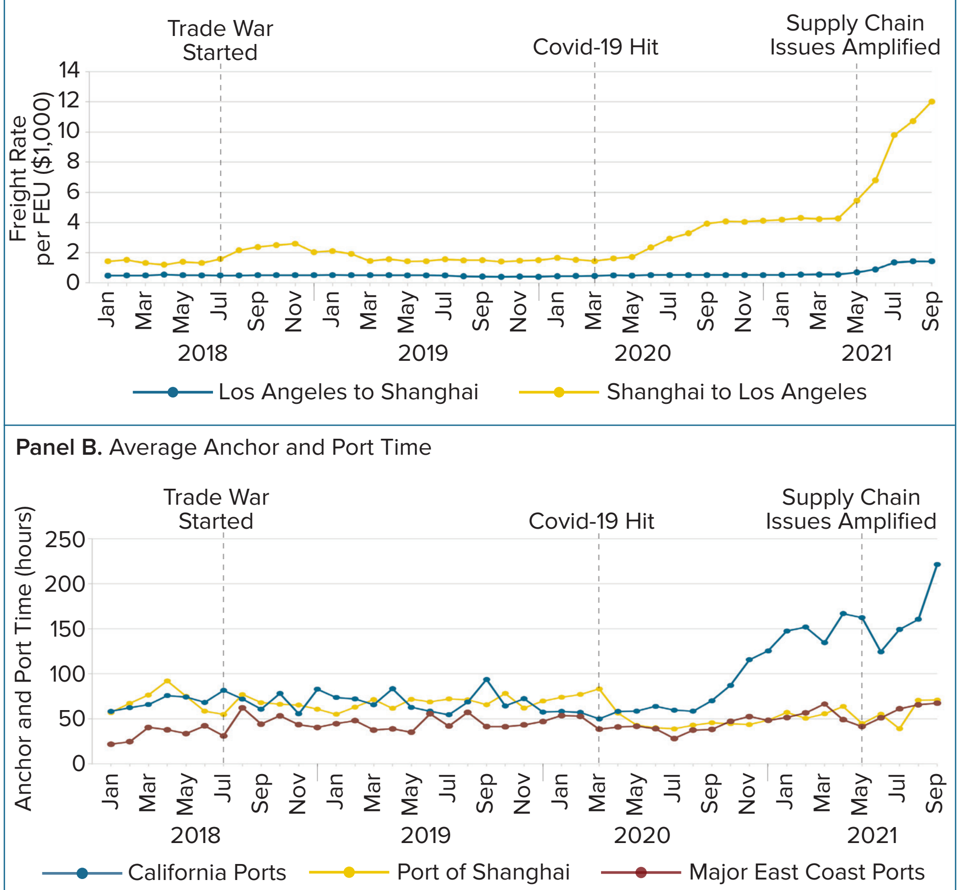
In years past, U.S. agriculture would typically fill over 40% of all loaded shipping containers leaving California ports, and about one-third of those containers carried California farm products; thus, containerized shipping is crucial for farmers in the Golden State. The standard measure for shipping container cargo capacity is the twenty-foot equivalent unit (TEU); the largest container ships carry about 24,000 TEUs.

In the summer and fall of 2021, there was a noticeable drop in TEU exports outbound from California ports loaded with agricultural products. For instance, from May to September 2021, the monthly number of containers loaded with agricultural products declined by 18% out of Los Angeles, 15% out of Long Beach, and 34% out of Oakland. At times, the supply chain bottlenecks left over 80 loaded vessels

Figure 1. Freight Rates and Port Congestion

Panel A. Freight Rate per Forty-Foot Equivalent Unit (FEU)

Panel B. Average Anchor and Port Time



Source: Freight rates come from the World Container Index (Bloomberg, 2021) and average anchor and port times were calculated from data provided by the Maritime Portal (IHS Markit, 2021).

Note: The figures show freight rates for Shanghai to Los Angeles and Los Angeles to Shanghai in Panel A and average anchor and port time in Panel B. In Panel B, we compare the five major container ports for agriculture in California (Hueneme, Long Beach, Los Angeles, San Diego, and Oakland) with the five major East Coast ports or port districts (Baltimore, Charleston, Virginia, Savannah, and New York/New Jersey district) and Shanghai. Anchor time refers to time spent waiting outside the port and port time to time spent at a berth in the port.

stranded off the Southern California coast and caused significant port congestion, with docks and warehouses running out of space. In some cases, ships were idled offshore for over two weeks, and as a result, shipping container turnaround time almost doubled. In addition, demurrage and storage fees paid by exporters increased substantially, forcing some agricultural exporters to re-route shipments through Texas, Vancouver, or the East Coast at a great expense.

The growing Asian demand for empty containers increased the imbalance in loaded containers inbound from Asia versus loaded outbound containers. Recently, for every ten containers inbound from Asia with freight, approximately eight were sent back empty. In September 2021, the fee for shipping a single 40-foot container (FEU) from Shanghai to Los Angeles was $12,000 versus only $1,400 for the backhaul from Los Angeles to Shanghai, as shown in Panel A of Figure 1. Due to the large difference in freight rates, shippers could not afford to wait for containers to be filled with agricultural goods stateside. Therefore, they canceled contracts and refused to supply empty containers to agricultural exporters, returning them unfilled to Asia instead. Some vessels returned to Asia directly from Southern California, rather than stopping at Oakland to pick up containerized agricultural products (as was done previously) and, ironically, leaving the Oakland port with excess capacity. Although detrimental to U.S. exporters, the reason more containers are being shipped back to Asia empty is to keep high-value imported products flowing into the United States.

