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ALSO IN THIS ISSUE

The Story of Rising Fertilizer Prices

Aaron Smith

High fertilizer prices in the past year have increased costs for farmers, but for some crops more than others. Multiple potential causes could explain these price increases, stemming from both supply and demand factors. If farmers respond to high prices by using less fertilizer per acre, it will provide an environmental benefit in the form of less nitrogen and phosphorus in streams, rivers, and lakes.

Fertilizer prices approximately doubled between the summer of 2020 and the end of 2021. Prices had been relatively stable in the prior five years at around $500 per ton for phosphate products (phosphorus) and just below $400 per ton for potash (potassium) and urea (nitrogen). In January 2022, phosphate products hit $900 per ton, and potash and urea prices were $800 per ton (see Figure 1).

What caused these price increases, and how much do they matter?

Agricultural Fertilizers

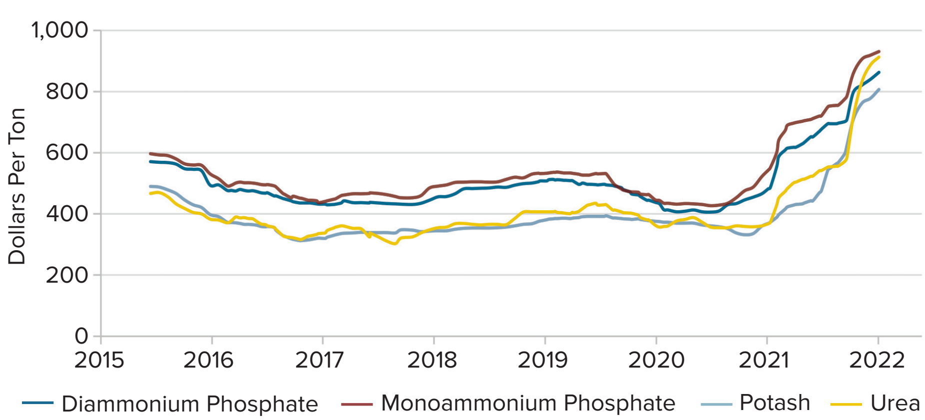
Most fertilizers deliver one or more of the following macronutrients to plants: nitrogen (N), phosphorus (P), or potassium (K).

Nitrogen makes up three-quarters of the air we breathe and is essential in plant growth. However, atmospheric nitrogen needs to be converted to ammonia (NH_3) before it is accessible to plants. This conversion process, known as fixation, occurs naturally through bacteria and archaea that live in the soil or in the roots of some plants. Animals also produce ammonia by eating nitrogen-laden plants and excreting manure.

These natural processes typically do not produce enough ammonia for crops to reach their maximum potential. The invention of the Haber-Bosch process in 1909 enabled the production of synthetic ammonia by reacting nitrogen with hydrogen under high heat and pressure. U.S. nitrogen producers use natural gas as an energy source in this process.

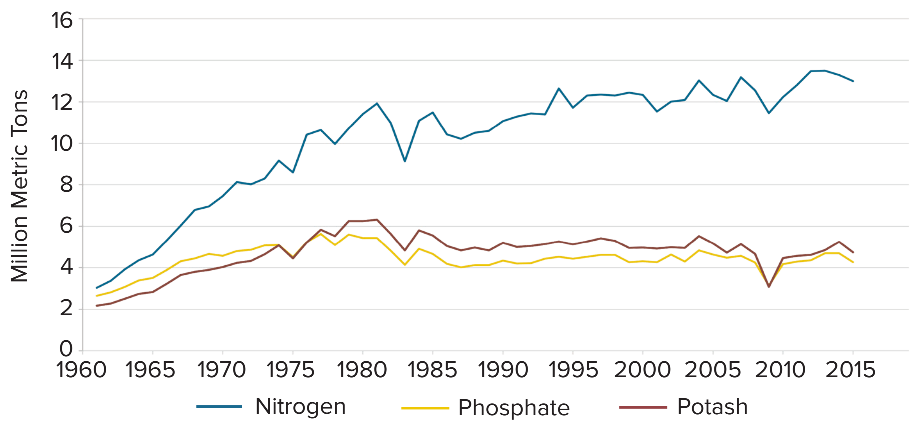
Phosphorus helps plants grow by promoting photosynthesis and other functions important for development. Phosphorus fertilizers are typically produced by mining phosphate rock and treating it with sulfuric or phosphoric acid, causing a chemical reaction that converts it to a form that can be absorbed by plants.

Figure 1. U.S. Fertilizer Prices



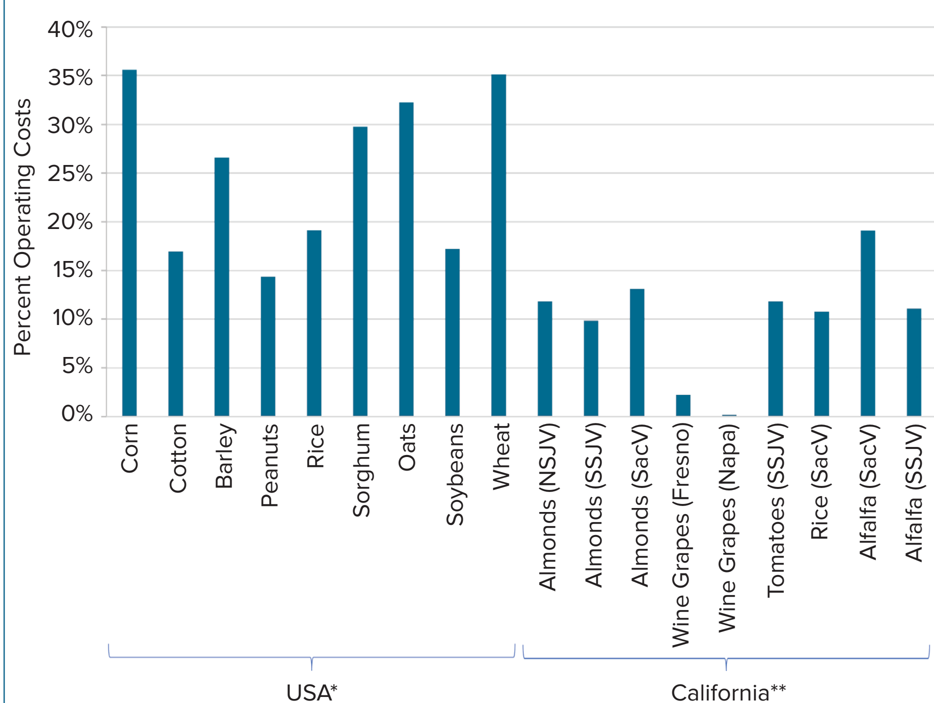
Source: DTN. Available at: https://www.dtnpf.com/agriculture/web/ag/crops/article/2021/12/15/nitrogen-fertilizer-prices-continue.

