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ALSO IN THIS ISSUE:

Controversies Surrounding U.S. Imports of Used Cooking Oil for Biofuel Production

Andrew Swanson, Shawn Arita, and Joseph Cooper

U.S. suppliers of byproduct oils cannot keep up with demand for byproduct oils driven by clean fuel policies like California's Low Carbon Fuel Standard. Renewable fuel producers are importing millions of metric tons of used cooking oil (UCO) from Asian countries to meet this demand. The price of UCO is often above virgin vegetable oils in China and Malaysia, providing an incentive to mix virgin oil with used cooking oil. We find little connection between Chinese UCO to palm oil spreads and net exports in China, but we do find that Malaysian net exports of UCO surged when UCO earned a substantial premium over palm oil.

Clean fuel programs like California's Low Carbon Fuel Standard (LCFS) and the federal Renewable Fuel Standard (RFS) have driven a boom in the consumption of alternative diesel fuels made from renewable sources. These alternatives are called biodiesel and renewable diesel, or biomass-based diesel (BBD) as a group. BBDs are made from feedstocks such as vegetable oils, animal fats like beef tallow, or byproducts such as used cooking oil (UCO). The greenhouse gas emissions of BBDs are estimated to be over 50% less than petroleum diesel. Biofuels are more expensive to produce than petroleum fuels, so the RFS sets yearly consumption mandates for national biofuel consumption. The LCFS also subsidizes alternative fuels and taxes petroleum fuels through a carbon credit market. These policies have resulted in BBDs attaining a 70% market share in the California diesel market.

The LCFS's formula for the number of credits generated per gallon primarily varies by the greenhouse gas emissions from each feedstock, though individual processor characteristics can also influence emissions. Virgin vegetable oils like soybean oil are associated with comparatively higher emissions than byproduct feedstocks. Vegetable oils receive higher emissions from crop production and from causing land-use change through higher crop prices. Byproduct feedstocks are assumed to have no secondary effects on the use and production of crop oils. BBD made from UCO and tallow receives almost twice the subsidies per gallon as BBD from crop-based fuels. The domestic supply of these waste feedstocks, however, cannot respond quickly to changes in price, leading the United States to import almost one million metric tons of UCO from Asian suppliers. Thus, new controversies are brewing around the sudden rise in UCO imports.

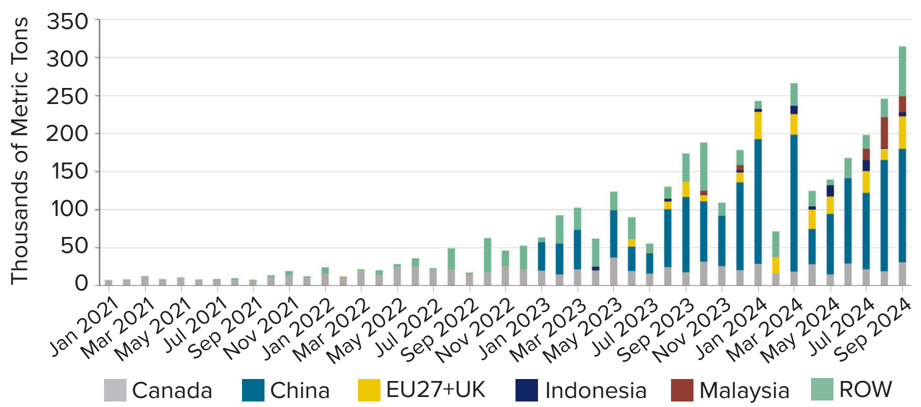
Demand from clean fuel programs has been so strong that the price of UCO has frequently exceeded the price of virgin crop oils in UCO-exporting countries. Industry leaders and policy makers are concerned that UCO collectors could be mixing in cheaper palm oil to boost their sales. If exporters are mixing virgin palm with UCO, the emissions of imported UCO could be far higher than currently estimated. Additionally, since palm oil is the cheapest substitute for UCO in Asian countries, increasing demand for UCO from biofuel policies could be indirectly increasing the price and consumption of palm oil through displacement effects from other uses, e.g., animal feed or soap making. We discuss the rise of U.S. UCO imports and connections between trade flows and UCO to palm oil price premiums in China and Malaysia. We find that Malaysia's net UCO exports surged during periods of positive premiums, but caution that this finding is not direct evidence of mixing palm oil with UCO. Rather, regulators concerned about mixing could pay attention to sudden changes in total exports during periods of large price premiums for UCO. We direct readers interested in the secondary price impacts of UCO on crop oil prices to our article in *farmdoc daily* (https://farmdocdaily.illinois.edu).

Meeting Rising Used Cooking Oil Demand Through Imports

California's per gallon subsidies for BBDs primarily depend on the emissions of the feedstock and the current price of carbon credits in the LCFS. The emissions of UCO are around 50% less than soybean oil, the primary crop-based feedstock for BBDs in California, based upon California Air Resources Board (CARB) calculations. LCFS credit prices are currently close to $60 per metric ton of CO_2, and soybean oil biodiesel receives close to $0.20 per gallon versus $0.40 per gallon for UCO. These additional credits have created a surge in the demand for BBDs made from waste feedstocks. Californians consumed close to 2 million metric tons of waste feedstocks in 2020, and this consumption has more than doubled to 4.5 million metric tons in 2023. UCO accounted for roughly 50% of California waste oil consumption in 2023 with tallow accounting for the rest.