Demand Shock and Port Congestion

According to the World Bank's Container Port Performance Index, California ports rank near the bottom in terms of global port performance. Out of 351 total ports, the latest figures rank Los Angeles at 337, Long Beach at 341, and Oakland at 334—far behind most ports in developing countries and those on the Atlantic Seaboard. Panel B of Figure 1 shows the average anchor and port time for container ships from January 2018 to September 2021. We calculated the average time required to discharge a container ship's cargo at the five California container ports that export agricultural products and compared them with Shanghai and the major U.S. East Coast ports. The recent performance of California ports has been abysmal.

Before Covid-19, California ports took twice as much time to unload cargo ships as the comparison group. After May 2021, the delays increased substantially, with the average container ship waiting for more than nine days before unloading. The ports of Long Beach and Los Angeles drove this effect, recording substantial delays since May 2021. Note that Shanghai and the East Coast ports kept up with the increasing demand for shipped products, with only slight increases in anchor and port time.

Panel A of Figure 2 shows that empty containers made up 63% of all containers exported from California before Covid-19. This share increased to 75% between May and August 2021, reaching a new record in September 2021, when about 79% of all containers leaving California ports were empty.

California Agriculture Trade Effects

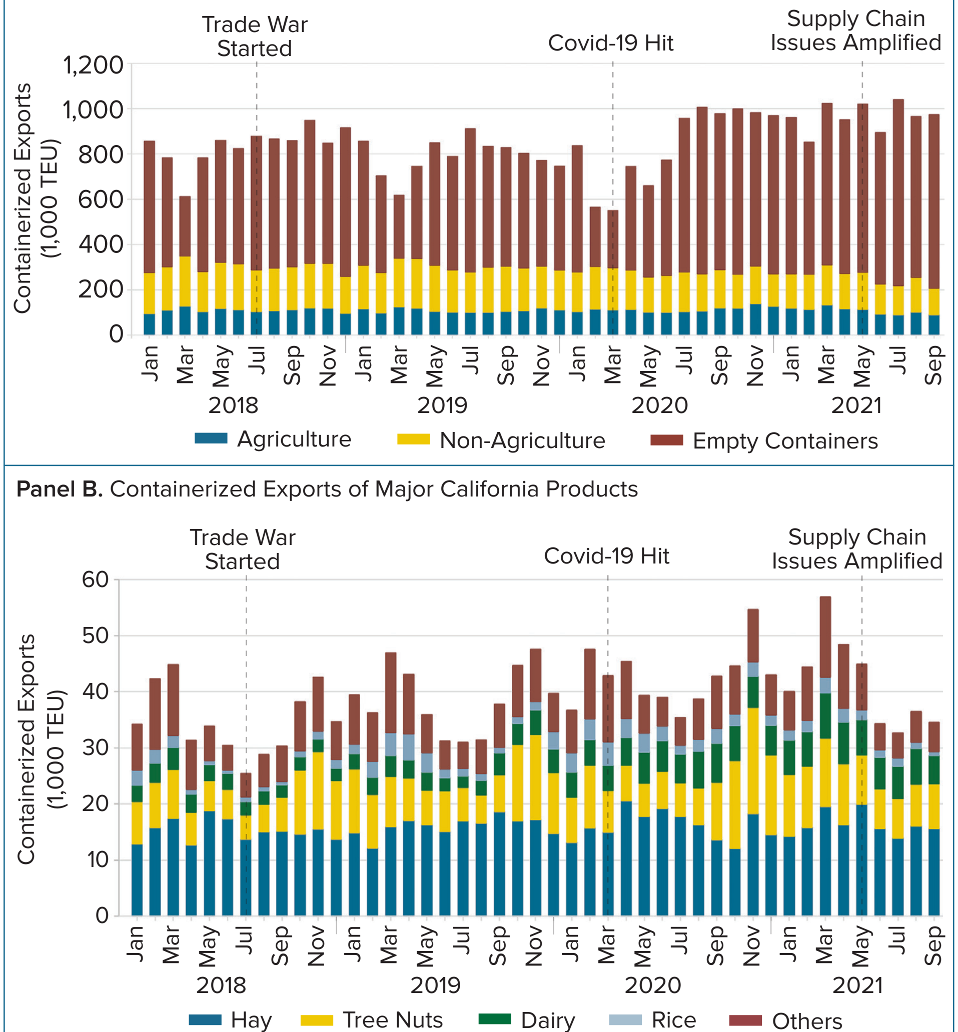
As shown in Panel A of Figure 2, containerized agricultural exports shipped from California remained relatively stable between 2018 and 2020, with average exports of about 111,000 TEUs per month. This is a measure of all agricultural exports from California ports, including products from other states. However, supply chain disruptions caused a 9% reduction in total TEU exports from May to September 2021, compared to the total TEU exports for the same timeframe in the previous year. This adverse effect peaked in September when California's ports exported about 25,000 fewer containers filled with agricultural products than in May 2021, a 22% decline.

The trade effects caused by the supply chain logjam vary substantially for different agricultural products. Focusing on the major agricultural exports produced in California, Panel B in Figure 2 shows that hay—the largest containerized agricultural export good measured by TEUs—saw a reduction in export volume. It dropped by about 4,000 TEUs in total (4% on average) from May to September 2021 compared with the same period in 2020. Keep in mind that hay is a low-valued commodity per weight unit compared to tree nuts, wine, or dairy products. Tree nuts recorded a slight increase of 2,000 TEUs (up 8%), dairy products experienced a small reduction in TEUs (down 1%), and rice recorded a marked decline of 48% (down 6,000 TEUs). In addition, although other California agricultural export products, such as citrus, processed tomatoes, table grapes, and wine, account for a smaller share of containerized exports, they also saw a substantial decline in export volume of 16%, with more than 5,000 fewer TEUs exported.

