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Trends and Challenges in Fruit and Tree Nut Sectors

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JEL Classifications: Q10
Keywords: Consumption, Fluctuations, Fruits and nuts, Labor shortage, Production, Trade

This series of *Choices* articles describes trends, issues, and problems facing the U.S. fruit and nut sectors. With $30.59 billion in cash receipts in 2017, fresh fruits and nuts account for about 20% of the value of farm production and are a vital part of U.S. agriculture (USDA, 2020a). As important inputs in food processing, fruits and nuts are also essential in value-added production in U.S. agri-food supply chains. Yet the sector faces many challenges: long-term locked-in investments, stagnant or falling bearing acreages and production, small growers being squeezed out as farm sizes expand, water shortages, groundwater restrictions, labor shortage, higher labor costs, pests and disease, production fluctuations, foreign competition, decline in juice consumption, and food safety issues. Many of these challenges are more pronounced for fruit and nut tree growers than for annual short-term crop farmers because of long-term investment and the irreversibility of planting decisions. The articles in this theme elaborate on these issues and focus on how growers can cope with these problems. They further consider the potential role of government policies—such as expanded crop insurance programs, the enaction of more favorable farm labor and immigration policy, export promotion and market expansion efforts, and incentives for agricultural research and development—to assist the sector.

The first article, by William Ridley and Stephen Devadoss, reviews trends in acreage, production, competition, and consolidation in the U.S. fruit industry. Fruit production is a vital part of the U.S. farm sector and underpins the agricultural economies of several states. In recent years, however, the industry has been faced with several ongoing disruptions to its long-term sustainability. Supply disruptions include declining bearing acreage and output, consolidation of growing operations toward fewer growers, and rising labor costs. These trends have coincided with falling domestic demand and ever-increasing foreign competition, suggesting that the fruit industry faces challenges on multiple fronts. This article describes the origins and consequences of these trends and explores their economic implications for production, input use, market structure, consumption, and trade.

Articles in this Theme:

The second article, by Reetwika Basu and Karina Gallardo, covers economic issues related to long-term investment in tree fruits. Asset fixity deals with investment in inputs and how these inputs adjust in the long run. In this context, fruit trees differ significantly from short-term crops. Many fruit trees start producing 2–7 years after planting, and they achieve full production only after 7–10 years. The investment in orchard infrastructure is quite expensive, irreversible, and often there is a lack of a secondary market for such capital goods. The recuperation period on the investment depends on the market price of fruits and ranges from 7 to 15 years. This article discusses the issues associated with asset fixity and the related asset specificity in tree crop production.

The third article, by Jeff Luckstead and Stephen Devadoss, deals with issues facing the citrus industry. Citrus is a key specialty crop with a production value of more than $3.35 billion in 2019. Florida and California account for most of the bearing acres (56% and 39%), with limited acres in Texas (3.6%) and Arizona (1.1%) (USDA, 2020a). Over the last two decades, total U.S. acreage has declined by 40%, with much of the decline in Florida. Citrus production endures wide fluctuations due to weather, pests, and diseases such as citrus greening and citrus canker. Because of health concerns and changing preference, orange juice consumption in the United States is declining. Further, the citrus industry faces greater import competition, particularly from orange juice imports from Brazil and Mexico. Unless these issues are resolved, the citrus industry will continue to exhibit a downward trend and the survival of many growers will be threatened. This article examines trends in production, consumption, foreign competition, severity of pests and diseases, and provides policy implications.

The fourth article, by Serhat Asci and Karthik Ramaswamy, describes the California fruit sector. The farm-gate value of fruits in California was about $18 billion in 2018 and accounted for 65% of US total fruit values (CDFA, 2020b; USDA, 2020a). The value of California fruits utilized for domestic consumption exhibited sustained growth, from $10 billion in 2009 to $13 billion in 2018, and fruit exports have also expanded noticeably, from $3.4 billion in 2009 to $4.7 billion in 2018 (CDFA, 2020a; USDA, 2020b). However, California fruit growers increasingly face several problems, including water curtailment, ground water management, labor shortages, labor regulatory compliances, invasive pests, and food safety issues. Public opinions on water, environmental, immigration and labor policies are diverse, and all stakeholders expect a legislative fix for these issues (CFFA, 2020). The authors present current and potential issues and future trends the Californian fruit sector may experience by assessing factors related to trade, policy, labor, water access, climate, pests and disease, and financial risks.

The final article, by Serhat Asci and Stephen Devadoss, covers trends and issues relevant for U.S. tree nut sector. Cash receipts from U.S. tree nut farming have expanded significantly in the last two decades, from $1.4 billion in 1998 to $3.9 billion in 2008 and to $10 billion in 2018 (CDFA, 2020c; USDA, 2020a). The United States ranks second in the world, behind only China, in total tree nut production. It ranks first in almond and pecan production, second in pistachio and walnut, and fourth in hazelnut. The leading nut producing U.S. states are California (94%), New Mexico (2%), Georgia (1%), and Oregon (1%). Most U.S. production is exported, generating $7.6 billion in trade revenue in 2018 (USDA, 2020c). Domestic demand is also steadily growing as nuts are promoted as nutritious and healthy snacks. However, tree nut growers experience several problems, including water shortages, labor shortages, immigration policies, and environmental issues (Hawkes, 2019). While policies pressure nut growers to decrease their water demand, policy makers should also focus on labor and trade issues. This article examines the trends in supply, domestic demand, export demand, and current and future potential issues surrounding the U.S. tree nut sector.

The articles in this theme are useful to growers, processors, and policy makers. Growers can use the information in their planting, production, and marketing decisions. Growers will need to be aware of import competition and the potential to expand overseas market opportunities for their products. They can also approach state and federal governments to seek financial support and research enhancements to help with pest and disease control and weather-related damages. Processors can utilize the information, particularly the production trend, to assess the availability of fruits and nuts for agri-food production in the downstream supply chain. The materials in these articles will be valuable to government agencies in deciding funding allocations for and coordination of various research projects aimed at controlling the pest and disease occurrences, climate impacts, weather incidences such as a freeze, and preventing acreage declines.

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Challenges for the U.S. Fruit Industry: Trends in Production, Consolidation, and Competition

William Ridley and Stephen Devadoss

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Keywords: Consolidation, Farm labor, Fruit production

The noncitrus tree fruit industry is a vital part of the U.S. agricultural sector, with $21.6 billion in revenues representing nearly 14% of the value of the country's agricultural production in 2017 (U.S. Department of Agriculture, 2019a). But value of production tells only part of the story of the industry's importance. Fresh fruit is a fundamental input into other segments of the food economy such as food processing and manufacturing. And since fruit production is typically a highly labor-intensive activity, with wages accounting for more than 25% of production costs in 2017 (U.S. Department of Agriculture, 2020b), the livelihoods of many farm workers are reliant on the industry. Further, U.S. exports comprise roughly 27% of world cherry trade, 13% of apple trade, 8% of plum trade, and 6% of peach and nectarine trade (Food and Agriculture Organization of the United Nations, 2020), making the United States one of the world's largest exporters of fruit.

National-level statistics on the industry's importance mask the extent to which the agricultural sectors of many states depend on fruit production. In California, the country's largest agricultural producer and exporter, noncitrus fruits accounted for more $10.6 billion of revenues (more than 25% of the state's crop production value) and nearly $3 billion dollars in export sales (U.S. Department of Agriculture, 2020a). Similar figures for Washington ($3.4 billion in total revenues), Oregon ($473 million), Michigan ($415 million), and other states reflect the industry's fundamental role in the farm sectors of large fruit-producing states (U.S. Department of Agriculture, 2020a).

Despite its importance, the industry has in recent years been beset by significant ongoing challenges and structural changes. In this article, we describe these trends in the noncitrus tree fruit industry (focusing on apples, cherries, peaches, pears, and plums, the top five noncitrus tree fruits by total value of production), detailing how stagnant or falling production of many fruits, declines in acreage, consolidation of production, labor supply issues, changing demand patterns, and trade competition have shaped the current situation in the sector. We further discuss potential policy responses that could be undertaken to ensure the viability of the sector.