Figure 2. Fertilizer Used in U.S. Agriculture



Source: USDA Economic Research Service.

Figure 3. Fertilizer as a Percent of Operating Costs, 2019/2020



Source: *USDA: https://www.ers.usda.gov/data-products/commodity-costs-and-returns/commodity-costs-and-returns/.

**California cost studies: https://coststudies.ucdavis.edu/en/current.

Note: NSJV=Northern San Joaquin Valley; SSJV=Southern San Joaquin Valley; SacV=Sacramento Valley.

Potassium strengthens plants, making them resistant to disease and higher in quality. Potassium fertilizers are created by mining potash from deep underground, similar to table salt. Chemical reactions convert it into a form usable by plants.

It is impossible to apply the exact amount of fertilizer that plants require, and there is a perception that many farmers over-apply fertilizer because they fear yield and profit losses from applying too little. This extra fertilizer is sometimes called "insurance nitrogen."

Nitrogen and phosphorus that are not taken up by plants often end up in waterways, where they can cause a massive overgrowth of algae, known as an algae bloom. Certain types of algae emit toxins that are absorbed by shellfish. Consuming these tainted shellfish can lead to stomach illness and short-term memory problems. Drinking or coming into contact with toxins from algae blooms can cause stomachaches, rashes, and more serious problems. Algae blooms also reduce the recreational value of lakes and rivers.

U.S. Fertilizer Consumption

Nitrogen fertilizer use increased by a factor of four from 1960–1980, as shown in Figure 2. This increase coincided with dramatic increases in crop yields. In the 1970s, high agricultural commodity prices created a farm boom in which farmers planted more acres to crops and increased fertilizer applications.

After a slight drop during the farm crisis of the early 1980s, nitrogen fertilizer use has increased steadily, but at a slower rate than in the 1960s and 1970s. Phosphate and potash use has been relatively constant since 1985. Use of all fertilizers dropped substantially in 2009 after fertilizer prices increased fivefold during the 2008 commodity boom—a much larger increase than in 2021.

Nitrogen is by far the most used agricultural fertilizer by weight. It now makes up almost 60% of all fertilizer used, whereas phosphate and potash each comprise just over 20%. However, the trends in phosphate and potassium use mirror those in nitrogen, perhaps because many farmers apply multi-nutrient fertilizers.

Two facts provide insight into the role of fertilizer in the U.S. farm economy. First, corn uses about 45% of each fertilizer type, yet it takes up only a quarter of all cropland—90 out of about 390 million cropland acres in the nation. Second, in 2020 fertilizer made up 35% of operating expenses for corn growers—more than any other crop. Fertilizer is a major expense for the biggest crop in the nation, so the 2021 fertilizer price increases will significantly raise the cost of growing it.

As Figure 3 shows, fertilizer makes up more than 25% of operating expenses for several other major crops, including barley, oats, sorghum, and wheat. Between them, these crops use an additional 50 million acres each year.

In percentage terms, fertilizer is a much smaller expense for major California crops than the major national crops. It makes up about 10% of the cost of growing almonds, less than 2% of the cost of growing wine grapes, and 11% of the cost of growing processing tomatoes.

These percentages are useful for understanding the salience of fertilizer price increases for farmers. A jump in the price of one of your largest expense items will be noticed.

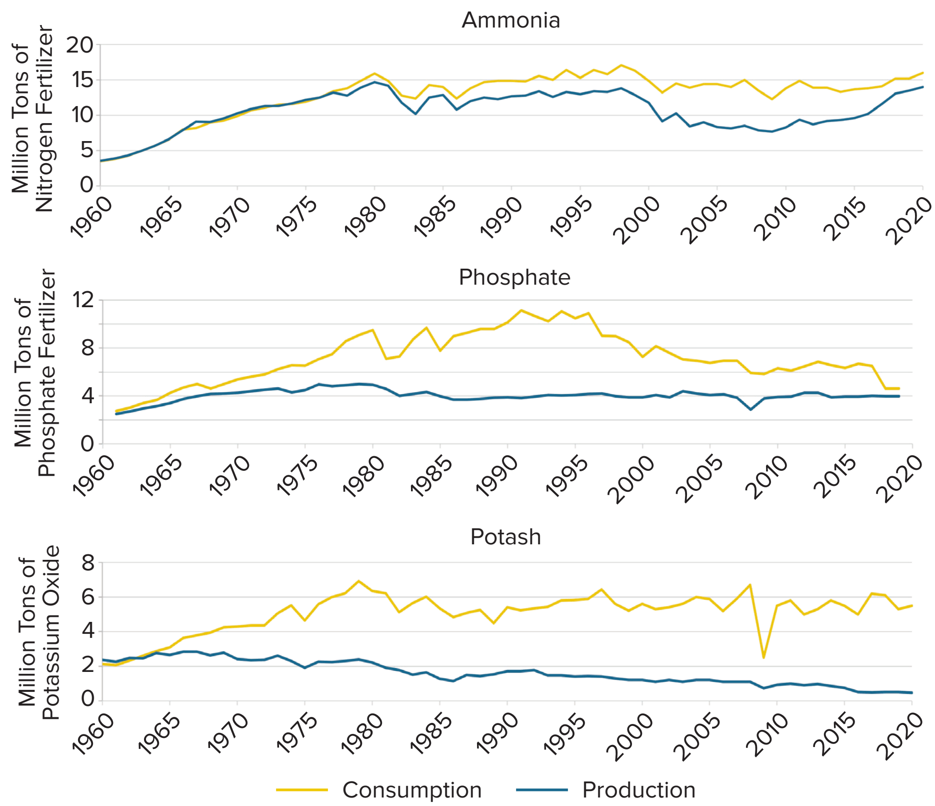
However, these percentages obscure the amount of fertilizer used on each crop because major national crops such as corn are relatively inexpensive to grow. Most corn is grown without irrigation, which saves the cost of acquiring and pumping water. Corn also requires little labor, especially now that tractors practically drive themselves.