Figure 2. Containerized Exports from January 2018 to September 2021

Panel A. Containerized Exports from California Ports

Panel B. Containerized Exports of Major California Products



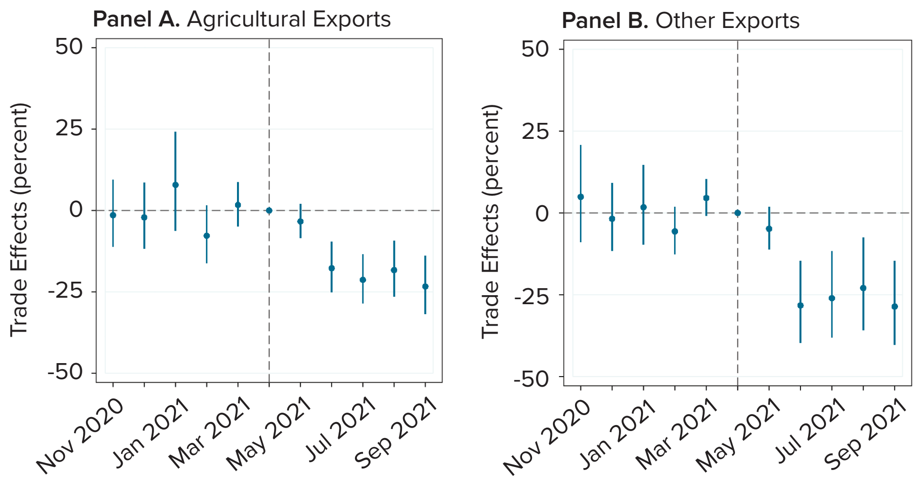
Source: The data for this analysis comes from the PIERS database (IHS Markit, 2021).

Note: The figures show changes in containerized exports for California between January 2018 and Septmber 2021. We aggregated agricultural exports (HS Sections 0 to 24) in Panel A and broke out selected agricultural commodities produced in California in Panel B. Tree nuts includes almonds, pistachios, and walnuts, and others includes citrus, dairy products, processed tomatoes, table grapes, and wine.

To better understand the causal effects of port congestion on California containerized exports, we conducted an event study, an empirical analysis of how the market responds to a significant event. We used a statistical model and historical trade data for California ports to measure how the 2021 port congestion and container shortages impacted exports of agricultural goods and other products. Our model controls for unobserved factors with port-product-year and port-product-month fixed effects. We assigned May 2021 as the treatment month and constructed an event window of five months before and after the pre-treatment month of April 2021. The statistical model identifies the treatment effect by comparing containerized exports from California ports with exports of the same commodities from all U.S. ports from 2015 to 2017.

Figure 3 (on page 4) shows the event study results. This type of figure is called a dot and whisker plot. The dots show the regression coefficients, and the whiskers represent the statistical confidence intervals. Note

Figure 3. Event Studies for Agricultural and Other Exports



Source: Data for this analysis come from PIERS (IHS Markit, 2021) and the World Container Index (Bloomberg, 2021).

Note: The figures show event studies for agricultural and other exports. All regressions include port, product-year, and product-month fixed effects and control variables. We plot trade effect estimates (dots) and corresponding confidence levels (whiskers) relative to the treatment month (April 2021). Detailed regression results are available from the authors upon request.

that we show estimated trade effects in percentage terms on the vertical axes. The regression coefficients are statistically significant if the whiskers do not cross the "zero" horizontal line. We find that California agricultural exports contracted slightly less (-17%) than exports of other goods (-22%) from May to September 2021. California ports handled about 97,000 fewer container exports (measured in TEUs) loaded with agricultural products compared to the counterfactual scenario. This amounts to $2.1 billion in lost foreign sales. These economic losses are driven by meat, tree nuts, dairy products, oilseeds, and beverages. In addition, we applied the event study to major California agricultural product groups and found considerable heterogeneity in the results. The average trade decline was most pronounced for processed tomatoes (-44%), followed by rice (-34%), wine (-26%), and tree nuts (-17%).

Based on constant prices for April 2021, we calculated that California tree nut producers lost about $520 million in foreign sales, followed by wine with a loss of more than $250 million, and rice with about $120 million lost. Note that the overall level of tree nut exports is lagging substantially behind the pre-congestion levels, including the 2018 or 2019 harvest-season export volumes, which points towards very significant export losses for this sector of California agriculture.

Conclusion

The 2021 supply chain disruptions affected many countries worldwide, with shipping containers stalling at various ports. However, the problem was especially acute for California agriculture. We found that containerized agricultural exports from California ports were $2.1 billion (or 17%) below their counterfactual level due to port congestion between May and September 2021. California farmers bore the brunt of these losses, with tree nuts, wine, rice, and dairy products suffering significant economic damages. The annualized economic impact is by far larger than that of the 2018 U.S.-China trade war, which caused economic losses of about $500 million to California agriculture during the fiscal year 2018/19. Moreover, the collapse of the supply chain had repercussions for the domestic market, with falling prices for tree nuts and other California agricultural products, and storage facilities overflowing. These additional impacts imply that the economic effects of port congestion are likely more extensive than just lost foreign sales. It has taken a supply chain crisis to fully reveal that California has inefficient port operations, even compared to ports in East Africa and Russia. As a result, the competitiveness of California agriculture in the world market is now being threatened by inadequate transportation infrastructure. We should have seen this coming.

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For additional information, the authors recommend:

IHS Markit. 2021. New Global Container Port Performance Index. Available at: https://bit.ly/3oNcgVU.