Table 1 documents the phenomenon of declining production of several major tree fruits over time (we also include grapes because growers of several major tree fruits frequently convert their orchards to grape production). After declining for most of the past two decades, apple production has only recently reattained levels seen in the late 1990s. Fruits such as peaches, pears, and plums have been afflicted by protracted declines in production. As an exception, cherry production has increased noticeably, but cherries are not produced in the same quantities as other major fruits.

While many factors have influenced these declines, the principal outcome of this phenomenon has been substantial reductions in the amount of land devoted to fruit production. As of 2018, total U.S. acreage devoted to major noncitrus fruits stood at roughly 1.5 million acres (compared to a high of roughly 1.9 million acres in 2000), lower than at any point in the previous four decades (U.S. Department of Agriculture, 2019a).

Figure 1 shows total bearing acreage for several major fruits. The trends in acreage largely mirror those in production. The amount of apple-bearing acreage declined by nearly 20% from 2002 to 2017 (in seeming contrast with total apple production, which actually rose slightly over this period, largely due to technological advances and farm consolidation), while peach and pear acreage decreased even more precipitously, with declines of around 40% and 30%, respectively. For plums, acreage in 2017 was less than half of its 2002 level.

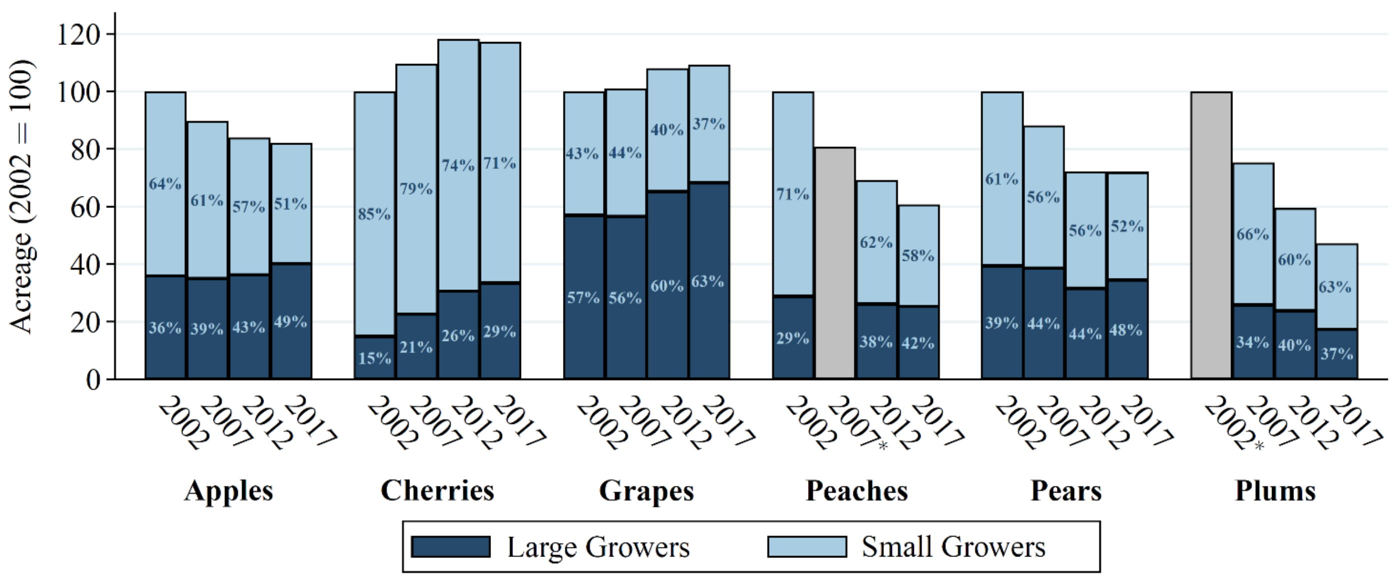
Several factors have influenced these broad changes in U.S. noncitrus fruit production, including consolidation of production, rising labor costs, and increased competition from foreign fruit growers. And to a large extent, the

Table 1. Five-Year Averages of Annual U.S. Production by Fruit, 1997-2017

	Average Annual Production (1,000 tons)				% Change,
	1997–2001	2002–2006	2007–2011	2012–2017	1997–2017
Apples	5,106.0	4,720.8	4,712.4	5,297.8	3.8
Cherries	370.3	354.4	454.8	487.6	31.7
Grapes	6,831.0	6,883.0	7,289.0	7,873.0	15.3
Peaches	1,244.0	1,206.0	1,117.2	872.6	–29.9
Pears	1,021.3	873.4	896.0	823.2	–19.4
Plums	762.7	630.6	547.4	417.2	–45.3

Source: U.S. Department of Agriculture (2020b).

Figure 1. Bearing Acreage and Grower Sizes by Fruit, 2002-2017



Notes: Data from the U.S. Department of Agriculture (2020b). Bar labels indicate the percentage share of acreage accounted for by large versus small growers. The cutoff for small versus large growers is defined here as 250 acres, with the exception of pears, for which we define the cutoff as 100 acres due to data availability issues. For disclosure reasons, complete data on operation size is not publicly available for some fruits/years.

decline in production of many fruits has coincided with landowners and operators substituting toward the production of other more lucrative fruits, a practice stemming from changes in the relative profitability of certain fruits—for example, many of California's apple orchards have been repurposed as vineyards because of the much higher prices fetched by grapes relative to apples (Bland, 2011).

While these changes might simply reflect fruit producers' rational supply decisions, the perennial nature of fruit production entails substantial switching costs and long-term investments that must be made years before profitable production can be realized. This particular feature of the noncitrus tree fruit sector means that changes in land use and supply have long-lasting impacts and significant implications for producers and consumers.

Consolidation of Fruit Production

In line with broader trends in the agricultural sector (MacDonald, Hoppe, and Newton, 2018), fruit production has increasingly consolidated toward fewer (but larger) growers. Figure 1 shows that this trend is not specific to any particular fruit. Focusing first on apples, roughly half of bearing acreage is on large operations of 250 acres or larger, compared to around a third of total bearing acreage 15 years prior (U.S. Department of Agriculture, 2020b). Similar trends (although not as stark) are evident for peaches, pears, and plums. Clear from this portrait of fruit production is that the decline in acreage for many fruits has occurred largely through a significant contraction in the number of small growers. In contrast, cherries have exhibited an upward trend in acreage and production because of growing domestic and foreign demand and declining overseas competition.

Fundamentally, however, the declines in acreage for most commodities have been caused by a dramatic contraction in the number of small operations. Statistics on the number of apple-growing operations in the United States make this clear. Between 2002 and 2017, the number of operations between 5 and 250 acres in size shrank from 8,151 to 4,710, while the number of operations of at least 250 acres largely held steady, only declining from 283 to 269 (U.S. Department of Agriculture, 2020b). While larger operations are likely to reap efficiency gains from their large scale, the increasing degree of consolidation threatens smaller growers' ability to compete. The concentration of production in the hands of fewer, but larger, growers exacerbates this threat to small growers and the diminished level of competition has further negative implications for consumer welfare.

Labor Shortages and the Need for Mechanization

As one of the most labor-intensive areas of agriculture, ongoing issues with the farm labor supply have put many fruit growers in an uncomfortable position. Growers have acutely felt the impact of rising farm wages and reduced migration rates among farm workers (Taylor, Charlton, and Yúnez-Naude, 2012; Fan et al., 2015; Charlton and Taylor, 2016). Because of this, the share of labor in fruit production has declined slowly but steadily. Since peaking in 2001 at around 33%, labor costs as a share of gross farm income fell below 25% in 2016 (U.S. Department of Agriculture, 2020b).