According to cost and return studies by the University of California, bearing almonds cost $3,000–$4,000 per acre per year, which is about 10 times as much as growing corn in Illinois. So, although they spend a smaller percentage of their budget on fertilizer, California almond growers spend about three times as much per acre on fertilizer as Illinois corn growers, including about 25% more on nitrogen and multiple times more on potassium.

Fertilizer Production

Fertilizers are produced throughout the world and traded heavily between countries. Figure 4 shows that the United States currently produces about 85% of the ammonia it uses, most of which becomes nitrogen fertilizer, and it produces 90% of the phosphate rock it uses, most of which becomes phosphate fertilizer. It imports 90% of its potash.

Figure 4. U.S. Production and Consumption of Fertilizers



Source: USGS for ammonia and potash; FAOSTAT for phosphate.

Most U.S. ammonia production capacity is in Louisiana, Oklahoma, and Texas—close to natural gas fields. Natural gas constitutes about 80% of the cost of producing ammonia. Domestic production declined substantially from 2000 to 2010, a period when U.S. natural gas prices were historically high. In the latter part of this decade, two major producers merged as part of a period of consolidation in the industry.

After 2010, the deployment of hydraulic fracturing (fracking) increased the supply of natural gas and thereby lowered the cost of production dramatically. Fertilizer prices, however, remained high in this period and U.S. firms enjoyed large margins. In the last five years, production has rebounded, as more plants were built to take advantage of cheap natural gas.

Ammonia imports have mirrored domestic production, increasing as production declined between 2000 and 2010 before declining when production rebounded after 2016. Two-thirds of U.S. imports come from Trinidad and Tobago, and most of the remainder comes from Canada.

U.S. potash production has declined by 80% since 1965. Most of the remaining U.S. production comes from deep mines in southeastern New Mexico. Most potash imports come from Canada, which is the world's largest producer by a significant margin.

Most domestic phosphate is mined in Florida and North Carolina, although there is also some production in Idaho and Utah. U.S. phosphate production declined steadily from 1980–2019, but phosphate fertilizer use in U.S. agriculture remained relatively constant over this period.

Each year between 1980 and 2019, the U.S. exported about half its phosphate production, mostly to Canada and Mexico. As production declined, the U.S. maintained domestic consumption by increasing imports, mostly from Morocco, Russia, and Israel. In March 2021, the U.S. International Trade Commission ruled that imports from Morocco and Russia had affected the U.S. producers adversely, and they imposed countervailing tariffs ranging from 9% to 47%.

The U.S. Geological Survey (USGS) is an excellent source for data on mineral commodities, and I use this source for ammonia and potash in Figure 4. For phosphate, USGS reports data on phosphate rock, which is the product that is extracted from mines. Production and consumption of phosphate rock shows an incomplete picture of the phosphate fertilizer market. Each ton of phosphate rock generates about 0.2 tons of fertilizer. The U.S. imports some phosphate rock, mostly from Peru, which domestic firms make into fertilizer. In addition, the U.S. imports a significant amount of phosphate fertilizer. Thus, Figure 4 presents phosphate fertilizer data from FAO rather than phosphate rock data from USGS.

Prices

So, why have prices increased? To answer this question, I consider supply- and demand-side factors.

On the supply side, U.S. natural gas prices doubled between the summer of 2020 and the end of 2021, which significantly raised the cost of nitrogen production. Energy is also a component of phosphate and potash mining costs, but it is much less important in the production of these products than for nitrogen. For this reason, the increasing price of natural gas cannot fully explain the fact that all fertilizers increased in price by a similar percentage.

Weather events also disrupted nitrogen supply, including the freeze in Texas in February 2021 and Hurricane Ida in August 2021. There were also some supply disruptions due to COVID-19. However, these events caused only a temporary reduction in production and so do not explain a sustained price increase. Moreover, these events did not hit phosphate and potash production regions.

Also on the supply side, shipping costs increased dramatically in 2021, especially on shipments from Asia to North America. However, most fertilizer imports to the U.S. come from the Americas and would be less affected by shipping costs.

On the demand side, crop prices are high. Corn, soybean, and wheat prices increased by 60% from the summer of 2020 through the end of 2021. High crop prices incentivize farmers to apply more fertilizer per acre, which would place pressure on fertilizer prices.

The high crop prices did not spur a substantial increase in acreage in 2021, and it is too early to know whether we will see an acreage increase in 2022. However, an increase in demand from farmers planning to expand acreage in response to high crop prices is a plausible factor behind rising fertilizer prices.

Conclusion

Predicting commodity prices is a fool's errand. When natural gas and agricultural commodity prices come down, I would expect fertilizer prices to also come down.

When the price of a pound of fertilizer exceeds the expected increase in revenue from spreading it on the field, it is not profitable to use that pound. Fertilizer prices have increased by more than most crop prices, so in 2022 producers have an incentive to apply less fertilizer per acre. If farmers do apply less fertilizer per acre, it will provide an environmental benefit in the form of less nitrogen and phosphorus in streams, rivers, and lakes.

Moreover, to the extent that farmers apply more than the recommended amount of fertilizer as insurance against low yields, reducing use in 2022 provides an opportunity to experiment and to learn how much such insurance is necessary.