Agri-Pulse. 2021. "Port Crisis Pulls California Farmers Into 'Perfect Storm' of Competing Interests." Available at: https://bit.ly/2Z9I5ja.

It's Not Always Sunny in California: Strategies to Increase Our Reliance on Solar Generation

Kevin Novan and Benjamin Dawson

Meeting California's goal of a 100% carbon-free electric grid will require an increased reliance on solar energy. To absorb the growth in solar, storage capacity must expand to shift output to hours when the sun is not shining. Consumers must also be charged time-varying rates that shift consumption to hours when the sun is shining.

California's solar production has increased from 0.4% to 22% of the market between 2010 and 2020.

American Public Power Association

In 2010, less than 0.4% of the electricity produced in California came from solar. Driven by declining solar photovoltaic (PV) costs and plenty of government support, solar rapidly grew to account for over 22% of California's electricity production in 2020—with roughly two-thirds coming from large-scale solar farms and the remainder from smaller units (e.g., rooftop solar).

Going forward, California's growth in solar production will be even more dramatic. With the passage of AB 100 in 2018, the state mandated that 60% of the electricity supplied to the grid must come from renewable sources by 2030, and 100% must come from carbon-free sources by 2045. Solar is expected to supply a large share of this clean output.

These efforts to create a cleaner grid are the key to achieving the state's ambitious greenhouse gas reduction targets. While the electric sector only accounts for 15% of California's greenhouse gas emissions, the state is working to shift the transportation sector away from oil and towards electricity and to move buildings away from natural gas to electricity for heating. By powering the state's transportation sector, buildings, and industries with a clean electric grid, policymakers are striving to dramatically reduce carbon emissions.

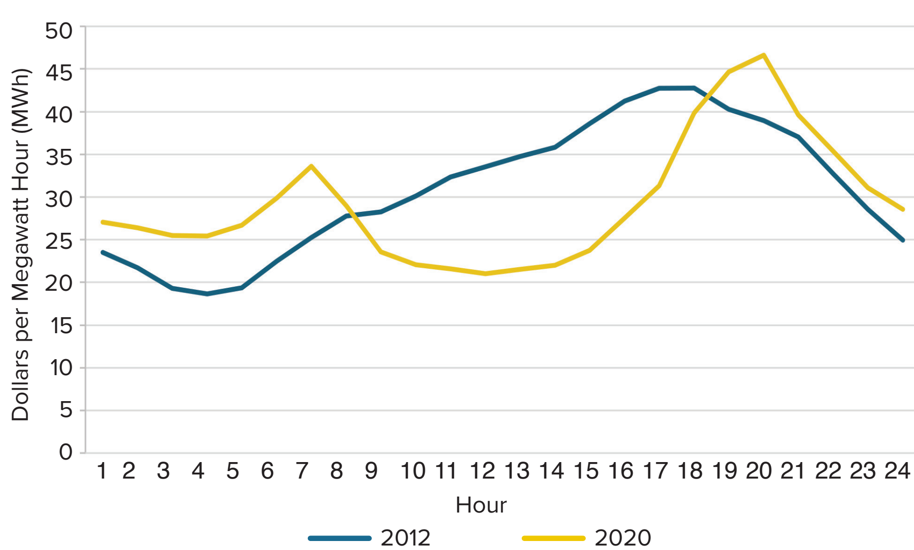
Pushing California's electric sector to become more reliant on solar requires overcoming solar's key shortcoming—all of the output is supplied when the sun is shining. This poses two challenges. First, electricity is still consumed when the sun is not shining. Indeed, in California, consumption peaks in the evening when solar generation is unavailable. Second, California's midday solar output already frequently exceeds what the grid can accommodate, resulting in solar output being reduced, or curtailed.

This article highlights what must occur for renewables, and in particular solar, to account for a substantially larger share of California's energy consumption. First, growth in storage capacity will be required to shift the surplus solar generation to hours when the sun is not shining. Second, the prices that consumers pay for electricity will need to meaningfully change. In particular, consumers will need to be charged time-varying prices that provide strong incentives to shift consumption to the middle of the day.

Market Impacts of Solar

In California, generators compete to supply electricity through markets overseen by the California Independent System Operator (CAISO). The

Figure 1. Average Hourly CAISO Day-Ahead Market Price, 2012 vs. 2020



Source: California Independent System Operator (CAISO).

outcomes in this market have already been reshaped by solar.

Figure 1 (on page 5) displays the average hourly prices in CAISO's day-ahead market in 2012 and 2020. In 2012, the minimum average prices occurred during the low-demand, early morning hours. In contrast, during 2020, the abundance of solar generation depressed midday prices to the point that the lowest average price occurred at noon.