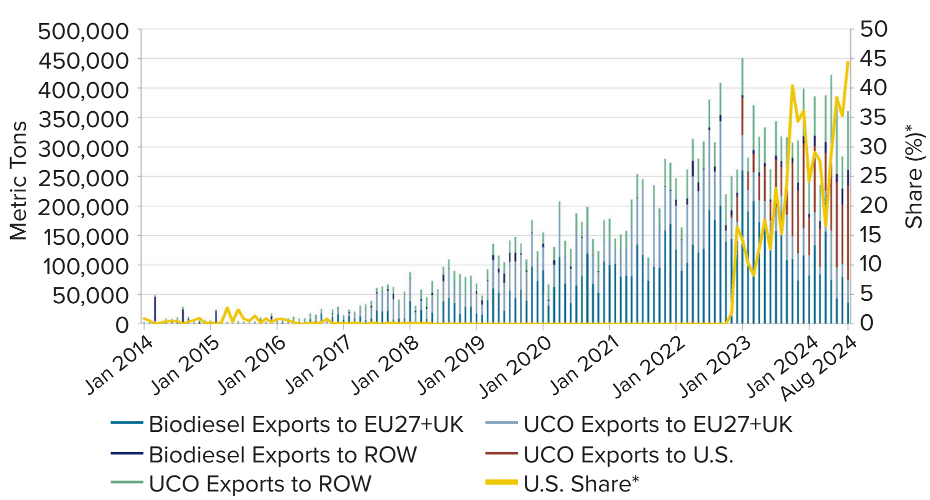
Producing more UCO requires food kitchens to increase their use of virgin vegetable oils or for collectors to find new sources. However, highly efficient food producers like McDonald's are unlikely to change their production practices without substantial price incentives, and starting collection from at-home kitchens is impractical. Likewise, increasing the supply of tallow requires more animals to be slaughtered or trimming more fat off valuable meat. Despite significant subsidies from clean-fuel policies, annual U.S. collection and rendering of waste oils has remained flat from 2016 to 2024, according to NASS surveys. Moreover, California fuel producers use more UCO than the United States can produce in a year. Displacement effects on other uses such as oleochemical production can further constrain domestic supply and contribute to rising import volumes. Therefore, imported UCO from Asian countries like China and Malaysia represents the easiest way to increase supply for biofuels.

Figure 1. U.S. Imports of Used Cooking Oil (Thousands of Metric Tons)



Source: Authors' calculations using data from U.S. Census.

Figure 2. China UCO and Biodiesel Exports (Metric Tons)



Source: Authors' calculations using data from Trade Data Monitor.

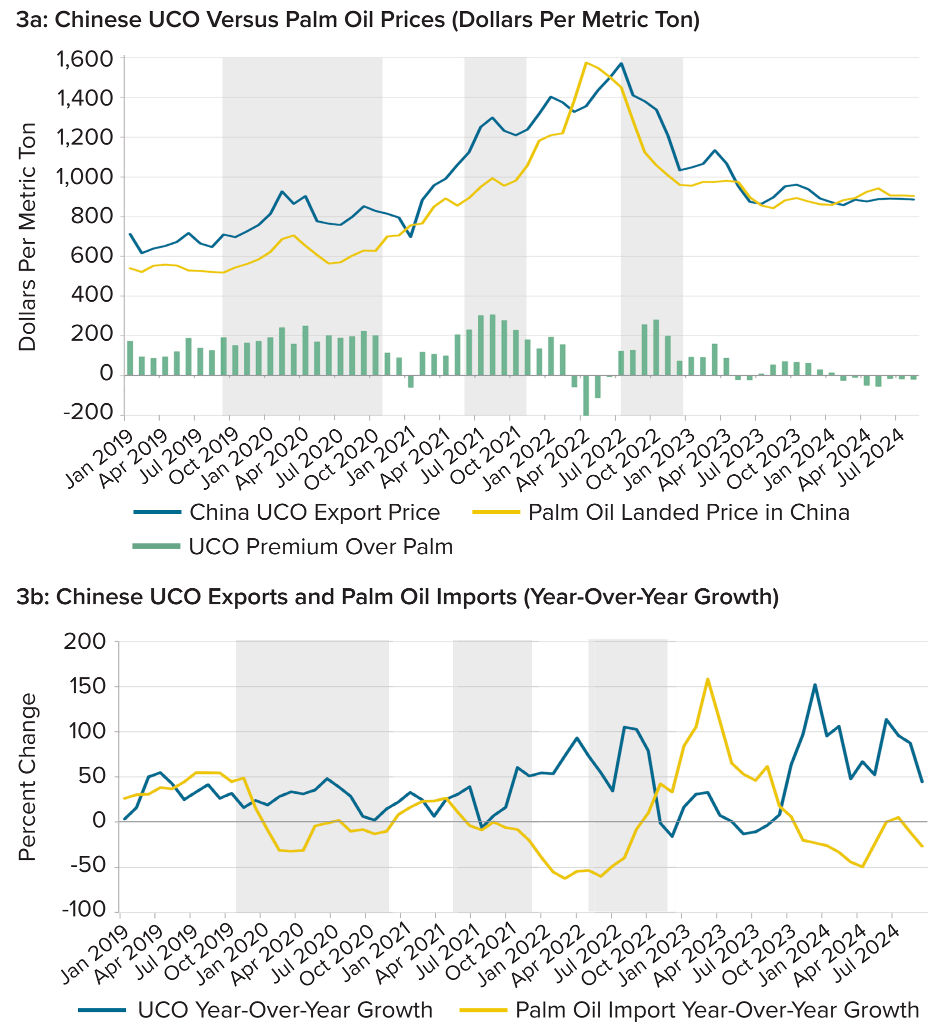
Figure 1 shows U.S. imports of UCO. These imports have surged dramatically in recent years, rising from negligible levels to over 1.4 million metric tons in 2023. These imports are valued at over $1.6 billion. China is the dominant supplier, accounting for over half of U.S. imports, followed by Canada, Australia, and, more recently, Malaysia. Imports of UCO account for approximately 40% of U.S. UCO consumption and imports are expected to keep rising as demand for BBDs grows. Globally, China and Malaysia are the world's #1 and #2 largest UCO exporters. They account for over 60% of global exports, and these two countries are at the center of the controversies over UCO's impacts on land-use change and the mixing of UCO with virgin palm oil. For this reason, we focus on the trade flows and prices of these two exporters.