Mechanization has not taken hold in much of the fruit sector the way that it has in other food and agriculture sectors. This is due in part to the barriers to adoption of technologies unique to fruit production (Gallardo and Sauer, 2018) and to the potential of mechanical harvesting to cause aesthetic damage to fresh fruits intended for retail consumers (Huffman, 2012). Even today, nearly all such fruit is harvested manually, with mechanical methods largely confined to fruits destined for processing. Despite this current limitation, labor-saving technological advances have the potential to drastically reduce demand for farm labor and thereby lower labor costs. The continued development and adoption of such technology will be essential for the industry to maintain its competitiveness in the future.

Also fundamental to the viability of the U.S. fruit sector is the continued presence of H-2A guest workers, who account for a substantial portion of the country's farm-labor force. While the Trump administration went to great lengths to limit legal immigration under other programs (such as H-1B visas for skilled workers), in the wake of the COVID-19 pandemic the administration took steps to expand and streamline the H-2A program by waiving interview requirements for H-2A applicants (Mohan, 2020). Maintaining a streamlined H-2A program will be crucial for the survival of the fruit industry while the pandemic endures. In addition to such steps, the administration also sought to lower minimum wage rates for H-2A guest workers (Ordoñez, 2020), with the thought that paying farm workers less will help solve the labor supply issues facing producers. Ensuring an adequate supply of labor is of crucial importance for the sector, and a well-functioning H-2A program—one that continues to incentivize guest workers to come and work in the United States—is an essential aspect of this. One of the first acts of the Biden administration was to freeze pending H-2A rules introduced in the waning days of the Trump administration that would have lowered the reimbursement employers are required to provide for migrant workers' travel to the United States, a sign that the new administration intends to adopt a different approach from its predecessor to farm labor issues.

Trends in Consumption and the Role of Export Markets

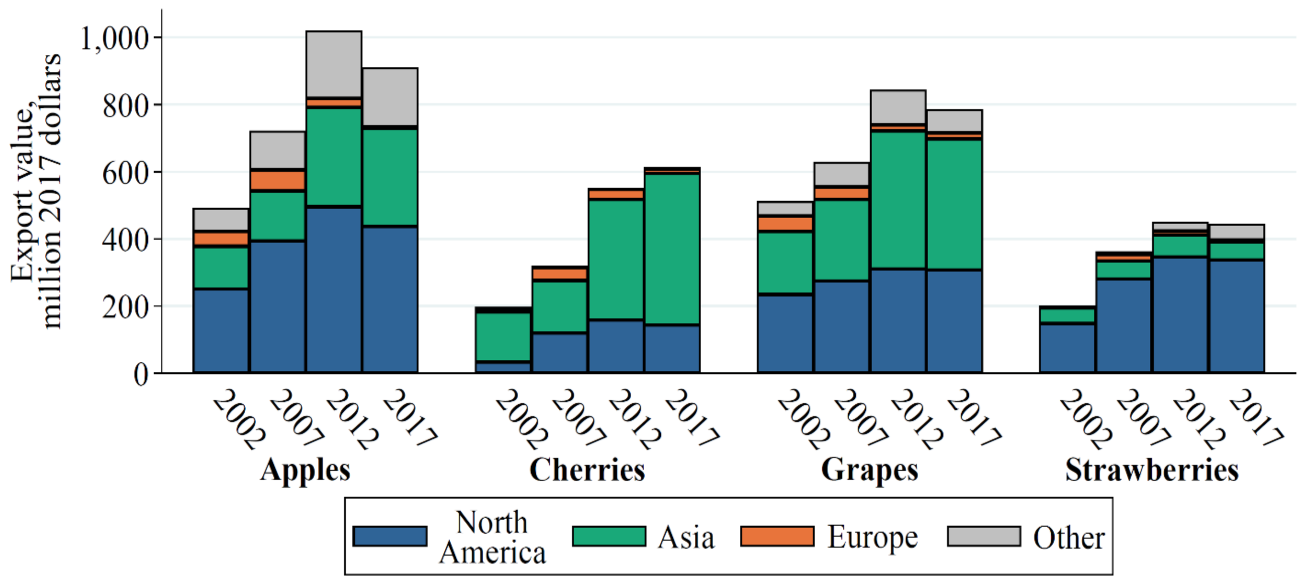
In line with declines in production, U.S. consumption of many fruits has also fallen steadily. The quantity of apples, cherries, peaches, pears, and plums on grocery store shelves is lower now than it has been in decades. For comparison, annual per capita retail availability of these fruits (a proxy for consumer demand) averaged 28.4 lb per U.S. resident in the 1990s, 25.7 lb in the 2000s, and 24.4 lb over 2010–2017 (U.S. Department of Agriculture, 2019b). These declines have been particularly stark in fruits such as peaches, nectarines, pears, and plums.

The origins of these trends are manifold. Other types of fruit (such as strawberries, pineapples, and mangoes) have become increasingly available to consumers, which causes households to demand less of the traditionally consumed varieties. Consumers might have adjusted their expenditures on fruits because of price or income effects or U.S. consumers' underlying preferences might simply have evolved such that fruit has become a less important component of food expenditures. Regardless of what drives declining consumption, these patterns represent a threat to the industry's long-term viability.

Because of plateaued or declining consumption of many fruits, access to export markets has been an enormous boon for American growers and has generated billions of dollars in revenues. Figure 2 illustrates the extent to which international markets have expanded U.S. fruit sales. For each of the depicted commodities (the top three noncitrus tree fruits by export value, and (for comparison) strawberries, the most exported noncitrus fruit), the real value of sales to foreign markets more than doubled (and in the case of cherries, tripled) from 2002 to 2017.

Most of this growth has come through expanded trade with Canada and Mexico, facilitated by their proximity to and low barriers to trade with the United States. The

Figure 2. Value of U.S. Fruit Exports by Commodity and Destination (million 2017 dollars)



Source: United Nations (2020).

United States also exports substantial quantities of fruit to Asian markets—not only to traditional trading partners such as South Korea ($486 million of fresh fruit exports in 2017), Japan ($424 million), and China ($320 million), but also to markets that have only recently begun to engage in substantial trade with the United States, such as India ($103 million), Indonesia ($84 million), and Vietnam ($76 million) (United Nations, 2020). These high numbers have risen despite significant import barriers in many of these markets, such as ad valorem tariff rates of 30% on most of India's fruit imports (United Nations Conference on Trade and Development, 2020). The contraction in U.S.–China trade resulting from the ongoing trade dispute has also dramatically affected exports of U.S. fruit to the region.

While exports to Asia and other North American markets remain large, it is apparent that export growth is rising less quickly than it was 10 years ago; in fact, exports generally stagnated or declined between 2012 and 2017. Also clear is that other markets account for only a tiny part of U.S. fruit exports: Europe, despite its relative accessibility, high incomes, and similar preferences for fruits, imports only limited (and shrinking) quantities of U.S. fruit. Other markets such as South America, the Middle East, and Africa likewise account for small (but growing) export shares.