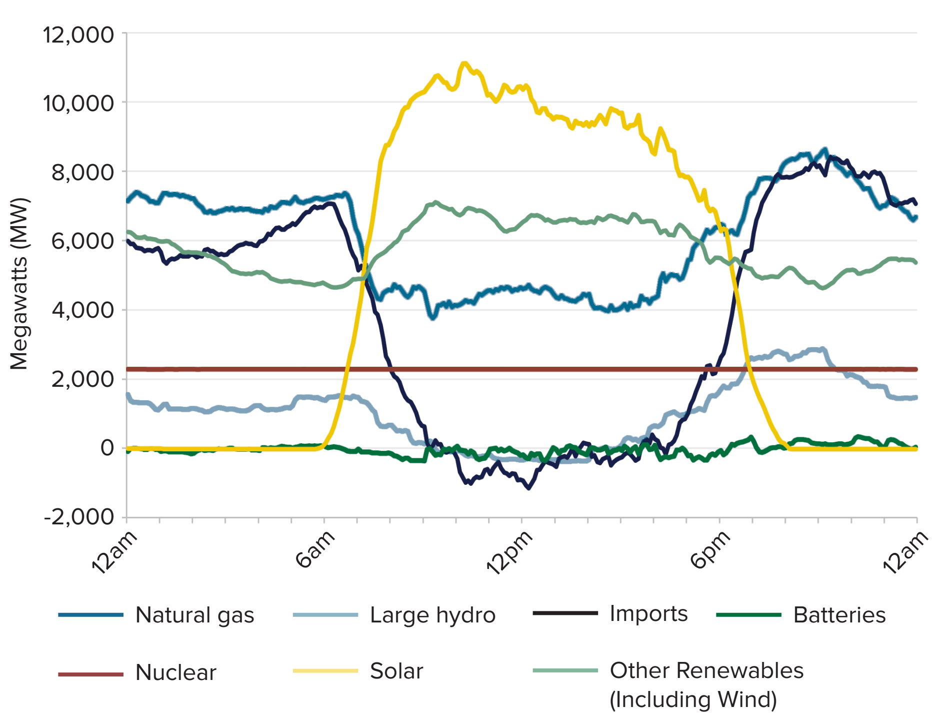
The impact of solar is also evident in the daily pattern of supply. Figure 2 displays the quantity supplied to the CAISO market on May 21, 2021. This pattern of supply represents what is becoming a typical spring weekday in the CAISO market.

In-state natural gas generation was the largest source of supply (26% of the daily consumption), while solar (19%) was the second-largest source. However, because the solar output was concentrated in less than half of the day, solar supplied half of the midday output.

While solar spikes midday, demand in the CAISO market does the opposite. On the day displayed in Figure 2, demand reached a morning peak of 24,000 megawatts (MW) at 9 a.m., then fell to 21,000 MW by noon before steadily climbing back up to 26,000 MW at 9 p.m. This drop in midday demand in the CAISO market is driven in part by regular patterns in consumption and in part by the growth in behind-the-meter solar capacity (e.g., rooftop solar) that reduces the amount of generation needed from the CAISO market.

Because CAISO demand does not increase with solar output, there must be sharp reductions in the midday supply from other sources to accommodate the solar output. Figure 2 highlights how imports from the regions surrounding California plummet from roughly 7,000 MW prior to sunrise to below zero midday (i.e., CAISO begins exporting the surplus production that exceeds midday demand in California).

Figure 2. CAISO Supply by Source (May 21, 2021)



Source: California Independent System Operator (CAISO).

Similarly, output from large hydroelectric plants falls from close to 2,000 MW prior to sunrise to become negative as energy is used to pump water back up into the reservoirs to be used to produce electricity at a later point in time. There is also a limited amount of battery storage capacity within CAISO. Figure 2 highlights how these units were, on net, charging up during the middle of the day.

Figure 2 also reveals that in-state natural gas generation, the dominant source of CAISO's supply, is cut in half during the daylight hours. However, there are limits to how far the gas generators can reduce supply without needing to shut down. When these units shut down, there are sizable costs to starting back up as well as limits to how fast they can ramp back up.

Until there is sufficient supply from alternative sources (e.g., more storage capacity) to meet demand in the evening when solar output disappears, gas units will continue to stay online and operate midday, albeit at lower levels of output.

Despite the reductions in midday natural gas and hydroelectric generation, the switch from CAISO being a net importer to a net exporter, and the use of storage, there was still more midday solar output than could be absorbed by the grid. That is, the quantity of electricity being supplied simply exceeded the quantity of electricity demanded. As a result, on the day displayed in Figure 2, 17% of the solar output from large-scale solar farms had to be curtailed (i.e., not utilized).

While the curtailment required on the day displayed in Figure 2 is currently on the high-end, Figure 3 highlights how solar curtailment has been steadily increasing as solar capacity has grown. Solar curtailment is now exceeding 300 gigawatt hours (GWh) during some months. To put that in perspective, 300 GWh of curtailed output in a month is equal to the monthly consumption of 538,000 households.

Increasing Trade

For California's grid to accommodate dramatic growth in solar capacity, several key changes must occur to avoid ever-increasing curtailment. First, with increased transmission capacity and coordination between CAISO and the surrounding regions in the western United States, surplus midday solar generation can be more effectively exported out of California.

Indeed, substantial progress has already been made to facilitate increased trading. In 2014, the Western Energy Imbalance Market (EIM) began coordinating real-time trading between CAISO and several utilities in the surrounding western United States. The EIM currently includes 15 entities, and by 2023, 8 additional entities are expected to join. This will ultimately bring over 80% of the electricity consumed across the western United States and Canada under the EIM's coverage.

The EIM is estimated to have already achieved over $1.7 billion in cost savings by more efficiently using the regional transmission system. In 2020 alone, it is estimated that 16% of potential CAISO solar curtailments were avoided due to EIM facilitated trading.

There are, however, limits to what increased coordination of trade can accomplish. For one, there is limited transmission capacity connecting CAISO and the surrounding markets. Moreover, California is not the only state that is pushing for increased renewables. For example, Nevada has mandated that 50% of its utilities' electricity comes from renewables by 2030. As solar production increases in the markets surrounding California, there will be less scope for exporting CAISO's midday glut of solar production.

Growth in Storage

While increased trade can help cost-effectively absorb greater levels of solar production throughout the western United States, exporting solar will not ultimately help California reach its goal of satisfying in-state consumption with 100% carbon-free energy. Instead, much of the renewable output will need to be consumed in California.