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For additional information, the author recommends:

Bushnell, James and Jacob Humber. 2017. "Rethinking Trade Exposure: The Incidence of Environmental Charges in the Nitrogenous Fertilizer Industry." *Journal of the Association of Environmental and Resource Economists* 4(3).

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Why Soil Fumigation Changed the Strawberry Industry

Ryan Olver and David Zilberman

We assess the U.S. strawberry industry and its transition from land to capital intensity, with emphasis on the role of methyl bromide, a broad-spectrum soil fumigant, and its impact on the supply chain. Historical analysis suggests strawberries' unique characteristics made them particularly well-suited for monoculture, and that disease control was the means—not the cause—for adopting this system. We also argue that the geographic concentration and the stability it permitted are the root causes of the immense productivity gains in strawberry production from the mid-20th century onward.

Early strawberry cultivation consisted of cottage industries located within short distances of eastern urban centers. Strawberries are both perishable and easily damaged, limiting the distance they can be shipped without spoiling. However, by the mid-20th century, California had become the single largest strawberry producer nationally; by the 1970s, the state had almost completely dominated the market. Today, strawberries are a high-value, capital-intensive crop grown primarily along the California coast; just five counties are responsible for over 80% of U.S. output.

As suggested by Figure 1, this transition was characterized by simultaneously increasing total output while decreasing total acreage. While several factors contributed to this transition, its continuation is inextricably linked to the introduction of methyl bromide soil fumigation in the 1960s.

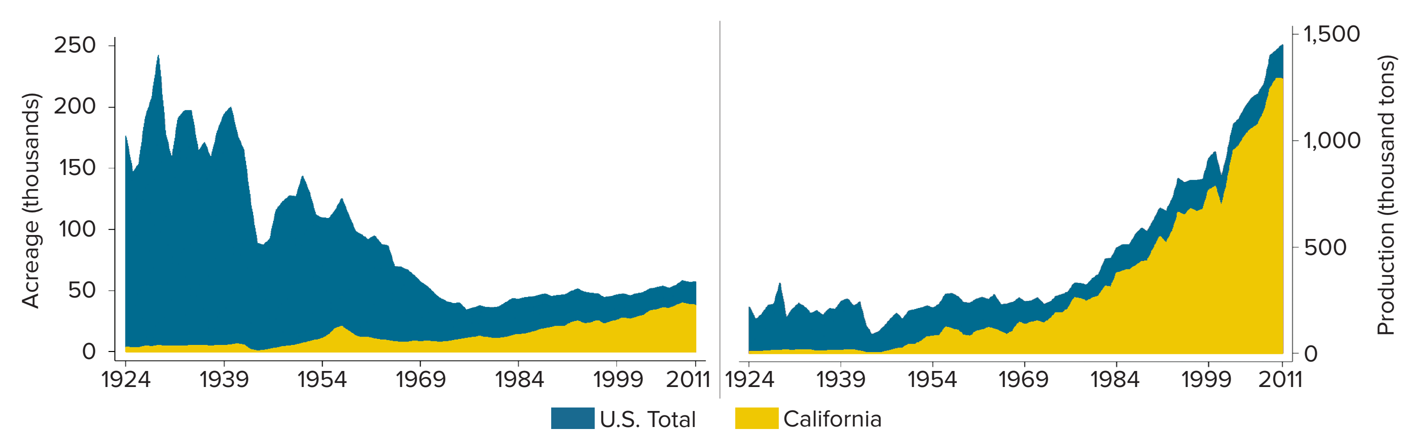
Early Commercial Production

Small pockets of commercial production first emerged at the beginning of the 19th century. They accounted for less than 1,500 acres nationally until the 1850s, when the railroad boom fundamentally altered the geographic distribution of production. While constraints were still comparatively strict, growers could feasibly supply markets within a few hundred miles. As a result, "strawberry fever" erupted in the late 19th century, and cultivation increased from 1,500 to 150,000 acres nationally by the 1880s.

The "shipping system," or long-distance strawberry marketing, required new physical and institutional infrastructure. Marketing over such distances was impossible for individual farmers, who now relied on commission agents and auction houses. Shipping demanded adequate facilities and available labor, while keeping freight costs low required cooperative agricultural associations. Perishability was mitigated by railcar innovations—first ventilated cars, then cars that could carry ice. Strawberry breeding, a private enterprise, was critical to developing firmer, more climate-tolerant berries.

This system could be extremely lucrative for strawberry growers given the right conditions. In particular, warmer climates in the South permitted earlier marketing, and early-season prices—sometimes an order of magnitude higher than normal—could generate astronomical profits. This caused the locus of production to shift further and further south throughout the late 19th and early 20th centuries. However, to justify investing in the necessary infrastructure, a district also needed sufficiently concentrated production;

Figure 1. National Acreage and Production, 1924–2011



Source: Author calculations based on data from Bain and Hoos, NASS, *California Vegetables*, and the Census of Agriculture.

one rule of thumb was a minimum of 100 acres within a few of miles from a shipping facility.

By the early 1920s, Tennessee, Missouri, and Arkansas had the lion's share of strawberry acreage. Establishment costs in these regions were relatively low (roughly $100–$110 per acre, in nominal dollars). Producers in these states focused on expanding strawberry acreage rather than investing in inputs and capital to sustain soil fertility, leading growers to relocate to previously unused land for each new planting. By the 1930s, land was starting to become scarce near shipping facilities.

California

California's strawberry industry emerged during the mass migration of the Gold Rush era and came to be characterized by intensive, costly cultivation practices. This was in large part due to irrigation requirements; after accounting for land leveling, flumes, and water, it could cost growers up to $200 an acre. Weeding, fertilizer, and soil cultivation—optional in the South—were also standard practices. As harvests were too large for household labor alone, it was also frequently necessary to supply workers with room and board. On the Central Coast, these costs could reach $700 an acre, or higher if a new building or well was required. In exchange, the fertile soil and favorable local climate led to yields that were three to four times higher than the national average. California's bearing season was also significantly longer: 4 to 5 months, rather than weeks.