International Competition

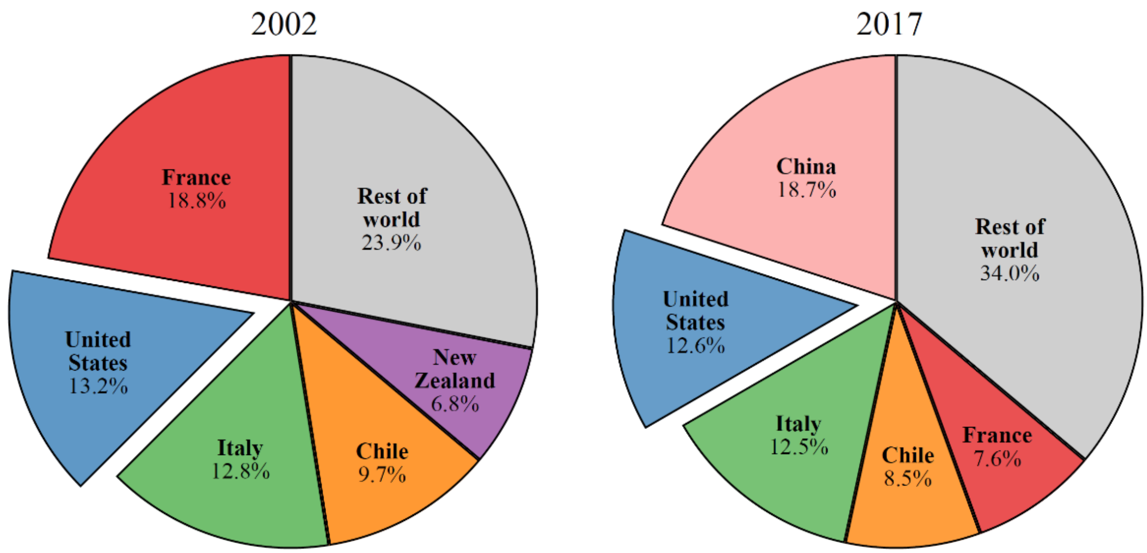
Stagnation in export markets is directly related to the ever-rising degree of competition in international markets. For apples, the most exported U.S. fresh fruit by value, Figure 3 makes clear how the global trade picture has evolved. The U.S. share of world apple trade has diminished slightly, but China's rapid entry into world fruit markets has been a seismic shock to global fruit supply: Between 2002 and 2017, China's annual exports of apples increased by approximately 560% (from $208 million to $1.37 billion in 2017 dollars); likewise, China's exports of pears increased more than 300% (from $136 million to $567 million), and its exports of peaches a staggering 1,800% (from $5 million to $95 million) (United Nations, 2020).

U.S. growers face heightened competition from other producers as well. European apple producers—such as those in Poland—have expanded exports considerably, with the real value of Poland's apple exports growing by more than 550%, from $72 million to $475 million, between 2002 and 2017 in the wake of its entry to the European Union (United Nations, 2020). Apple producers in other countries (such as Chile and New Zealand) have also seen their international sales increase. Such is also the case in global markets for other fruits—for example, Chile expanded its cherry exports from $51 million to $610 million over the 2002–2017 period, a 12-fold increase, and Turkey's peach exports expanded from $11 million to $86 million over the same period, a 684% increase. The current international market environment has only added to the pressure faced by U.S. producers; declining consumption and processing demand for many fruits means that U.S. growers rely more than ever on export markets.

Implications and Policy Recommendations

The U.S. fruit sector faces challenges on several fronts—declining production and acreage, consolidation, labor shortages, changing consumer preferences, and ever-rising international competition. These challenges

Figure 3. Shares of World Apple Exports, 2002 versus 2017



Source: United Nations (2020).

have no single origin, nor does a single remedy exist with which to address them. However, there are several strategies that policy makers can emphasize to encourage the long-term sustainability of this vital part of American agriculture.

With the supply of farm labor in the United States continuing to decline, the long-term competitiveness of the sector will depend on process innovation and investment in labor-saving technologies. For growers, this could include introducing new varieties, planting high-density orchards with more efficient layouts, and increasing their use of harvesting machinery.

The problem suggests a clear role for policy makers in incentivizing research and development and technology adoption. Technological innovation and substitution from labor to capital has the potential to enhance the global competitiveness of U.S. fruit growers and to increase the productivity of the workers that remain in agriculture, which could lead to higher wages and reduce the physical impacts of fruit picking on workers. Gallardo and Sauer (2018) note that the main promise of automation is not that it will displace labor but that it will offer farm workers the opportunity to take on high-skill occupations higher up in the agricultural value chain. Simplifying and reducing the cost of H-2A visas could also be a boon in the medium run while labor-saving technology is being developed and adopted.

While American fruit growers face ever-rising competition from foreign producers, the opportunities promised by international markets suggest that the long-term viability of the sector will continue to hinge on export opportunities. Policy makers should make every effort to expand foreign-market access, both by strengthening ties with existing partners and by gaining concessions in markets that U.S. fruit does not reach in large quantities. Along these lines, future presidential administrations would be wise to reconsider the country's abandonment of the Trans-Pacific Partnership (the TPP, rechristened and enacted without the United States as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership, to which many of the original signatory countries are party) and exert more effort toward concluding the currently stalled negotiations on the Transatlantic Trade and Investment Partnership (T-TIP) with Europe.

The nature of perennial production implies that the trends in the noncitrus tree fruit sector that we highlight will have long-lasting, hard-to-reverse impacts on the supply and demand for fruit. But while the U.S. noncitrus fruit sector faces several headwinds, there are many reasons for optimism about the industry's future. On the consumer side, fruits such as apples and cherries continue to be enduringly popular with American consumers and have become well-established in many foreign markets. For producers, technological advances in production and harvesting and the continued development of new fruit varieties and production practices will continue to ensure that American fruit growers are among the most efficient and innovative in the world. And if steps are taken to address the challenges faced by the industry, the U.S. fruit sector will be able to maintain its cornerstone position in American agriculture.

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Economic Issues Related to Long-Term Investment in Tree Fruits

Reetwika Basu and R. Karina Gallardo

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Keywords: Asset specificity, Production costs, Tree fruits

The concept of asset fixity—which Galbraith and Black (1938) defined as the "lumpiness" of salient production factors due to high fixed costs, making their temporary reduction or reorganization very expensive and unprofitable in the short run—in agriculture has interesting implications for perennial crops such as tree fruits. Johnson (1950) introduced the concept of asset fixity in agriculture, explaining that most farm machinery and land have low opportunity costs because they have few alternative uses outside of agriculture. Johnson (1958) later stated that the existence in agriculture of fixed resources with low opportunity costs leads to persistently low rate of returns. Further, Johnson and Quance (1972) later argued that fixed asset theory has implications for an overproduction trap, or the tendency in agriculture to maintain high aggregate production levels even when real prices are declining. However, Johnson and Pasour (1981) questioned the implications of the asset fixity theory, stating that it contrasts the concepts of choice-influencing cost and the rule of resource allocative efficiency, while admitting that asset fixity theory helps explain why the supply function is irreversible. Chambers and Vasavada (1983) applied statistical tests to prove the existence of asset fixity in U.S. agriculture and found no fixities involving agricultural capital, labor, or materials at the aggregate level, concluding that asset fixity should not be used uncritically as the basis for explaining supply irreversibilities. However, they recognized that data aggregation was a potential caveat to their study. Edwards (1985) disputed their findings, suggesting that the work by Chambers and Vasavada did not support the rejection of asset fixity applications to a single farm when comparing opportunity costs of capital with alternatives for acquisition and salvage. Nonetheless, Chambers and Vasavada (1985) replied that their 1983 findings were only applicable to the context discussed in their paper.

Farmers have tried to improve and increase their output volumes in response to increased demand, but in attempting to do so, they have gathered more fixed assets than variable assets, making the production supply inelastic and negatively affecting farmers' income. Vasavada and Chambers (1986), when studying the dramatic change in U.S. agriculture, argued that aggregate factors of production adjusted slowly to price changes. Labor and capital were the most difficult to adjust, and the shortest lag in adjustments was observed in the land and intermediate input markets. In an attempt to solve the difficult adjustment in labor markets, policy makers implemented wage-oriented policies; however, these policies were ineffective in reducing the level of labor utilization during production.

This article is a description of policies oriented to mitigate the consequences of asset fixity. In addition, this article includes a description of the investment needed for tree fruit production comparing such with annual row crops.