EU's Fraud and Dumping Concerns Shift Chinese UCO Exports to the United States

A key driver of the surge in Chinese UCO imports has been shifting dynamics in the trade of its UCO and biodiesel to Europe. China's primary outlets for UCO are 1) exports and 2) domestic BBD production, where UCO is the main feedstock. Additionally, a considerable amount of UCO is also likely diverted to the gutter oil market, an illicit practice of reusing cooking oil for food purposes, which carries human health hazards. However, the size of this gutter market is unknown. For years, the EU has been the main destination for both Chinese UCO and BBD. EU policy incentives supporting biofuels made by waste feedstocks led to rapid growth in EU imports of both Chinese UCO and biodiesel.

However, the EU and member state officials have long-held concerns about fraudulent activities involving UCO and biodiesel. In July 2024, the EU imposed anti-dumping tariffs on BBDs, claiming these imports were seriously harming their industry due to subsidized prices. The EU also launched a new Union Database for Biofuels in January 2024 to track compliance with their emission reduction goals as well as provide traceability on biofuels and feedstocks. UCO exports to the EU peaked in 2022 but have since declined, coinciding with weaker biodiesel and UCO prices and heightened scrutiny over fraud concerns and anti-dumping investigations.

Figure 3. Chinese UCO Price Premiums and Export Growth



Source: Authors' calculations using data from Trade Data Monitor.

Note: Gray shaded areas indicate months in which UCO carried a significant premium over palm oil. Year-over-year growth is a 12-month percent change. China imports significantly more palm oil than it exports UCO (2–3 times more in 2023, which dropped to 1.25 times more in 2024).

Correspondingly, Chinese UCO exports shifted to the U.S. market, where biofuels made from UCO receive federal tax credits along with subsidies from clean-fuel policies like the LCFS. As Figure 2 shows, China's UCO exports have grown at an unrelenting pace, averaging more than 30% annualized growth over the past five years. U.S. imports of Chinese UCO were negligible prior to 2023, and the U.S. share of Chinese exports has grown from less than 15% in 2022 to almost 50% in recent months. Thus, the recent surge in U.S. imports is in part driven by deflection of China's UCO exports away from the EU market. Significant volumes of UCO are still being supplied to the EU—either through UCO or BBD manufactured elsewhere and imported to the EU. Yet, the United States could gain even greater market share if the EU continues to apply higher levels of scrutiny or additional trade actions.

While other Asian countries have larger populations, Malaysia is the second-largest UCO exporter after China. However, Malaysia's export levels are significantly above their estimated collection capacity, including imports, according to market research groups ICCT and Strata's Advisors. This raises concerns about the true sourcing of UCO supplied from Malaysia. The EU imported over 50% of Malaysian UCO from 2020 until 2023, but just like in China, the European share has steadily declined. The United States and Singapore now combine for over half of Malaysian exports, each importing over 20,000 metric tons a month in 2024. The United States also imported roughly 350 million gallons of BBDs from Singapore in 2023, so the United States' effective share could be higher than the raw export numbers would suggest. While Malaysia's total export volumes are roughly one-third of China's, Malaysian UCO exports represent another opportunity for the

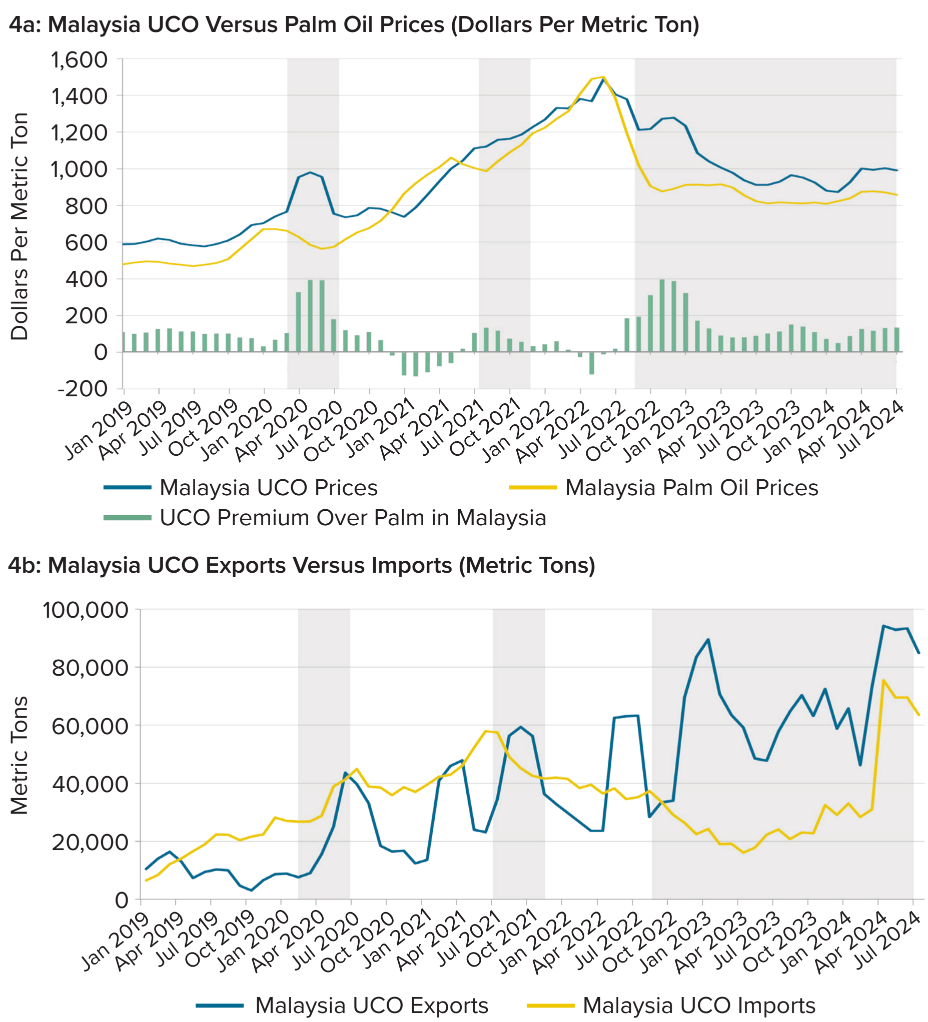
United States to meet its demand for low emission feedstocks for biofuels production.