Despite substantial differences between the regions, California growers also noticed declining yields when replanting on old strawberry land, and growers began to avoid old ground even after crop rotation. In combination with the high cost of establishment, this resulted in the widespread adoption of intercropping; growers cultivated strawberries between rows of new orchards, providing early income for the landlord while allowing them to split investment costs. However, intercropping appears to have fallen out of practice by the late 1930s, likely as new orchard acreage declined; this left strawberry growers to seek out previously untouched soil or old pastures for new plantings.

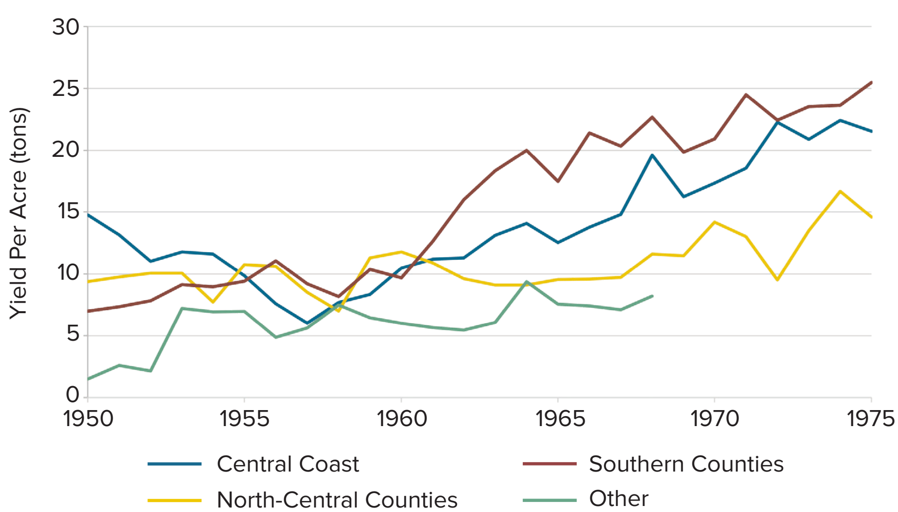
Post-war Transition

Prior to the mid-20th century, California's participation in the wider shipping system was restricted due to technological limitations; consumption either occurred locally or in adjacent states. This began to change in the 1920s, as innovations in transportation—pre-cooling and rudimentary refrigeration—made longer distances physically feasible, if not economically sound. After WWII, California producers began to market to East Coast consumers in earnest. The University of California's breeding program had recently introduced five high-yielding varieties, and this coincided with new demand for frozen berries and a series of weather shocks back east that impeded the slow post-war recovery in their own strawberry industries. By 1956, California had become responsible for nearly half of all strawberry production in the United States.

It is important to note that the relative costs of production had not materially changed; the Central Coast remained perhaps the most expensive district to cultivate strawberries in nationally. The overall cost per acre was 50% to 100% higher than in the Pacific Northwest or Michigan—now major producers in the post-war era—and several times greater than most southern districts. Depending on the market, California growers also faced an additional shipping premium of 0.4 to 1.2 cents per pound—an increase of 25% to more than 100% in transportation costs. Extended time in transit also magnified the impact of any pre-shipping damage or spoilage. Therefore, shipping over long distances depended on high yields and efficient capital to keep unit costs low, minimizing time spent between harvesting and cooling.

The transition from local to national supplier was in large part facilitated by the University varieties, which nearly doubled pre-war yields. Critically, this increase was limited to California's climate and declined substantially if cultivated elsewhere. Compared to other regions, the extended

Figure 2. California Strawberry Productivity by Region; 1950–1975



Source: Data from the California Agricultural Commissioners Crop Reports, 1950–1975. Available at: https://ageconsearch.umn.edu/?ln=en.

bearing season also enabled processing facilities to devote 5 to 6 times the number of annual operating hours to strawberries. In turn, this permitted greater capital specialization, keeping average total costs below other regions despite higher local wage rates.

Systemic Disruption

While agricultural innovation and California's natural advantages compensated for transportation costs, average productivity was also beginning to decline, falling from 7–8 tons per acre in the early 1950s to 5–6 tons in the second half of the decade. This was attributed to several factors, including disease pressure and limited availability of new land; both of these resulted from an expansion of acreage in an increasingly concentrated geographic area.

Some degree of land scarcity was an inevitable result of post-WWII urban expansion. However, it was exacerbated by increasingly virulent outbreaks of Verticillium wilt, a disease caused by a pathogenic soil-borne fungus, *Verticillium dahliae*. Although wilt affects numerous crops, strawberries are particularly vulnerable; plant loss could be catastrophically high, on the order of 75%. In addition, any soil inoculum (pathogen remaining in the soil) becomes a pervasive issue, as *V. dahliae* can remain viable in soil for up to 25 years.

Given the importance of location and capital, the combination of land and disease pressure posed an existential threat to California's dominant market position. At the beginning of the 1930s, wilt was considered to be a growing threat to strawberry plantings; incidence was particularly concentrated around the Central Coast, possibly due to the heavy cultivation of other host crops. For strawberries, plant loss was most severe in plantings that followed tomato, cotton, or potato crop rotations, leading growers to avoid any land previously used to grow those crops. In addition, just two of the five University varieties—Shasta and Lassen—comprised the large majority of acreage in California. While Shasta demonstrated slight resistance to *Verticillium*, it was more susceptible than Marshall, its predecessor. Lassen possessed no resistance at all.