Box 1. Helpful Definitions and Terms regarding the Economics of Orchard Investments, Production, and Policy

asset fixity—The difficulty of adjusting agricultural inputs in the short run or the slow adjusting of such inputs in the long run.
assets—Equipment and infrastructure in an agricultural operation.
inputs—What is needed for agricultural production.
opportunity costs—The forgone revenues that could have been realized if the funds would have been invested in an alternative activity or if an input was sold or rented.
preproduction years—Years

Policies to Mitigate Asset Fixities: An Analysis of the Literature Review

This review summarizes contributions centered on policies to mitigate asset fixity. Vasavada and Chambers (1986) concluded that wage-oriented policies aiming to mitigate asset fixity in agricultural labor were not appropriate. In relation to policies dealing with asset fixity in agricultural lands, Kuchler and Tegene (1993) concluded that such policies had a positive effect on landowners wealth but not on farmers wealth. Fixed farmland costs are expected to cause a rise in farmland prices, and all rents are owed to the owners of the fixed input. In absence of complete fixity, the rents derived from the changes in agricultural policies are expected to spread throughout the agricultural sector. Therefore, farmers need to substitute among inputs in response to policy changes for the input suppliers to benefit from the policy changes. Bonnen and Schweikhardt (1998) emphasized that one of the major problems in the agricultural sector is the fixity of assets and suggested that future policies for the commercial farm sector would be a collection of specific tax and commercial code features, commodity, and market regulations, with adaptations to regional differences in production and marketing choices. In the long run, policies in the long run would involve price supports, production controls, or direct income transfers, although they predicted that policies that were much less transparent would soon replace the above-mentioned suggestions. Richards and Green (2003) discussed "hysteresis"—the perpetuation of an economic phenomenon long after its initial cause has disappeared—to explain why producers continue to grow crops that have become uneconomical in perennial crop production. Producers of perennial crops, such as wine grapes, are often reluctant to switch to production of new crops because doing so entails high establishment costs. Lower establishment costs and more stable expected returns improve adoption. Policies can help enhance financial stability by enabling revenue insurance or the use of production contracts. Lambarraa, Stefanou, and Gil (2016) concluded that decision support training and tools for olive farmers can help mitigate technical inefficiency and its persistence in the presence of irreversible investment. The Common Agricultural Policy (CAP) of 2006, modified in 2007 and adjusted in 2009, introduces provisions that would guarantee a more secure environment for future investment.

In sum, the literature on policies oriented to mitigate asset fixity in agriculture concurs that the formulation and implementation of policies is complex. The research also concurs that policies should vary depending on the characteristics of the fragmented agricultural production and marketing sectors. Appropriate policy measures should include tax collection, price supports, and production control. Direct income transfer should be specific to production and marketing regions. In addition, allowance for crop and revenue insurances were found useful for mitigating the issue at hand.

Focusing on Tree Fruits

In the United States, tree fruits are categorized into citrus, noncitrus, and tree nuts. The agricultural sector is of economic importance to a number of rural communities in the United States, generating annually, on average, over $25 billion in farm cash receipts. Interestingly, tree fruits and nuts are produced on less than 2% of agricultural lands; however, the farm cash receipts account for 7% of total receipts for all agricultural commodities and around 13% for all agricultural crops (Department of Agriculture, 2020). Besides being important to local rural communities across the United States; the tree fruit and nut industry supports a nationwide supply chain infrastructure of market intermediaries including packers, processors, brokers, and shippers. Also, export markets are important for this sector; about 20% of all domestic production is exported.

Peterson (1992) observed that as developing nations increase their gross domestic production, they import more tree fruits improving the quality of life of their citizens. Gallardo and Sauer (2018) indicate that the specialty crop sector, including tree fruits, have witnessed productivity increases stemming from technological innovations including improvements in seed, fertilizers, and pest management. However, the development and adoption of labor-saving technologies has been lagging compared to most annual crops, making tree fruits increasingly dependent on manual labor. Tree fruit crops, different from annual row crops, require intensive crop management. Hence, the value added and the general production costs for specialty crops are higher compared to other crops.

Tree Fruit Production Costs Overview

The establishment of a tree fruit operation is a considerable investment and can be expected to pay off only after a number of years—for tree fruit, the production lifecycle is at least 15 years. The first years are considered establishment years, when the tree has not reached its full maturation and hence not yet in full production or full bearing. Only after four to five years is the tree in full fruit production. Yields across full production years are also highly variable, which induces uncertainty about yield levels and revenues (Gallardo and Garming, 2017).

In general, tree fruit production costs include both cash and noncash costs. Cash costs comprise direct or variable costs—such as expenses for seeds or trees, fertilizers, plant protection, wages for seasonal and permanent labor—and overhead costs—such as fuel, energy, water, farm office space, advisory fees, and insurance as well as the costs for renting land and capital. Noncash costs refer to depreciation and opportunity costs. Opportunity costs are the forgone revenues that could have been realized if the funds had been invested in an alternative activity or if an input had been sold or rented. Examples of opportunity costs are unpaid family and operator labor, preowned machinery, and preowned land (Gallardo and Garming, 2017).

Another way to measure tree fruit production costs include variable versus fixed costs. Variable costs vary depending on the expected yield per unit of production. They include all production costs or field activities, the inputs for every activity, and labor associated with each. For example, winter pruning, flower thinning, green fruit thinning, and the application of fertilizers, pesticides, and plant growth regulators, among others. Fixed costs would not vary with the expected yield per unit of production. These costs will generally be calculated for the whole farm enterprise and be allocated for the unit of production, such as depreciation rates, cost of opportunity interest rates, and management costs (Gallardo and Garming, 2017).

To calculate the profit accrued by the tree fruit operation, first, the gross revenue is calculated. This is the total yield multiplied by the market price. When assessing the profitability of a tree fruit enterprise, it is common to use gross profit (gross income minus direct costs and seasonal labor costs), accounting profit (gross income minus cash costs and depreciation), and profit (gross income minus total cost of production) (Gallardo and Garming, 2017). Tree fruit operations do not always have profits above zero. Due to varying yield levels as well as output prices, full cost recovery is not achieved in all years. To analyze the short-term economic situation of the agricultural operation, only direct costs and seasonal labor costs should be considered. To analyze the longer-term economic situation, cash costs and imputed costs (that is, total cost of production) should be included. Note that for tree fruit production, variable costs might not be variable in the strict sense; once the orchard is established, a farmer could consider the establishment costs as fixed costs and would continue to produce even if the production results in negative profits (Gallardo and Garming, 2017).

Examples of Tree Fruit Production Costs

Table 1 compares total costs (cash plus noncash) of five tree fruit crops grown in the United States: almonds, walnuts, Honeycrisp apples, sweet cherries, and plums (Duncan et al., 2019; Hasey et al., 2018; Gallardo and Galinato, 2020; Grant et al., 2019; Day et al., 2019). Establishment costs vary across the tree fruits presented, being more expensive for trees planted at higher tree densities (number of trees per surface area). Trees density varies by crop (Table 1); from 64 trees/acre for walnut to 1,452 trees/acre for Honeycrisp apple. A high-density plantation means there are more trees per surface area compared to medium or low density. For example, a high density could refer, depending on the specific production context, to more than 1,400 trees per acre such as Honeycrisp apples; and a low density, to less than 500 trees, such as almonds, walnuts, sweet cherries, and plums in Table 1. High tree density implies, compared to low-density plantings, that additional investment is needed to plant a larger number of trees with dwarf rootstocks and orchard infrastructure. Dwarf rootstocks produce trees with smaller trunks than regular rootstocks. A small trunk will not offer a strong enough support for the tree canopy, requiring a trellis system—additional infrastructure, such

Table 1. Costs and Revenues for Selected Tree Fruit Crops Grown in the United States

	Unit	Almonds[a]	Walnuts[b]	Apples Honeycrisp[c]	Sweet Cherries[d]	Plums[e]
Tree density	Trees/acre	130	64	1,452	134	202
Costs						
Establishment—year 1	$/acre	8,584	8,262	24,672	6,040	7,436
Preproduction—year 2	$/acre	2,830	2,861	9,344	3,238	2,237
Preproduction—year 3	$/acre	-	2,907	-	3,352	-
Production—year 3	$/lb	9.51	-	1.69	-	0.66
Production—year 4	$/lb	6.39	6.89	1.20	3.77	0.60
Production—year 5	$/lb	3.44	2.96	1.06	3.51	0.53
Production—year 6	$/lb	-	1.63	1.06	-	-
Production—year 7	$/lb	-	1.05	-	-	-
Gross revenues—full production year	$/lb	2.50	1.00	1.07	2.06	0.57
Profits—full production year	$/lb	-0.94	-0.05	0.02	-1.45	-0.05