Used Cooking Oil and Palm Oil Mixing Controversy

Asian UCO suppliers are ultimately responding to price and subsidy signals delivered by Western biofuel policies. Both China and Malaysia have experienced sustained periods when UCO was worth more than palm oil due to cheaper production and transportation costs of vegetable oils in these countries. When UCO is more valuable than palm oil, then mixing UCO with virgin palm becomes profitable for producers willing to undertake the risk. If mixing at a large scale is occurring, then there should be connections between the trade flows of UCO and vegetable oils.

Figure 3a (on page 3), which focuses on Chinese price relationships, shows that UCO prices in China have often carried a significant premium over the cost of palm oil. From 2019 to 2022, UCO had an approximate $200 per metric ton premium due to rising demand for waste feedstocks. Moreover, prior to the spring of 2022, Chinese UCO prices appeared to move faster and higher than palm oil prices. However, the UCO premium has not always been present, and palm oil prices have occasionally surpassed UCO prices. For example, palm oil prices surged following Russia's invasion of Ukraine in the spring of 2022 and during the subsequent export bans from Indonesia. Tighter supply conditions in 2024 have led to a current state of parity in prices. Thus, while current conditions do not offer strong economic incentives for mixing, our analysis indicates that past periods have created such opportunities.

Figure 4. Malaysian UCO Price Premiums and Net Exports



Source: Authors' calculations using data from Trade Data Monitor.

Note: Gray shaded areas indicate months when UCO carried a significant premium over palm oil.

While UCO premiums can provide incentives for mixing, our analysis of export growth patterns does not indicate a strong correlation. As Figure 3b shows, China's UCO exports have grown regardless of whether UCO prices were at a premium relative to palm oil. Additionally, the growth rates of China's palm oil imports do not correlate with UCO-palm oil premiums or UCO export growth. For instance, China's imports of palm oil decreased through 2024 during a period of surging UCO growth, and the trends appear to be dominated by the development and expansion of its internal supply chain to the sector. While the observed growth patterns in China's UCO exports do not strongly support the notion of widespread mixing, it does not dispel this possibility on a smaller scale. UCO and palm oil prices can vary spatially across China, with potential profit-making opportunities incentivizing mixing along various points of the supply chain.

However, in Malaysia, we find a closer connection between UCO exports and the UCO-palm oil price premium. Figure 4a shows the prices of UCO and palm oil in Malaysia along with trade flows. Malaysia is a major global producer of palm oil, ranking second or third in global production, and East Asian palm oil production is heavily associated with deforestation and greenhouse gas emissions from land-use change. This adds to the concerns over the connections between Malaysian UCO and palm oil. UCO prices were regularly above palm oil prices from January 2020 to the summer of 2024. Since the summer of 2022, the UCO to palm oil spread appears to have grown. Thus, U.S. biofuel policies may be increasing the price premium for UCO in Malaysia—and thereby, the incentives to cheat as well.

Figure 4b displays the exports and imports of Malaysian UCO. Malaysia acts as a UCO hub in Asia, importing and consolidating UCO from other sources and exporting it globally. Before 2022, exports roughly matched imports. However, since then, exports have significantly outpaced imports. Moreover, periods of widening UCO-palm premiums are followed by an expansion in Malaysian net exports. For example, in the second half of 2022, when palm prices dropped significantly (50%) due to easing Russia-Ukraine tensions, the UCO premium relative to palm oil rose above $200 per metric ton. The rise in UCO premium was followed by a major increase in Malaysian UCO exports compared to imports. To our knowledge, no Malaysian policies or collection practices have changed, so it's unclear where this additional UCO originated. This uncertainty is a driving force behind concerns raised by U.S. industry leaders and policymakers over mixing of used and virgin product.

Discussion

Incentives for mixing virgin palm oil with UCO arise when the market prices of UCO exceed those of virgin palm. Suppliers might attempt to profit by selling virgin oil as UCO or by marketing fuel made from virgin oil as UCO BBD. The potential exists because UCO and virgin oil have similar compositions, requiring specialized tests to detect mixing. So far, there is no evidence of widespread mixing of UCO with palm oil. This is in part because there has been no way to document fraud. There is no standard for UCO, and no official agency is currently testing the imports or verifying the chain of custody in foreign markets. However, the price and trade flow figures we show here document a close connection between UCO and palm oil markets. While it is unclear if widespread mixing is occurring, as UCO demand or policy measures supporting UCO as a feedstock increase, the incentives for such mixing are expected to grow.

In response to concerns over legitimacy and cries of unfair trade practices, the EU is placing greater scrutiny on "certified" UCO, implementing data programs to track BBD feedstocks, and imposing anti-dumping duties on cheap Chinese biodiesel. Likewise, CARB recently received comments on methods for testing the legitimacy of UCO supplies, including tests on fatty acid content and degraded food material in the oil.

Asian UCO currently plays an important role in meeting the rising demand for low-emissions feedstocks from U.S. clean fuel policies. The U.S. production of byproduct feedstocks like UCO and beef tallow cannot easily increase to meet rising biofuel demand. Asian UCO suppliers have met the increased demand with a surge in exports over the last year and a half. However, policymakers are now starting to question subsidizing foreign products by U.S. taxpayers and fuel consumers. For instance, a group of legislators has proposed restricting biofuel tax credits to fuels only made from foreign feedstocks. Additionally, Chinese policymakers suddenly ended the export tax credits for UCO in mid-November to boost their domestic biofuel production and possibly limit government expenditures. Thus, policies that support Asian UCO could face an uncertain future.

Finally, the indirect effects of UCO consumption on land-use change warrant further investigation. The growing biofuel demand for UCO may lead to other industries substituting palm oil or other vegetable oils for UCO, leading to higher prices and making it more profitable to clear forests for new plantations. Our analysis has revealed strong price linkages between UCO and palm oil. Future research could delve deeper into these indirect impacts to gain a more comprehensive understanding of the overall environmental consequences of UCO-based biofuels.