Fumigation

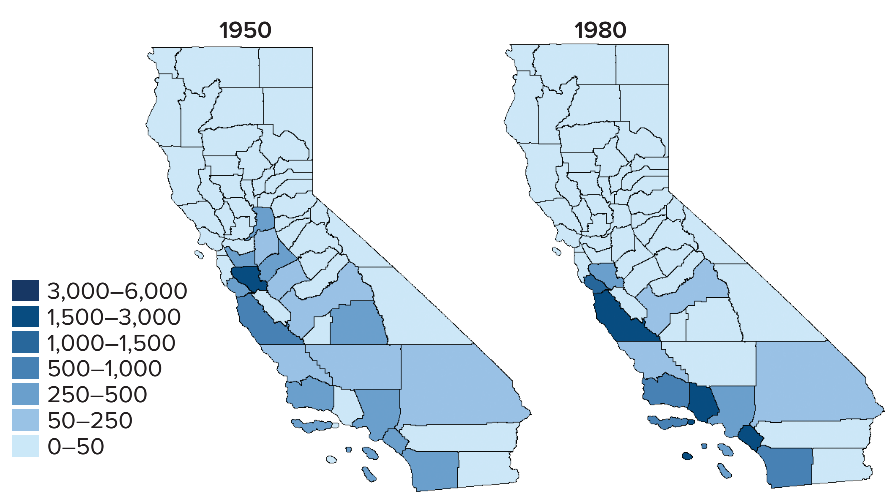
The threat posed by Verticillium wilt drove a significant amount of phytopathological (plant disease) research during the mid-20th century, and featured prominently in the numerous trials of soil fumigants throughout the 1950s. A mixture of two chemicals—methyl bromide (MB) and chloropicrin (Pic)—was soon discovered to be a "silver bullet" against *Verticillium*. MB-Pic treatment was expensive at $300–$400 per acre—increasing establishment cost by 20% to 30%—but was associated with a 94% to 97% reduction in plant loss. As an herbicide, methyl bromide also mitigated some of this cost through a sizable reduction in weeding labor, which comprised roughly half of pre-plant labor expenses.

Impact

Fumigation with MB-Pic was introduced in 1960. While quantitative data on its early usage is sparse, some authors suggest it reached 100% adoption on new strawberry land by 1965. As shown in Figure 2, there is indeed evidence of a sharp, localized increase in productivity post-1960, first in southern districts and then the Central Coast. California strawberry acreage was increasingly concentrated within these two regions (Figure 3), even as total acreage declined by a third from 1960 to 1966. Output, however, remained nearly constant, as yield per acre rose by almost 50% over the same period. Crop budgets for Orange and Los Angeles counties as well as Santa Cruz and Monterey counties indicate owned capital per acre increased roughly 200% between 1959 and 1976.

Aside from *Verticillium* control, the adoption of MB-Pic permitted technologies and production practices that would have either been economically difficult or physically impossible otherwise. Plasticulture adoption, for example, was directly related to the use of MB-Pic, and in particular, with methyl bromide. The use of clear plastic sheets as an early-season soil covering generated significant positive responses in both plant growth and yields, but interference with hand-weeding made herbicidal fumigation virtually mandatory.

Figure 3. Changes in California Strawberry Acreage, 1950 vs. 1980



Source: Data from the California Agricultural Commissioners Crop Reports, 1950 and 1980. Available at: https://ageconsearch.umn.edu/?ln=en.

Yield and quality gains from new varieties have been almost entirely predicated on MB-Pic, as the vast majority of cultivars adopted post-1960 are highly susceptible to disease and rely on fumigated soil. While not directly reliant on MB-Pic, existing transplant propagation systems are also tied to improved cultivars and the use of plastic to accelerate plant growth. These systems also require chilling hours in high-elevation nurseries at considerable distances from production districts, requiring phytosanitary control; MB-Pic is a preventative measure against cross-site contamination.

Drip irrigation was introduced in the 1970s and complemented the new production system; the improved weed control and use of plastic mulch improved the profitability of drip systems by reducing the labor required to maintain them. Drip systems also require significant capital investment, which would have been difficult to justify under migratory practices. More generally, any technological adoption or capital investment was arguably made more economically feasible by the overall reduction in risk provided by fumigation.

It is also worth noting that early yield gains from MB-Pic were essentially confined to California and, to a lesser extent, Florida. Outside of California, extension services generally discouraged the use of MB-Pic as it was prohibitively expensive, and returns were unlikely to justify expenditures. This served to widen the yield gap between California and the rest of the country.

Phaseout of Methyl Bromide

MB-Pic fumigation became a staple of California strawberry production and remained so for the next 30 years. Unfortunately, however, methyl bromide was later identified as a Class-1 ozone-depleting agent. Under the Montreal Protocol, methyl bromide soil fumigation was progressively restricted from 1994 onward until it was completely banned in 2005. Many agricultural stakeholders lobbied against the phaseout; some were granted temporary reprieves in the form of critical-use exemptions (CUEs), but these came to an end in 2017.

Methyl bromide's phaseout has had significant implications for the strawberry industry, particularly as the incidence of both new and previously controlled diseases continues to increase. Alternative fumigants, as well as tighter management practices, have thus far preserved the existing system. However, the loss of methyl bromide is not the only issue the industry currently faces. The increasing cost of labor and, for certain regions in California, greater import volume from Mexico, pose further challenges.

Lessons

The relationship between methyl bromide and the strawberry industry is in large part a story about the evolution of its supply chain. Improved transportation has shifted the locus of production over time, first to the southern United States, then to California. Disease control then allowed acreage to concentrate on California's coast, where production depended on economies of scale to mitigate high relative costs. MB-Pic provided a means to remain in one place in order to utilize capital more efficiently.

Despite the economic benefits of this system, there are obvious vulnerabilities. The long search for a suitable alternative to methyl bromide emphasizes the value of ongoing, continuous research as well as the distinct possibility that the strawberry industry of today, almost unrecognizable compared to the one from 50 or 100 years ago, may appear fundamentally different from the one that will exist 50 years in the future.

Looking Forward

We feel it is unlikely that the existing system will change drastically in the immediate future, although incremental improvements to existing techniques and cultivars will continue to accrue. In the medium-term, however, we may also see different modes of production become mainstream. Enclosed environments—vertical farms, greenhouses, scaled-up container farming—provide greater control over growing conditions and allow farmers to substitute capital investment for land quality. We would expect this to lower reliance on chemicals.

For strawberries in particular, elevated systems of cultivation may also make harvesting easier, improving speed and lowering costs. If yields increase, we would also expect this shift to be land-sparing and potentially reduce emissions. If these types of technologies become sufficiently inexpensive, they may lead to more decentralized production, as transportation becomes a larger component of total costs.