[a]Duncan et al. (2019).
[b]Hasey et al. (2018).
[c]Gallardo and Galinato (2020).
[d]Grant et al. (2019).
[e]Day et al. (2019).

as poles and wires, to support the canopy. Related to asset fixity, investment in a trellis system is irreversible and difficult to adapt to other crops. Preproduction years refers to the previously mentioned establishment years, that is, those years in which the trees do not yet produce fruit. The cost variation across crops (Table 1) is mostly due to differences in tree density across crops. Compare Honeycrisp apples, with establishment costs of $24,672/acre and tree density at 1,452 trees/acre, with the other crops, with establishment costs ranging from $6,040/acre to $8,584/acre and tree densities from 64 trees/acre to 202 trees/acre. Similarly, compare preproduction costs in year 2 (Table 1): Honeycrisp apples at $9,344/acre with the other crops ranging from $2,237/acre to $2,861/acre. Note that not all crops report preproduction costs in year 3 in Table 1. For example, costs are reported for walnuts and sweet cherries but not for almonds, Honeycrisp apples, and plums. This indicates that not all trees produce fruit in the same year. Tree precocity is related to rootstock type and refers to the year in which the trees start producing fruit.

Dwarf rootstocks are more conducive to precocious trees (that is, trees that would produce fruit in higher volumes sooner) than regular rootstocks. Depending on the precocity of the tree variety and rootstock, trees start producing fruit in the third or fourth year. For example, Honeycrisp apples, almonds, and plums start producing fruit in the third year. Walnuts and sweet cherries produce fruit in the fourth year. Trees will not produce to their fullest until the fifth or sixth year. For example, almonds, sweet cherries, and plums achieve full production in the fifth year, Honeycrisp apples in the sixth year, and walnuts in the seventh year. The longer the tree takes to produce fruit and the longer it takes to achieve full production, the more years are needed to recover the investment. To facilitate comparison across crops, the $/lb costs in Table 1 were calculated by dividing the costs presented in each study in $/acre (Duncan et al., 2019; Hasey et al., 2018; Gallardo and Galinato, 2020; Grant et al., 2019; Day et al., 2019) by the yields converted to lb/acre.

Table 1 also presents gross revenues and profits (gross income minus total cost of production) for the above-mentioned tree fruits. The revenues and profits correspond to the year when the tree achieved full production and are presented in $/lb. Similar to the cost in production years, the $/lb revenues were calculated by dividing the revenues presented in each study (Duncan et al., 2019; Hasey et al., 2018; Gallardo and Galinato, 2020; Grant et al., 2019; Day et al., 2019) by the yield realized in a full production year and expressed in pounds.

Unlike Honeycrisp apples, plums, almonds, walnuts, and sweet cherries do not exhibit profits. The profits accrued by crops presented in Table 1 range from -$1.45/lb to $0.02/lb. This difference is mainly driven by market prices. Honeycrisp apples face higher costs compared to other apple varieties but enjoy a market price premium, enough to cover the higher costs incurred (Gallardo and Galinato, 2020). The above-zero profits will not apply to all apple varieties but only dessert-quality apples, which exhibit the texture and flavor profile preferred by U.S. consumers and usually exhibit a price premium (Gallardo et al., 2018). For the other crops, the information in Table 1 show evidence of hysteresis, as producers keep producing even if profits are negative. One can observe evidence of the reluctance to switch production to more profitable varieties or crops. Also, this is a cautionary note for producers contemplating investing in tree fruits. Information on profits in Table 1 signals that investment should consider varieties whose market prices would ensure a positive profit stream in the long run.

Table 2 presents production costs in two categories (land and nonland costs) for five selected annual row crops: corn, soybean, spring wheat, canola, and alfalfa (Lattz and Zwilling, 2019; Schnitkey, 2020; University of Minnesota Extension, 2020; Johnson, 2020; Texas A&M AgriLife Extension, 2020). Costs per pound range from

Table 2: Costs and Revenues for Selected Annual Row Crops Grown in the United States

Annual Row	Unit	Corn[a]	Soybeans	Wheat[b]	Canola[c]	Alfalfa[d]
Costs						
Land costs	$/lb	0.02	0.11	0.03	0.05	0.03
Non-land costs	$/lb	0.06	0.06	0.07	0.12	0.06
Total costs	$/lb	0.08	0.17	0.10	0.17	0.09
Gross revenues	$/lb	0.06	0.14	0.10	0.13	0.12
Profits	$/lb	-0.02	-0.03	0	-0.04	0.03

[a]Lattz and Zwilling (2019), Schnitkey (2020).
[b]University of Minnesota Extension (2020).
[c]Johnson (2020).
[d]Texas A&M AgriLife Extension (2020).

$0.10/lb for wheat to $0.17/lb for canola and soybeans. Gross returns and profits are also presented in Table 2. Similar to tree fruits, one observes profits not above zero for corn, soybeans, and canola. A zero profit is observed for spring wheat and an above-zero profit is observed for alfalfa. Results in this table suggest the overproduction trap noted by Johnson and Quance (1972) (that is, the tendency in agriculture to maintain high aggregate production levels even when real prices are declining).

Information in Tables 1 and 2 enables us to discern differences in cost structures between annual crops and tree fruits. For the annual crops, costs are divided into land costs, nonland costs, and total costs; for tree fruits, the establishment cost alone includes an amount dedicated to land, and the rest is divided between labor and capital. The production year costs include costs accrued to labor, materials, energy, and miscellaneous. In the years of full production, however, the cost entailed in growing tree fruits is minimal compared to that needed during production/maintenance years. Moreover, this information demonstrates that the investment in tree fruits is larger by far than the investment in annual row crops. The uncertainty surrounding tree fruits is also larger, as there is no production until year three or year four, depending on the tree crop—and within the crop, the variety—and the rootstock type. Per pound gross revenues are higher for tree fruits compared to those for annual row crops, hence the perception that tree fruits are highly valuable crops. Given the magnitude of the initial investment, the time to recover the investment, and the increased uncertainty, one can conclude that the low opportunity costs for the investment will be magnified for tree fruits compared to annual row crops.

Targeting Efforts to Mitigate Asset Fixity

Asset fixity in agricultural production deals with investment in inputs and how these inputs adjust in the long run. The formulation and implementation of policies to mitigate the problematic asset fixity is complex. In general, policies should vary based on the characteristics of the fragmented agricultural production and marketing sectors and should include tax collection, price supports, and production control; direct income transfer should be specific to production and marketing regions. When identifying targeted crops for policies oriented to mitigate asset fixity, tree fruits stand out from annual row crops. The investment in orchard infrastructure is extensive and irreversible, and there is a lack of secondary market for such capital goods. The recuperation period on the investment is longer for tree fruits, proving that asset fixity problems are exacerbated for tree fruits compared to annual row crops. Policies directed to mitigate asset fixity in tree fruits as described in the literature could range from contracts and revenue insurance, as market price stability is crucial in ensuring positive returns in the future.

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Trends and Issues Facing the U.S. Citrus Industry

Jeff Luckstead and Stephen Devadoss

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Keywords: Citrus, Imports, Labor shortages, Oranges, Pests and disease, Production

Citrus fruits are consumed throughout the world, but production is concentrated in a few countries. The United States is a leading producer, behind Brazil and China (Jegede, 2019; Zhang, 2019). The total value of the U.S. citrus industry is about $3.33 billion (U.S. Department of Agriculture, 2020b). Major citrus crops grown in the United States are oranges, grapefruit, tangerines, and lemons. Based on the average value of production between 2013 and 2018, oranges are by far the leading citrus fruit (59%), followed by lemons (19%), tangerines (15%), and grapefruit (7%) (U.S. Department of Agriculture, 2020b). Though oranges are the leading citrus fruit, only 17% of oranges enter the fresh market; the remainder are used for processing. By contrast, about 76% of lemons, 73% of tangerines, and 55% of grapefruit are used for fresh consumption and the remaining are utilized for processing. With fruit and juice combined, citrus consumption exceeds that of any other fruit in the United States (Flores-Gonzalez et al., 2019).