To accomplish this goal, there are effectively two options: 1) excess renewable output can be stored and used to meet demand when the sun is no longer shining or 2) consumption can be shifted to the middle of the day.

Historically, pumped hydroelectric has been the dominant form of storage. Going forward, batteries will be taking over. Between 2015 and 2019, the capital costs for large-scale battery units fell by 72%.

Consequently, investment is now beginning to take off. While CAISO's large-scale battery power capacity was only 500 MW at the end of 2020, there is already 4,000 MW of planned capacity additions over the next three years, the majority of which will be co-located with solar farms.

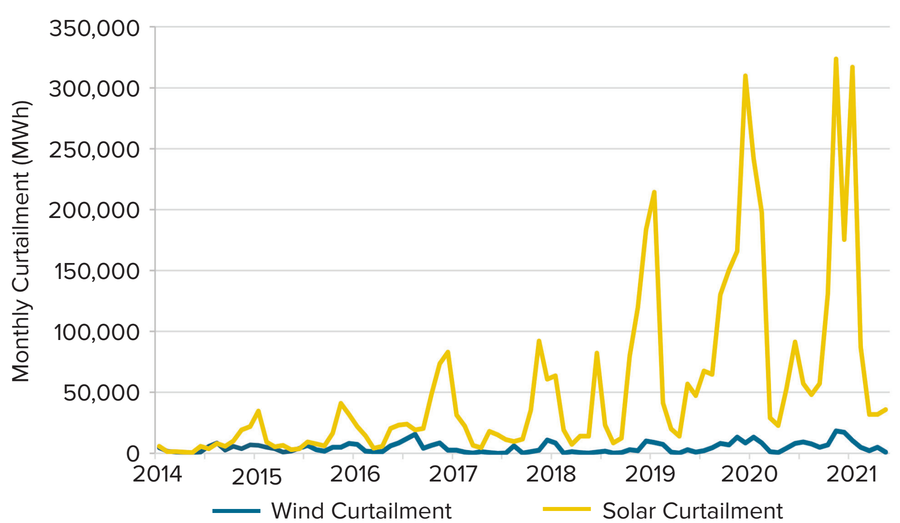
Over the coming decades, battery storage technologies are poised to dramatically alter the electric sector. Not only will the storage be vital in storing renewable output to meet demand when the sun sets and the wind dies down, but it will also play an important role in maintaining the stability of the electric grid by providing a range of important services currently dominated by fossil fuel units (e.g., frequency regulation). However, in the near term, the amount of battery storage capacity available will continue to pale in comparison to the amount of renewable output being curtailed.

Shifting Consumption

While storage will certainly play a vital role in increasing the share of consumption supplied from intermittent renewable sources, there is a much more immediate, and much less costly, strategy for increasing the share of consumption met by renewables: we can shift more of our consumption to the periods of the day when renewable output is being supplied.

Historically, there has been no incentive for households to shift consumption across hours in response to variations in wholesale market prices.

Figure 3. Monthly Curtailment of CAISO Solar and Wind



Source: California Independent System Operator (CAISO).

Until recently, the vast majority of consumers have paid a constant price for electricity, regardless of when they use it. This is now changing.

Customers in Sacramento and San Diego have already been transitioned to default time-of-use (TOU) prices that vary across periods of the day. During the "peak" evening hours when wholesale prices are at their highest levels, customers face a higher price per kilowatt hour (kWh). Pilot studies have demonstrated clear potential for these TOU rates to reduce consumption during peak periods, which can provide huge cost savings.

By the end of 2022, customers served by the two largest investor-owned utilities, Pacific Gas & Electric (PG&E) and Southern California Edison (SCE), will also be transitioned to default TOU pricing. Customers will have the option to opt-out of the new TOU rates, but those that do not elect to do so will begin paying time-varying rates.

To begin, the default TOU rate structures have been kept incredibly simple. There will be only two different rates within a day: 1) a peak price for electricity consumed between 4 p.m. and 9 p.m. and 2) an off-peak price for electricity consumed outside of these hours. Moreover, the spread between these peak and off-peak prices has been kept quite small.

For example, from June through September, PG&E's default residential TOU rates will charge low-consuming households (i.e., those consuming less than 100% of their monthly baseline allowance) a peak price of 34 cents per kWh from 4–9 p.m. and an off-peak price of 28 cents per kWh during all other hours. For high-consuming households, the peak and off-peak rates jump up to 42 cents and 36 cents, respectively.

From October through May, the peak versus off-peak price difference is even less pronounced. For low-consuming households, PG&E's peak price will only be 2 cents per kWh more than the off-peak price. For high-consuming households, the peak price will only be 1 cent per kWh above the off-peak price.

Initially, the default TOU rates will be kept incredibly simple to increase customer acceptance and to shift as many customers as possible to TOU rates. Going forward, to achieve the full potential benefits from time-varying retail prices, the differences in prices across different parts of the day will need to increase to reflect the variation in wholesale prices.

For example, as Figure 1 highlights, wholesale market prices now reach their lowest levels during the middle of the day. As solar capacity continues to expand, the gap between midday prices and morning and evening prices will only continue to increase. To incentivize customers to shift more of their consumption specifically to these midday hours, when surplus solar output is regularly being curtailed, the TOU programs will need to meaningfully reduce midday retail rates relative to the morning and evening rates.

While more pronounced time-varying rates cannot concentrate all consumption to the daylight hours, there is certainly scope to shift more of our consumption to the middle of the day. For example, customers who are home during the day could save money by drying their clothes and charging their electric vehicles midday. Moreover, customers who are not home midday can take advantage of increased automation—e.g., using programmable thermostats to pre-cool their homes prior to returning home in the evening. Ultimately, by shifting a larger portion of energy consumption to the middle of the day, solar will be able to supply a larger share of California's electricity consumption without requiring the same dramatic growth in storage capacity.