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California's Proposed Cap on Crop-Based Biofuels and What it Means for Fuel Prices and Biofuel Producers

Felipe G. Avileis and Andrew Swanson

The California Air Resources Board (CARB) plans to cap the percentage of Low Carbon Fuel Standard (LCFS) credits from crop oils in response to concerns about land-use change. While there could be small short-run effects on gasoline and diesel prices, the cap could more negatively impact Midwestern biofuel producers dependent on crop oils. The long-term impact on fuel and credit prices will depend on the success of electric vehicles in California and a consistent supply of used cooking oil (UCO) from Asia.

California is the largest consumer of alternative diesel fuels in the United States. A California policy called the Low Carbon Fuel Standard (LCFS) implicitly taxes petroleum diesel and subsidizes diesel fuel from alternative sources. The goal of the LCFS is to generate a 20% reduction in the transportation sector's greenhouse gas emissions by 2030 by consuming fuels with lower emissions than petroleum gasoline and diesel. The LCFS accomplishes this task by awarding carbon credits to fuels with low-carbon emissions and issuing carbon credit deficits to petroleum fuels. Companies must supply enough low-carbon fuels to offset their carbon credit deficits from petroleum gasoline and diesel sales, or they must buy credits from other suppliers of alternative fuels to offset their petroleum fuel deficits.

Alternative diesel fuels largely come in the form of two biofuels called biodiesel and renewable diesel, which are collectively called biomass-based diesels (BBDs). BBDs are made from renewable, natural sources like soybean oil or used cooking oil (UCO), and they are estimated by the California Air and Resources Board (CARB) to have 50% less greenhouse gas emissions than petroleum diesel. Moreover, the renewable diesel form of BBD can be used in current diesel engines without any technological change, unlike battery or fuel-cell vehicles. BBDs are an important means for fuel suppliers to meet emission compliance with the LCFS, and they were the largest source of carbon credits for the LCFS in 2023.

However, environmental groups have raised concerns over the use of biofuels made from crop oils like soybean oil and canola oil. Crop-based biofuels are associated with causing the conversion of native grasslands and forests into cropland through higher commodity prices, negating part of the emissions benefits. CARB assumes that BBDs made from byproducts like UCO have no land-use change impacts because the producer only creates the byproduct as a consequence of intending to make a different product. For this reason, CARB and other clean-fuel regulators assume byproduct BBDs have less emissions than crop-based BBDs. The majority of BBDs in California are made from byproducts, but the share of biofuels made from crop-based oils has been increasing as demand for biofuels grows in California.

In response, CARB is considering capping the share of carbon credits generated from BBDs made from soybean, canola, and sunflower oils, starting in 2028. The proposed policy would cap the number of credits generated from crop-based BBDs for each company at 20% of total BBD credits. The proposal only caps the share of credits a company can generate from crop-based fuels; it does not cap the volume of crop-based BBDs. Thus, companies can continue to sell crop-based BBDs above the threshold, but will not receive any more credits.

Farm groups have raised concerns about the effects of this cap on the demand for domestic crop oils. The policy does not apply to already approved BBD producers until 2028, but many diesel producers are shifting from conventional diesel to BBDs. For these producers, the policy would take effect right away. This cap limits their feedstock (input) options if they want to participate fully in the LCFS. Thus, it could negatively impact the profitability of these facilities.

This article considers the economic effects of the proposed cap on credit generation from crop-based BBDs. We find that in the short run the cap may only have a small impact on the total share of crop-based BBDs in California and credit prices. However, producers that rely partly or totally on crop oils as inputs could be more affected, and they would either have to change their supplies or lose a key part of their revenue stream. Moreover, this cap will reinforce California's reliance on increased zero-emission vehicles (e.g., electric) use in the future.

Understanding Biomass-Based Diesel Feedstocks

BBDs are currently the most important fuel for meeting the carbon emissions goals set by the state of California. BBDs are the single largest source of credits, generating almost 14 billion credits under the LCFS in 2023. Electric vehicles were the second largest source of credits at 7 billion. On the other side of the equation, gasoline and petroleum diesel combined for just over 20.3 billion credit deficits.

Thus, BBDs cover almost 70% of the carbon credit deficits from petroleum fuel consumption. BBDs have secured their role in the credit market through surging consumption. California's consumption of BBDs increased fourfold from 2019 through 2023. As BBD consumption has increased, so has the importance of crop-based BBD feedstocks.

CARB considers a feedstock a byproduct if its value is a small portion of the total value from processing a commodity. For example, distillers corn oil (DCO) is a byproduct of ethanol production, and DCO's use in biofuels is assumed not to impact the amount of corn processed because DCO's value per bushel is far less than ethanol's. As a result, CARB assesses any emissions from land-use change from corn production to ethanol, not to DCO. This assessment leads to more credits per gallon for BBDs made from byproducts.

The emissions of biodiesel from UCO or from corn oil are close to 35 grams of carbon dioxide emitted per megajoule (gCO_2e/MJ), while the emissions of canola biodiesel are around $50gCO_2e/MJ$. BBDs made from byproducts generate more credits per gallon sold as a result. LCFS credit prices are currently close to $60 per metric ton. Thus, a gallon of cooking oil biodiesel generates $0.45 in credits compared to $0.25 for a gallon of canola oil biodiesel.

However, increasing the domestic byproduct supply has proved difficult. Collecting more UCO requires highly efficient food producers to increase their vegetable oil use or for collection from at-home food consumption. Despite surging biofuel demand, domestic production of UCO and rendered beef fat has remained stagnant within the United States. The domestic production of the byproduct corn oil has increased by 15% over the last several years, but the increase is far short of meeting the rising growth in biofuel demand. Thus, supply growth from low-emission byproducts is now reliant on the growth of imports, primarily UCO from Asia.