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Inflation Risks are on the Rise

Jens Hilscher, Alon Raviv, and Ricardo Reis

U.S. inflation rose sharply in 2021. Perhaps this is temporary, due to soaring energy prices and a fast recovery, or perhaps there will be a sustained increase in prices. Forward-looking market expectations show a sharply higher risk of high inflation.

The probability of inflation lying above 3% over the next five years jumped from 6.1% (November 2020) to 66.2% (November 2021).

Photo Credit: iStock.

In December 2021, U.S. inflation measured by the annual change in the all-items CPI was 7%—its highest value since March of 1982, almost forty years ago! Unsurprisingly, public interest in inflation has spiked as well, with the Google index of searches for inflation rising in May of 2021 to twice its average value during the previous five years. Price increases have been most salient in energy, with California gasoline prices experiencing a new all-time high at $4.68 in November. But, the increase in prices is broader than that; for example, December inflation for food at home was 6.5%, for electricity 6.3%, and for new vehicles 11.8%.

Temporary or Permanent?

Some inflation was, perhaps, inevitable. The most important question is whether higher inflation is temporary or persistent. The case for temporary inflation can be made by pointing towards temporary COVID-related shocks. First, at the trough of the recession, in April 2020, oil prices were negative. Since then, they have steadily increased—the average price in December was close to $70 dollars a barrel. Natural gas prices have also risen, from around $2.58 per British thermal unit (BTU) a year ago (December 2020) to $5 in November 2021. As it looks like energy prices are stabilizing at the higher level, or even coming down, their impact on inflation should disappear.

Second, the very fast recovery from the recession may have pushed prices up. Consumers, coming out of the lockdown with a high stock of savings (the savings rate out of personal disposable income in 2020 was one of the highest in decades) rushed to spend it in 2021; spending on durable goods was about one-third higher in 2021 than it had been in 2019. At the same time, firms took some time to reopen their doors, re-establish their links to suppliers, and hire back qualified workers. As soaring demand has been chasing sluggish supply in some sectors, prices have risen. As 2022 unfolds, some of the pent-up demand may slow down or disappear, and many firms should be able to expand supply in response to increased demand.

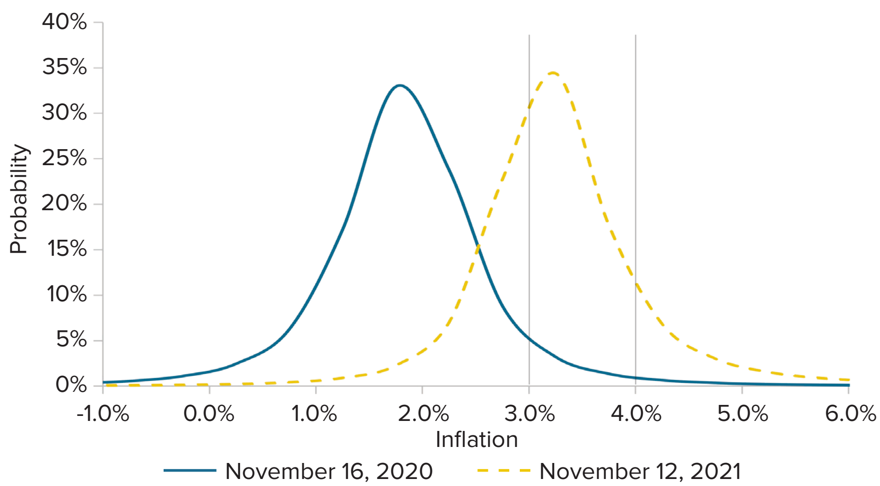
Third, global supply chains, especially in the production of semiconductors, were severely disrupted by the pandemic, leading to large increases in the price of an essential input to many sectors. Again, the semiconductor industry is already adapting and making large investments in capacity so that prices may soon fall.

However, inflation may also be here to stay. Global supply disruptions due to COVID could take longer to resolve, and higher new vehicle prices may persist, or increase further, if chip shortages persist. Perhaps most importantly, consumers may start to expect higher inflation and translate this into their wage demands. Many people are noticing that the purchasing power of their monthly paycheck has decreased significantly—at the pump, in grocery stores, when buying a new vehicle, or heating their home. If history is a guide, soon they will start demanding higher wages to restore their purchasing power. If this happens once, in 2022 alone, inflation may continue in 2022 but not beyond that. But, if companies raise prices in response to higher wage demands by workers, leading to further high expectations of inflation, further wage demands, and so on, then the United States could enter the wage-price spiral that is often at the heart of high and persistent inflation.

What Do Markets Think?

There are active financial markets in which people can trade the risk of inflation. Namely, there are financial contracts that pay off if inflation lies above a certain cutoff for a specific period. Such an inflation option pays off only if, for example, inflation lies above 3%. Another option, with a different cutoff price (the strike or exercise price), pays off if inflation lies above 4%.

Figure 1. Average Inflation Distribution Over the Next Five Years



Source: Based on inflation derivatives data from Bloomberg.

The fact that both contracts are trading in the market allows us to calculate the probability that inflation lies between 3% and 4%. If inflation is lower than 3%, neither contract pays anything, and if inflation is above 4%, both contracts pay off. The reason they are different is because sometimes inflation lies between 3% and 4%. If both options have a price that is similar, market participants view the probability of inflation lying between 3% and 4% as small, but if the prices are very different from each other, then the probability of lying in between is large. This classic insight allows us to construct the whole distribution and get a sense of how likely it is that inflation will lie above or below certain cutoffs.

Figure 1 shows one such distribution, for the average value of inflation over the next five years, measured in November of 2020 and 2021. Because of the long horizon, these forecasts focus on the inflation that is expected to persist. The striking rightward shift of these distributions is clear. According to these markets, there are signs that the risks of sustained higher inflation are increasing. Specifically, the probability of average inflation lying above 3% or above 4% over the next five years has increased substantially over the last few months.