Conclusion

Solar capacity in California will continue to climb as the state drives towards a 100% carbon-free electric grid. To cost-effectively absorb the growing midday solar output, changes will need to be made on the supply-side—e.g., increased coordination of trade and expansions in storage capacity.

There will also need to be a change on the demand side of the market. In particular, consumers will need to be charged retail prices that meaningfully vary across periods of the day. Importantly, the retail rates must not be designed solely to reduce consumption during peak hours. They must also incentivize consumption to move to the periods of the day when wholesale prices are the lowest—which is now in the middle of the day when the sun is shining.

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For additional information, the authors recommend:

Bushnell, James and Kevin Novan. "Setting With the Sun: The Impacts of Renewable Energy on Conventional Generation." *Journal of the Association of Environmental and Resource Economists* 8(4): 759–796. Available at: https://bit.ly/3ybmHa7.

California's Organic Agriculture: Diverse and Growing

Rachael Goodhue, Joji Muramoto, Daniel A. Sumner, and Hanlin Wei

California is the leading U.S. state in organic agriculture by value, as it is for conventional agriculture, and accounts for well over a third of national organic production. In 2016, California's farm-level organic revenue reached over $3.1 billion, increasing to over $4.1 billion in 2019. Organic farm revenue was more than 8% of California farm revenue in 2019 and much more for some commodities, such as produce, where organic certification is more prevalent.

California is the only state with an organic program approved by the National Organic Program, which operates under the United States Department of Agriculture. The State Organic Program is responsible for regulating organic agricultural production, the processing of organic dairy, meat, and poultry products, and retail organic activities.

Producers, handlers, processors, and wholesalers involved in certified organic products must register with the state annually. We use information collected as part of the registration process to provide a snapshot of California's organic agriculture for the years 2014–2016. Reporting requirements were altered in 2017, eliminating the capacity to provide directly comparable information for later years.

Value of Organic Production is Concentrated Across Commodities

California farms and ranches produce a wide range of organic commodities—over 360 in 2016. As is the case for California's overall agricultural production, a much smaller set of commodities accounts for the major share of total value; in 2016, the top 10 organic crops were slightly over a third of total organic farmgate sales value, and the top 20 were just under half (Table 1). Milk was the top-ranked organic commodity, accounting for 8% of total organic sales at $250 million. Sweet potato sales increased significantly relative to those of other commodities, rising from 20th place in 2014 to 6th in 2016. Processing tomatoes also realized a significant increase in rank. Processing spinach fell considerably, from 4th to 15th.

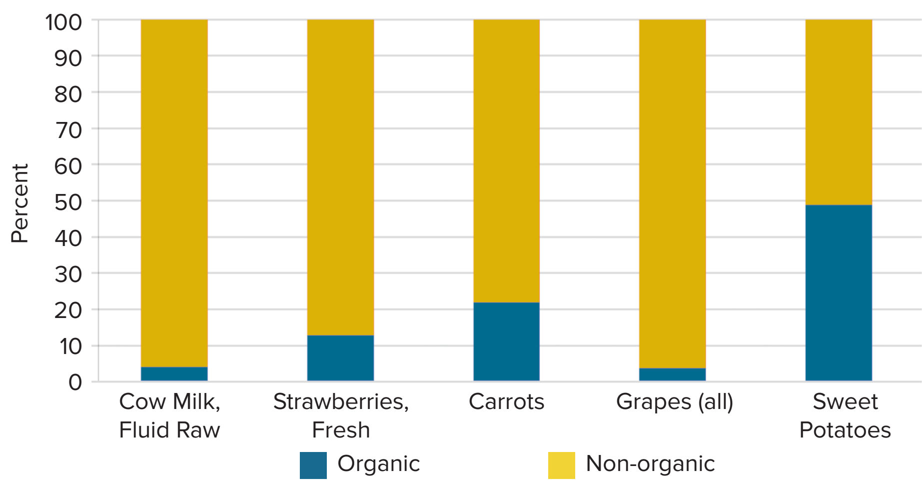
There are distinct similarities between the rankings of organic sales by commodity and overall sales by commodity. The top-ranked crops for California agriculture as a whole in 2016 were milk and cream, grapes (of all kinds), almonds, cattle and calves, and lettuce, followed by strawberries, pistachios, tomatoes, walnuts, and oranges. The noticeable differences in rankings are driven by the larger share of fruits and vegetables in organic production. Carrots, the third-ranked organic commodity, ranked 14th for all agriculture. Organic carrots and sweet

Table 1. Top 20 Organic Commodities by Value ($1,000)

Farm Commodity	2014		2015		2016	
	Value	Rank	Value	Rank	Value	Rank
Cow Milk, Fluid Raw	189,403	1	222,945	1	250,803	1
Strawberries, Fresh	146,276	2	207,067	2	201,887	2
Carrots	132,240	3	158,609	3	160,810	3
Grapes, Wine	73,700	6	107,736	5	103,947	4
Grapes, Table	92,228	5	112,473	4	76,611	5
Sweet Potatoes	27,510	20	60,250	11	73,971	6
Almonds	47,643	10	62,570	9	72,198	7
Raspberries	56,441	9	102,819	6	68,612	8
Salad Mix	64,821	8	64,889	8	63,598	9
Eggs, Chicken	43,063	14	59,042	12	62,190	10
Tomatoes, Processing	30,527	19	41,506	16	55,631	11
Broccoli	44,394	11	48,840	14	45,617	12
Kale	43,458	13	54,663	13	45,033	13
Lettuce, Romaine	41,985	16	41,170	17	42,685	14
Spinach, Processing	109,259	4	62,463	10	42,182	15
Blueberries	43,835	12	43,533	15	38,657	16
Avocados	39,916	17	29,922	23	37,677	17
Rice	35,791	18	36,585	18	35,738	18
Grapes, Raisins	26,170	23	28,693	24	33,952	19
Lemons	22,115	26	32,128	22	33,719	20

Source: Statistical Review of California's Organic Agriculture: 2013–2016.