Seizing the opportunity created from growing biofuel demand, soybean and canola oil BBDs have steadily gained market share in California. Figure 1 shows the total volume and credit share of crop-based BBDs in the California BBD market. Since 2019, crop-based BBDs volume shares have grown from a 10% market share to 30%, and crop-based BBDs now account for 20% of credits from BBDs versus 5% in 2019. A primary reason for this growth is the relative availability of crop-based oils. The United States produces over 24 billion pounds of crude soybean oil versus 2 billion pounds of UCO. Biofuels only account for 45% of U.S. soybean oil use, so there is room for future growth in the use of domestically-produced soybean oil for biofuels. Nonetheless, CARB's proposed cap on crop-based BBD credits could limit this growth.

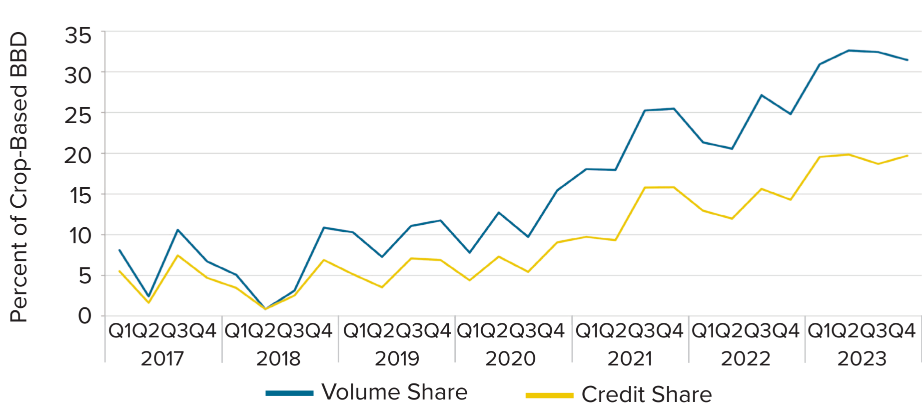
Distributional Effects of the Proposed Cap

Figure 1 shows that soybean and canola oil now generate nearly 20% of the total BBD credits for the LCFS, so a 20% cap does not seem too restrictive. Yet, the market share from Figure 1 is in the aggregate, and the cap applies at the company level. Individual companies that specialize in converting crop-based fuels into BBD could likely face a steep drop-off in the number of credits generated. However, this does not mean that crop-based BBDs no longer have any value in California once a company exceeds the 20% cap.

LCFS credits are an important policy incentive for biofuels, but national biofuel policies and California taxes on petroleum fuels also incentivize the use of BBDs. Selling petroleum diesel in California incurs around $0.50/gallon in taxes from climate-change policies. Renewable diesel is a near-perfect substitute for petroleum diesel, and its use offsets the $0.50/gallon in carbon-fuel taxes on petroleum diesel. Moreover, soybean renewable diesel generates around $1.80/gallon in federal biofuel policy incentives. LCFS credits provide an additional $0.25/gallon in value. Thus, LCFS credits only represent 9% of the total policy incentives for crop-based BBDs.

Producing BBD is costlier than petroleum fuels, making it sensitive to small changes. Renewable diesel requires about 8 pounds of oils per gallon, with soybean oil priced at $0.42 per pound, totaling $3.36/gallon for renewable diesel. Refining adds further costs. In contrast, wholesale petroleum diesel costs $2.30/gallon,

Figure 1. Crop-Based Biomass-Based Diesel Shares



Source: The California Air and Resources Board.

even with $0.50 in taxes. Subsidies are thus crucial to incentivize renewable diesel production and consumption. Without credits, some fuel suppliers may revert to petroleum diesel due to higher costs.

This provision can create notable distributional effects on a large share of different BBD producers. For example, of the 89 entities with currently approved pathways to sell BBDs and generate credits under the LCFS, only 42 do not have crop-based pathways approved (i.e., they neither use, nor plan to use, crop oils in renewable diesel production). Among the remaining 47 companies, 34 have both crop-based and waste oil pathways approved, while 13 rely solely on crop-based pathways.

As a result, the cap would have no effect on some companies, while others would need to overhaul or rethink their business models. For instance, a company relying solely on crop-based oil pathways would lose 80% of its LCFS credit revenue under the cap.

Discussion

What are the likely effects of the proposed cap on credit prices? In the short run, likely none. As discussed, the current mix of crop-based BBD that enters California is near the 20% cap, and the policy will not impact current producers until 2028. Moreover, fuel suppliers generated 4 million more LCFS credits than deficits in 2023. The LCFS does not currently need more credits.

However, individual companies could face significant switching costs. While the overall mix of crop-based BBDs is low in California, many suppliers primarily rely on crop-based feedstocks. Since national biofuel demand currently outstrips domestic production of waste oils, producers may have to find overseas suppliers, such as UCO from Asia, instead of using domestic oils. The effects are likely to be largest for BBD producers in the Midwest that primarily use crop-oils. These producers are far from ocean-going ports, so importing UCO or tallow will also require shipping the feedstock over a thousand miles inland. These oils are bound to become more expensive due to recent changes in Chinese tax rebates for UCO which could undermine profitability.

Some producers may struggle to establish new, more complex supply chains. While the policy would start in 2028 for companies with already approved pathways, companies may begin to shuffle their supply chains in anticipation of the policy. Supply chain shuffling could increase credit prices, especially as this transition picks up. The primary mechanism of this credit price increase would be higher input costs for these firms, leading to either higher abatement costs or less credits generated.

There is greater uncertainty in the long run. CARB states in its proposal that it expects the policy to have only a small impact on credit prices. Part of CARB's rationale is its expectation of declining demand for fossil fuels in the future. That is, CARB expects less deficit generation in the future. If total fuel demand declines as expected, then the current feedstock supply conditions will be sufficient to meet future demand, and the cap will only have a minor impact on credit prices.

However, this expectation hinges on the continued and increased adoption of zero-emission vehicles (ZEVs) over the coming decade. Petroleum diesel currently generates around 2 billion LCFS deficits, while gasoline generates over 18 billion deficits. Thus, the 14 billion credits from BBDs are primarily used to offset deficits from petroleum gasoline consumption.