In November 2020, the probability of average inflation lying above 3% over the next five years was equal to 6.1%; in November 2021, it was equal to 66.2%, a remarkable increase. To see this in Figure 1, note that in November 2020, only 6.1% of the total distribution lies below the curve to the right of the left vertical line (3% cutoff line), while 66.2% lies beyond the cutoff in November 2021. The probability of lying above 4% (to the right of the second vertical line), meanwhile, increased from 1.6% to 14.1%.

Figure 2 shows the probability of sustained high inflation over the next five or ten years. We plot the probability of average inflation lying above 3% or above 4% over the next five and ten years. It is apparent that market participants view sustained high inflation as much more likely now, compared to late 2020 and earlier in 2021. The probability of average inflation over the next five years lying above 3% is now significantly larger than 50%. In fact, even the probability of average inflation over the next ten years lying above 3% is almost equal to 40%. The probability of average inflation above 4% is much lower—14% over the next five years—but that probability has also risen sharply over the last several months. Also noticeable is that the risk of high inflation over the next five years has become higher than the risk of high inflation over the next ten years.

This difference supports the view that some of the inflation drivers are temporary. At the same time, it reflects the natural tendency of inflation not to be the same every year. If we think that it is likely that inflation will move around, it is also more likely that it may not be high and stay high. The other probable reason is that market participants may assume that inflation expectations are stable. If everyone thinks that inflation is close to, for example, 2% (close to the average over the last twenty years) then prices and wages will be set accordingly. The risk is that these expectations shift, and if that happens, it is likely that inflation may be here to stay for a while.

What Does It Matter if Inflation Is High?

There are several reasons why high inflation matters. First, high inflation is often also variable inflation. This makes planning by everyone more difficult. When writing a contract, deciding how much to save, or whether to purchase new equipment, people must figure out the value of alternatives at different points in time. The dollar is the unit of account to measure these values. When inflation, which is the change in what a dollar is worth, is variable, making these decisions becomes more difficult and prone to errors. A firm may plan for higher prices and perhaps higher profit margins of agricultural products or food items in grocery stores. If these do not materialize, costs will become a burden.

Second, because loans are written in dollars, when inflation is higher, the lender's payment is worth less in goods and services when she gets it back. On the other side, borrowers gain, paying less in real terms. Any existing long-term debt that is nominal will be easier to repay if inflation is high, and especially if inflation is high for many years. At the same time, any new debt will take this into account, so the interest rate charged will be higher to guard against the expected inflation. Worse, because high inflation tends to be variable inflation, lenders will start asking for higher interest rates beyond their expected inflation rates to get some insurance against the risk that inflation will be even higher. As a result, access to credit will suffer.

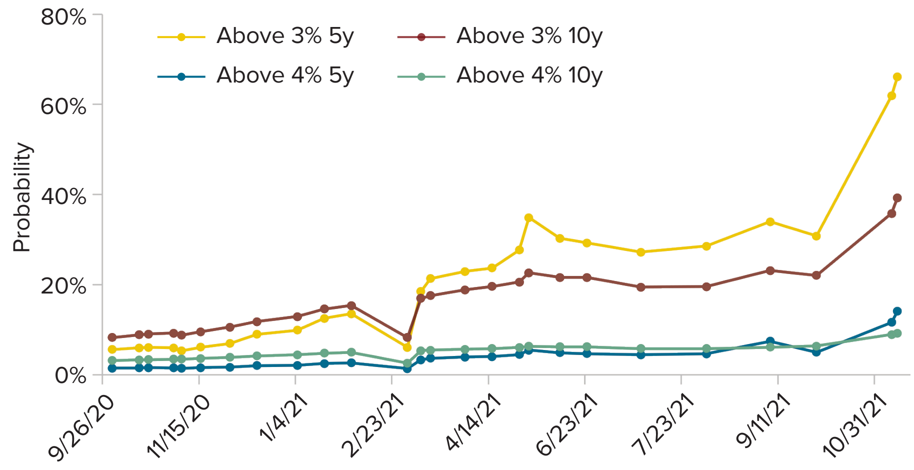
Third, and related, the largest borrower in the economy is the government. Recently, the U.S. government has been running record-high budget deficits, partly because borrowing costs have been low. Higher inflation, at first, lowers the real value of the public debt, making the U.S. government better off at the expense of those who bought its bonds. Soon after though, expected higher inflation will mean higher borrowing costs.

Where Do We Go From Here?

Over the next 6 to 12 months, the transitory effects pushing inflation up, from energy prices to supply chains, will have abated. At the same time, the higher expectations of inflation may have led to wage increases that are passed through to the prices firms set. How inflation behaves in 2022 will reveal the likely path for the next five years.

The financial markets data shows that uncertainty is high today, and that a favorable outcome is increasingly less likely. On its website, the Federal Reserve (the Fed) reports that its mandate is to conduct policy "so as to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates." Currently, however, inflation is expected to clearly exceed the target of

Figure 2. Probability of Inflation Lying Above 3% or Above 4% Over the Next Five or Ten Years



Source: Based on inflation derivatives data from Bloomberg.

"stable inflation at the rate of 2% per year."

During 2022, we will see how the Federal Reserve reacts. So far, U.S. policymakers have put a greater weight on the dangers of stalling the recovery, or of creating financial instability, that might result from raising interest rates. Relative to these concerns, the risk of persistently higher inflation has been downplayed.

However, recently, the perception of the relative importance of these risks appears to have shifted. During his January confirmation hearings in the Senate, Fed Chairman Powell called inflation a "severe threat," while another voting member of the rate-setting committee indicated that four interest rate rises in 2022 "appear likely."

Importantly, what the Fed does will have a direct impact on how inflation evolves and especially on whether people expect inflation to persist. A central bank that is very committed to a stable inflation target can always bring inflation down, even if only by causing a recession. But the longer it waits, and the less people trust it to keep to that target, the higher are these costs.

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For additional information, the authors recommend:

Hilscher, Jens, Alon Raviv, and Ricardo Reis. 2021. "Inflating Away the Public Debt? An Empirical Assessment." *The Review of Financial Studies*. Available at: https://bit.ly/34xf6YK.

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