Figure 1. Share of Organic Value of Production in Total, 2016



Source: Statistical Review of California's Organic Agriculture: 2013–2016.

Table 2. Top 10 Counties by Organic Farm-Level Sales Value ($1,000), 2014–2016

County	2014	2015	2016
Kern	287,760	355,838	380,692
Merced	159,705	154,735	329,945
Sonoma	242,516	277,312	306,686
Monterey	273,122	359,045	260,161
Fresno	96,395	242,420	249,478
Ventura	114,538	172,071	170,813
Santa Barbara	86,796	119,918	151,281
San Benito	112,537	123,966	131,933
Santa Cruz	113,132	99,503	113,872
San Bernardino	49,329	60,666	105,780

Source: Statistical Review of California's Organic Agriculture: 2013–2016.

Table 3. Top 10 Counties by Number of Operations with Organic Sales

Year	Field Crops	Fruit & Nut Crops	Livestock & Dairy	Nursery	Pasture & Rangeland	Vegetable Crops	At Least One Category
2014	483	1,861	240	162	4	763	2,879
2015	493	1,855	238	172	6	801	3,025
2016	503	1,896	266	170	7	838	3,109

Source: Statistical Review of California's Organic Agriculture: 2013–2016.

potatoes replaced all cattle and calves and almonds in the top five, when counting all grapes as one commodity. In addition, pistachios and walnuts are absent from the top 20 organic commodities.

The top five ranked organic commodities' shares of organic production value are much different than their shares for total production value (Figure 1). Compared to other organic commodities, the absolute value of organic milk production is large; however, it is a small share of total milk production (about 4%). Note that raw fluid cow milk is compared to milk and cream in the statewide figures.

The share of all grapes produced organically is slightly lower than milk's share. Separating into the three types of grapes, wine grapes have the lowest share of organic production (just under 3%), while table grapes have 5% and raisin grapes have over 8%. In contrast, almost 13% of the value of production for fresh strawberries was accounted for by organic production. A fifth of the value of carrot production was organic, and for sweet potatoes, almost half was organic.

Value of Organic Production is Concentrated Across Farms

More than 3,100 farms produce organic products, about 4% of all farms in California. However, the value of organic production is concentrated among large farms. Growers selling over $1 million of organic commodities accounted for 89% of the value of production but only 14% of all registered growers. Another 5% of the value of production was from operations with $500,000 to $1 million in organic sales.

Organic Agriculture Present Statewide

All but one county (Inyo) reported farm-level sales of organic commodities in 2016. However, production is geographically concentrated. The top 10 counties accounted for 70% of sales (Table 2). The top three, Kern, Merced, and Sonoma, together accounted for a third. Kern was also the top-ranked county for the total value of agricultural production in 2016. Merced was fifth, while Sonoma did not reach the top 10. Table grapes and carrots were Kern County's two most valuable organic crops. Almonds, Kern's most valuable crop overall, accounted for a negligible share of its organic production. Sweet potatoes and milk were Merced County's most valuable organic commodities, while milk dominated Sonoma's organic production.

Organic Growers Concentrated in High-Value Commodities and Coastal Counties

Of the 3,109 farm operations reporting organic sales in 2016, 1,896 (61%) had sales in the high-value fruit and nut category, and 838 (27%) had sales in the high-value vegetable category (Table 3). Only 266 organic operations (9%) sold livestock and dairy. Four individual commodities were sold by over 300 growers: fresh tomatoes, avocados, kale, and summer squash. The total number of operations with any organic sales grew by roughly 10% between 2014 and 2016.

Among the 10 counties with the largest number of operations with organic sales, only Fresno is not located on the coast (Table 4). San Diego County alone is home to 10% of all operations with organic sales, and the top 10 counties account for half of all organic operations. Illustrating how farm revenue per farm differs across the state, San Diego does not reach the top 10 in farm revenue and Kern does not reach the top 10 in numbers of farms.

Table 4. Top 10 Counties by Number of Operations with Organic Sales

County	2014	2015	2016
San Diego	318	322	313
Sonoma	224	219	226
Fresno	136	142	154
Riverside	141	147	153
Monterey	138	135	146
Santa Barbara	117	123	126
Humboldt	121	125	123
Santa Cruz	102	116	121
Mendocino	110	108	114
Ventura	97	111	105

Source: Statistical Review of California's Organic Agriculture: 2013–2016.

Organic Agriculture Since 2016

Based on stakeholder input, in 2017 California reduced the number of commodity categories organic producers reported from several hundred to only six. Starting in 2018, the number of categories was increased to 29. Thus, more recent information from state registrations is not directly comparable on a commodity basis. Overall, organic farm revenue in California has continued to grow, reaching over $4.09 billion in gross farm revenue in 2019, up by 12% from 2018, as reported by the State Organic Program. The number of producers increased to 5,452. Monterey County organic farm revenue has grown to rival Kern County, which remains the top organic farm county by revenue. Merced, Fresno, and Sonoma counties complete the top five in 2019. As the market for organic foods expands—based on trends to date—California is well-placed to continue to increase organic production and remain the U.S. leader.

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For additional information, the authors recommend:

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