So, what does this policy mean for California fuel prices? Likely not much over the coming months as the policy will take several years to have full effect and the credit market is running a large surplus. However, CARB's emissions goals become more stringent over time, and meeting these future goals requires ZEVs to continually gain market share in miles traveled in California. If the ZEV transition fails to materialize as CARB expects, then restrictions on BBD credit generation could lead to a credit shortfall, sending credit and gasoline prices higher.

Additionally, a large portion of byproduct feedstocks like UCO are imported from China, and future protectionist trade policies could lead to a shortage of byproduct feedstocks. Thus, the cap having little-to-no effect on credit and fuel prices hinges on a smooth rollout of ZEVs and for supplies of Asian UCO to keep flowing to the United States biofuel sector. If either of these two pillars falls—either for economic or political reasons—then the credit cap on crop-based BBDs could cause both credit and fuel prices to increase.

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Adapting the U.S. Federal Crop Insurance Program for Climate Change: Critical Lessons for Policy Design

Francis Annan

The U.S. Federal Crop Insurance Program stabilizes farm incomes but destroys possible incentives for ex-ante adaptation to climate change—the very source of income risk we aim to manage under the program. The optimal policy design would minimize this observed trade-off between income stabilization and incentives to adapt. I present a descriptive framework that sheds light on alternative policy redesigns for climate resilience, with implications for ongoing discussions around the Farm Bill.

The Federal Crop Insurance Program may decrease farmers' climate reslience.

Photo Credit: Clark Wilson on Unsplash

Farm Bill discussions are currently underway and program-level decisions under the U.S. Federal Crop Insurance Program (FCIP)—the type of insurance policies, the type of crops, the level of coverage choices, the level of premium subsidies, among others—are all on the table again. Introduced in 1938 in response to the Great Depression and the Dust Bowl and funded with mandatory appropriations from Congress ("such sums as necessary"), the central goals of the Insurance Program, a major component of Farm Bills, are to help stabilize farm incomes and reduce reliance on ad hoc disaster assistance. The FCIP has emerged as a main tool for subsidized crop insurance to U.S. farmers, aimed at managing their production and price risks.

Before January 1, 2025, Congress will need to either pass a new Farm Bill or an extension of the 2018 version. I pose four critical questions that should be asked to inform the discourse around such federal decisions, with a focus on crop insurance and its broader implications for climate change: 1) To what extent do program-level decisions increase the adoption of crop insurance and help stabilize farm incomes? 2) How might the program reduce possible incentives for ex-ante adaptation to climate change? 3) How does access to subsidized insurance under the program affect farmers' production decisions and climate resilience? 4) Can we improve the design of the program to promote climate resilience and how does this inform our thinking about broadly designing insurance programs for climate change?

I now present four results, labeled as facts, that shed light on the four critical questions above and then emphasize their implications for policy. I draw on a multi-year research project by Annan, Saxena, and Yu, where we combine data from multiple sources spanning 1990 to 2023: crop insurance contracts from the USDA Risk Management Agency (RMA), weather data from the PRISM Climate Group at Oregon State University, crop yield, area planted and price data from the USDA National Agricultural Statistics Service (NASS), and farm income and input expenditures data from the Bureau of Economic Analysis (BEA).

Fact #1: The Program Has Expanded Rapidly in Recent Decades

The FCIP offers financial protection to farmers when their revenue or yields fall below predetermined levels, providing a crucial safety net in response to both climate and market risks. Since its introduction, the program has expanded significantly, particularly after the 1994 Crop Insurance Reform Act, which introduced substantial subsidies to make the program more accessible. These subsidies, which now cover about 65% of insurance premiums, on average, have been a major driver of the program's growth. Today, the FCIP accounts for the largest portion of financial support provided to farmers, according to the Congressional Research Service.

However, the costs of maintaining the FCIP have increased alongside higher participation rates. From 2012 to 2022, total FCIP expenditures—including premium subsidies, program delivery costs, and underwriting gains—averaged \$10.58 billion per year, with this figure continuing to rise over time. As shown in Figure 1, a notable trend within this system is the expansion of insured lands, particularly for the two major crops: corn and soybeans.

Insured lands have expanded rapidly, while planted acreage has grown at a slower rate. This suggests that enrollment rates are rising in response to reforms from recent farm bills and increasing subsidy rates, despite minimal expansion in actual planted cropland over time. As a result of these government subsidies, the insured acreage has increased substantially, influencing how farmers manage risks, particularly those related to extreme weather events.

Fact #2: Insurance Helps Stabilize Farm Incomes in the Event of Abnormally Hot Weather

The empirical model links real net income, input expenditures, and agricultural yields to exposure to extreme heat over the planting season—extreme degree days (EDD)—and its interaction with the share of area insured. The model follows the framework of Annan and Schlenker and takes into account trends in weather over the years, including any differences in counties across the United States. The key parameter of interest is the interaction term between the EDD and the share of the area insured. This interaction captures the extent to which crop insurance incentivizes or disincentivizes farmers' adaptive behaviors, considering both pro-adaptation effects, such as stabilizing income and enabling investment in adaptive practices, and anti-adaptation effects, including reduced private adaptation efforts due to reliance on insurance. The main set of results focuses on major corn- and soybean-producing counties, where there is less measurement error in income and input expenditures.