However, in the past two decades, the U.S. citrus industry has faced many challenges—serious disease problems, weather damage, import competition, dwindling farm-retail price spread, and labor shortages—threatening its survival. Very recently, scientists have discovered a potential cure for citrus greening—a particularly devastating bacterial disease—that could revive the citrus industry. This article focuses on these issues, current status, and trends of the U.S. citrus industry.

Citrus Supply and Demand

With the spread of pests and diseases, frequent winter freezes, and health factors, it is worth examining trends and volatility in citrus acreage, production, consumption, trade, and prices over the last three decades.

Acreage

In the United States, much of the citrus acreage is devoted to orange production, while tangerine, grapefruit, and lemon acreages lag behind (Figure 1).[1] The trend in orange acreage varies considerably, falling in the first half of the 1980s from 800,000 acres to about 550,000 acres, growing to more than 800,000 acres by 1998, and then steadily declining to about 500,000 acres by 2018. Grapefruit bearing acreage experienced some fluctuations from 1980 to 1997 but has since decreased persistently. Tangerine and lemon bearing acreages are relatively stable. The decline in orange and grapefruit acreages should be of significant concern to growers, processors, and policy makers.

Production

The trend in the volume of production for all four fruits follow the general pattern of the bearing acreages (Figure 2). However, production does exhibit greater year-to-year fluctuations, which could be attributed to the susceptibility of these fruits to frequent pest and disease outbreaks and weather problems. Flores-Gonzalez et al. (2019) note that the steep declines in production in 2005 and 2015 are due to the endemic presence of the citrus greening disease. Total citrus production has fallen precipitously by 65.3% from its peak in 1998. Orange and grapefruit lead the way, with declines of 71.6% and 80.4%, respectively. By contrast, tangerine production has steadily increased and surpassed grapefruit production. The increase in tangerine production is attributed to a shifting trend in consumers' preference for fruits that are easier to peel, segmented, and seedless (Forsyth and Damiani, 2003).

Oranges are grown mostly in Florida and California, with Texas producing only about 2% of total production. The two major orange varieties grown in the United States are Valencia and navel. Florida is the major producer of Valencia oranges, at about 78% in term of value of production, while California accounts for about 20%. California is the leading producer of navel oranges, at about 65%, and Florida produces the remaining 33% (U.S. Department of Agriculture, 2020e). In Florida, more than 90% of Valencia and navel orange production is used for processing, and the remaining enter the fresh

[1] The data source for all figures is the U.S. Department of Agriculture (2020b).

Figure 1. U.S. Bearing Acreage

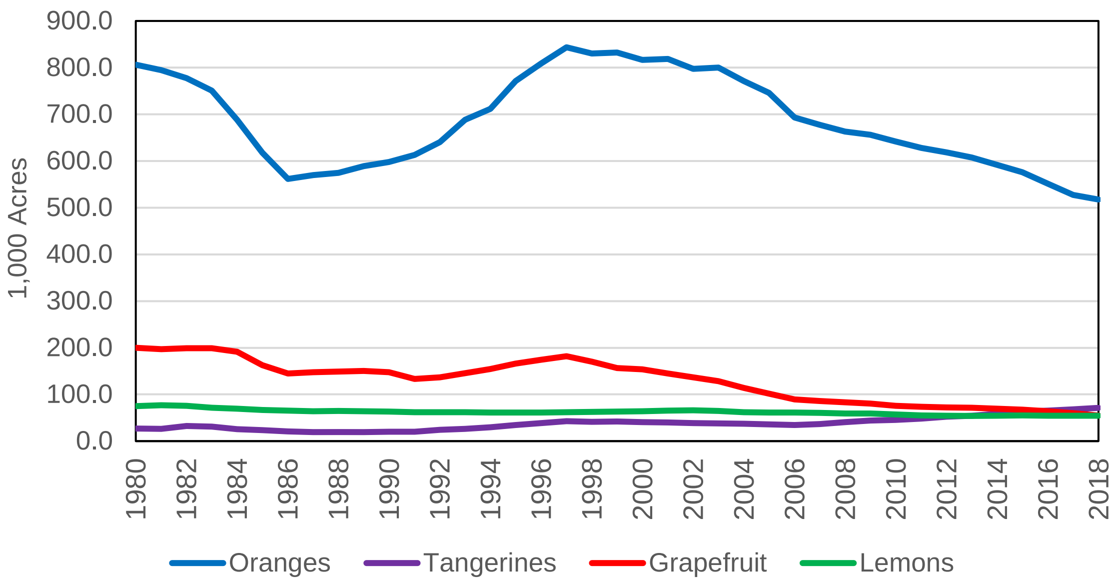
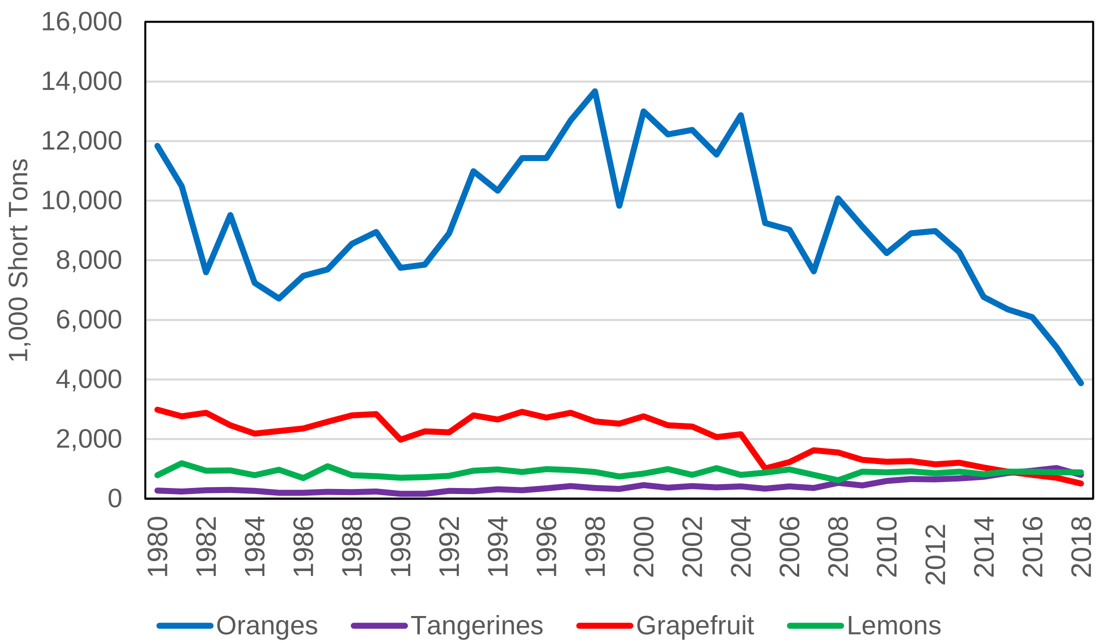


Figure 2. U.S. Total Commercial Production



market (U.S. Department of Agriculture, 2019). By contrast, in California, about 80% of navel oranges and 74% of Valencia oranges are used for the fresh market, and the remaining are utilized for processing (U.S. Department of Agriculture, 2019). Though navel oranges are grown in the winter and Valencia in the summer, the growing seasons overlap some in the spring.

Florida orange yields are generally higher than those in California (Figure 3). However, since 2013/14, California's yields have exceeded Florida's because citrus canker and citrus greening diseases have drastically lowered yields in Florida. Further, yields in both states exhibit considerable fluctuations, which are largely attributable to winter freezes, pests, and diseases. The large drops in California's yield in the 1990/91 and 1998/99 seasons are attributable to major freeze events that adversely impacted fruit and vegetable production alike (Brooks, 1991; Rural Migration News, 1999).