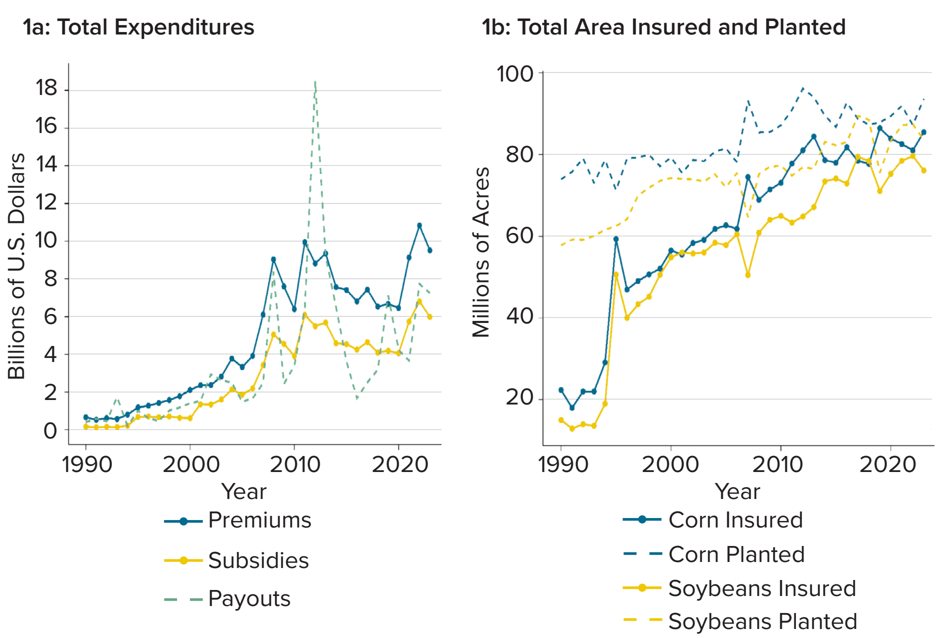
The results reveal a complex relationship between crop insurance and farmers' responses to extreme weather. Positively, crop insurance substantially mitigates income losses from extreme heat. Specifically, for each additional EDD, insurance reduces net income loss by $5 million, covering 76% of the total net income loss attributed to extreme heat. This demonstrates the financial protection that crop insurance offers, providing crucial stability to farmers amid extreme weather events.

Fact #3: Insurance May Reduce Incentives to Adapt to Extreme Weather Shocks

However, this financial protection comes with an increased agricultural vulnerability to extreme weather shocks in terms of yields. The study finds that insurance coverage intensifies yield losses, with corn yields experiencing an additional 5 bushel per acre loss and soybean yields a 1.4 bushel per acre loss for each additional EDD. This suggests that corn and soybean yields are 41% and 32% more sensitive to extreme heat shocks, respectively. Our analysis also provides suggestive empirical evidence that these yield losses may stem from farmers reducing their efforts to adapt to extreme weather shocks when covered by insurance.

Under extreme heat conditions, uninsured farmers increase their input expenditures on fertilizer and petroleum—indicating greater adaptation efforts to mitigate the negative impacts of extreme weather. Petroleum usage is associated with increased irrigation, while fertilizer application could be a way to mitigate the negative yield impacts of extreme weather. In contrast, fully insured farmers reduce their expenditures on fertilizer by 5.5% and on petroleum by 3.6% per extreme degree day, effectively offsetting any increase in input expenditure when faced with extreme heat.

Figure 1. Expenditures and Area Insured Under the Federal Crop Insurance Program



Source: Author's calculations using data from the USDA Risk Management Agency (RMA) and National Agricultural Statistics Service (NASS).

Fact #4: Cost Disincentives to Adapt Under the FCIP

A back-of-the-envelope calculation suggests that the cost of disincentives to adapt under the FCIP, leading to agricultural output losses, amounts to $19 million per county annually, assuming a 10-degree-day increase in extreme heat. We estimate this is based on average corn and soybean prices and planted acreage from 1990 to 2023. This amount represents approximately one-half of the income stabilization provided by insurance, estimated at $34 million per county annually. Although the income stabilization effect is larger in magnitude, the associated agricultural output losses constitute a meaningful reduction in social welfare. These estimates highlight the important trade-off between income stabilization and incentives to adapt to extreme weather under the FCIP and call for alternative policy designs to build climate resilience. We present three of such alternatives below.

Implications for Designing Insurance for Climate Change

Government intervention in insurance markets, such as flood, wildfire, and crop insurance, is a common response to the growing risks associated with climate change. As the frequency of extreme weather events increases, these aggregate shocks necessitate policies that help stabilize incomes and mitigate the economic fallout. However, subsidized insurance programs may also reduce incentives for ex-ante adaptation.

I consider three alternative budget-neutral or budget-improving policies that may be available to the government:

Unconditional cash-for-subsidy: This design entails replacing subsidies with unconditional transfers, with the insured bearing full premium costs. The payments are unconditional in the sense that a beneficiary's eligibility to the cash transfers is not linked to the purchase of any insurance protection. Payments can be set so that the total unconditional cash transfers are less than or equal to the total premium subsidy under the current system to attain budget neutrality.

Conditional cash-for-subsidy: This entails replacing premium subsidies with conditional cash transfers and beneficiaries faced with full premium costs. The payments are conditional in the sense that beneficiaries must purchase at least catastrophic levels of insurance protection to be eligible for the cash transfers. Payments can be set to maintain budget neutrality.

Adjusting the subsidy schedule: This requires varying the magnitude of premium subsidies at higher coverage levels (specifically, making premium subsidies significantly less generous at higher coverage levels). This policy generates a constrained contract that requires the farmer to bear some of the risk relative to the status subsidy levels.

These alternative schemes have the potential to stabilize farm incomes while promoting incentives for climate adaptation. This operates through several channels: increased ex-ante investment in farm inputs, especially in situations where farmers are income-constrained, ex-post protection from insurance, and farmers taking "unobserved actions" during production that make them less vulnerable to weather shocks. Moreover, to the extent that total transfers to farmers under each policy alternative are less than or equal to the total premium subsidy under the current policy, the proposed schemes are budget-neutral or -improving because they do not require additional federal resources. The efficacy of the alternative schemes relative to the status quo today vis-à-vis the choice for one scheme over another will depend on the specific context.

Indeed, our discussions about designing the Federal Crop Insurance Program for climate change provide a useful template for thinking about how large, government-backed insurance programs may be conceived and designed for climate resilience. Climate-related risks are inherently systemic, constraining the ability of the private sector alone to finance such risks. Conversely, consumers may underestimate the risks and underinvest in insurance. These factors necessitate the government's intervention in climate risk insurance markets. I highlight the trouble in achieving resilience through insurance and present a framework that sheds light on alternative policy re-designs for climate resilience and adaptation.

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For additional information, the author recommends:

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