Costs of production differ between Florida and California. In Florida, the per acre cultural cost in 2015 for central Florida was $1,554.55, of which $953.33 was

Figure 3. U.S. Orange Yield per Acre

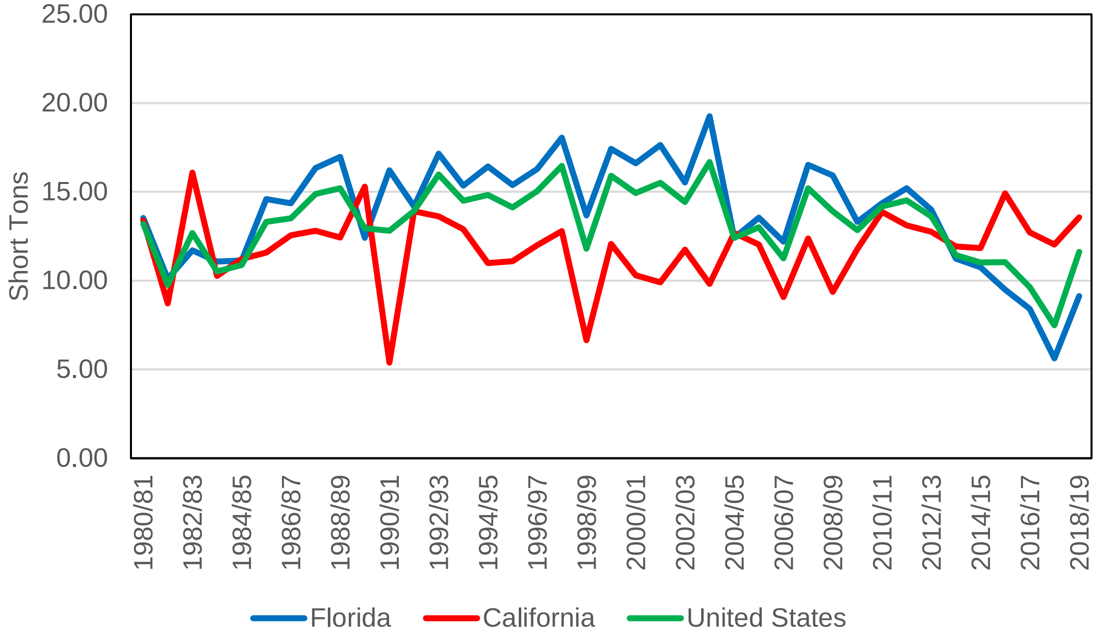
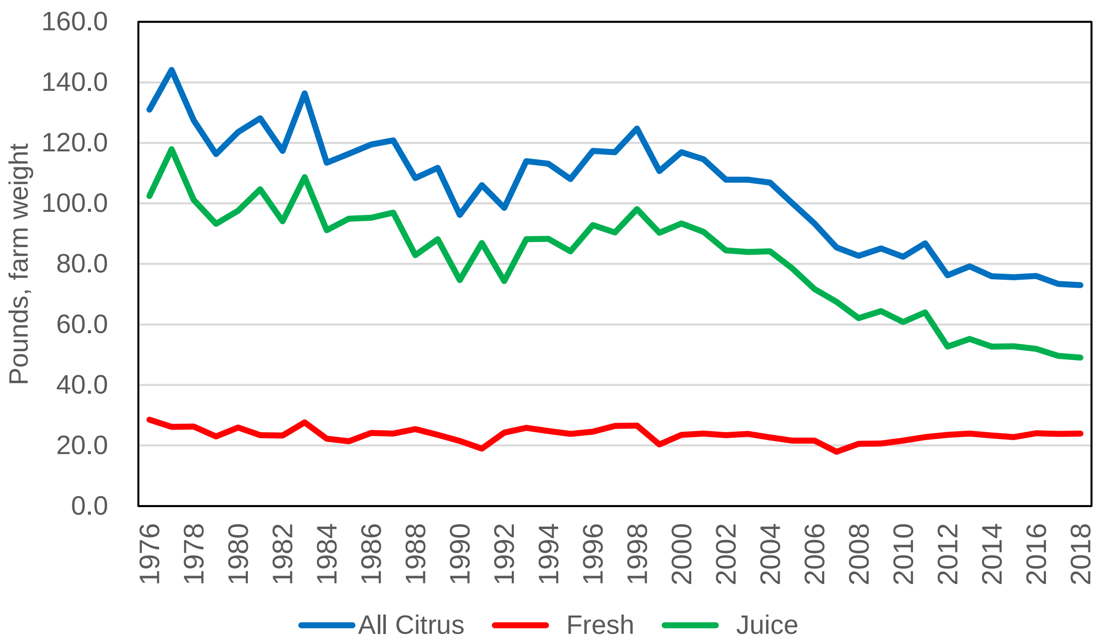


Figure 4. U.S. Per Capita Use



spent on materials, $390.34 on labor, and $180.88 on irrigation (Singerman, 2015). In California, the per acre cultural cost in 2015 for the San Joaquin Valley was $2,140, of which $1,172 was spent on customs and rental, $524 on materials, $392 on labor, and $52 on fuel, lubricants, and repairs (O'Connell et al., 2015). It is worth noting that categories included in the cultivation costs for Florida and California differ considerably and are therefore not directly comparable.

Consumption

Figure 4 plots per capita consumption of all citrus fruits, both fresh and juice. U.S. consumers tend to consume considerably more juice than fresh fruits. However, in the last two decades, juice consumption has fallen steadily because of health concerns and due to more availability of substitute beverages such as energy drinks, flavored water, and exotic fruit-based drinks with low or no added sugar; by contrast, fresh consumption remained stable, with a slight positive trend in recent years (Fox, 2019). This trend generally holds for oranges and grapefruit;

Figure 5. U.S. Fresh Oranges Supply and Utilization

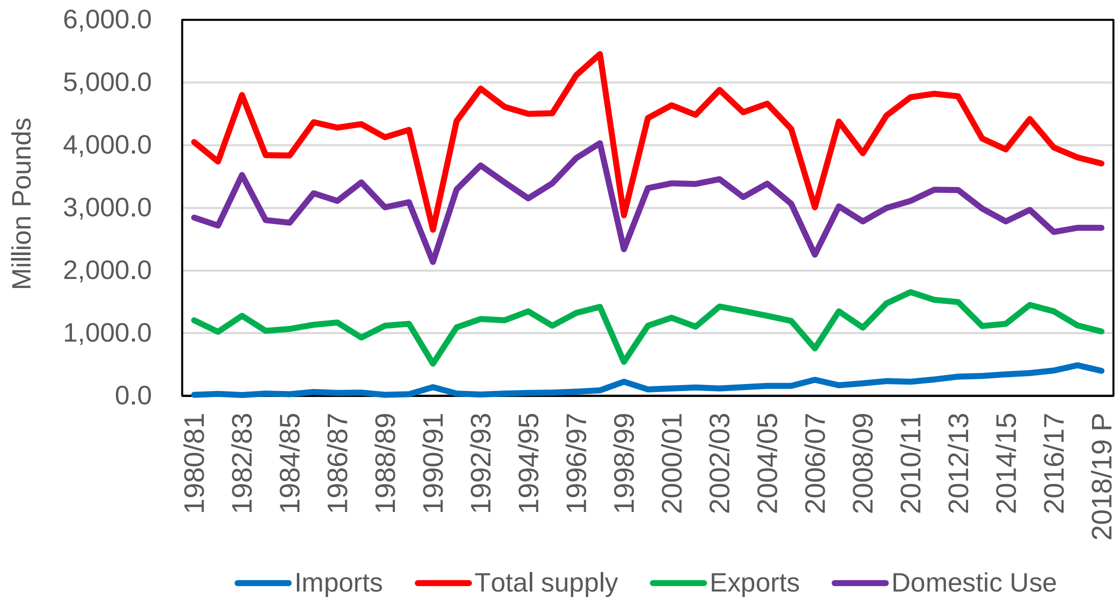
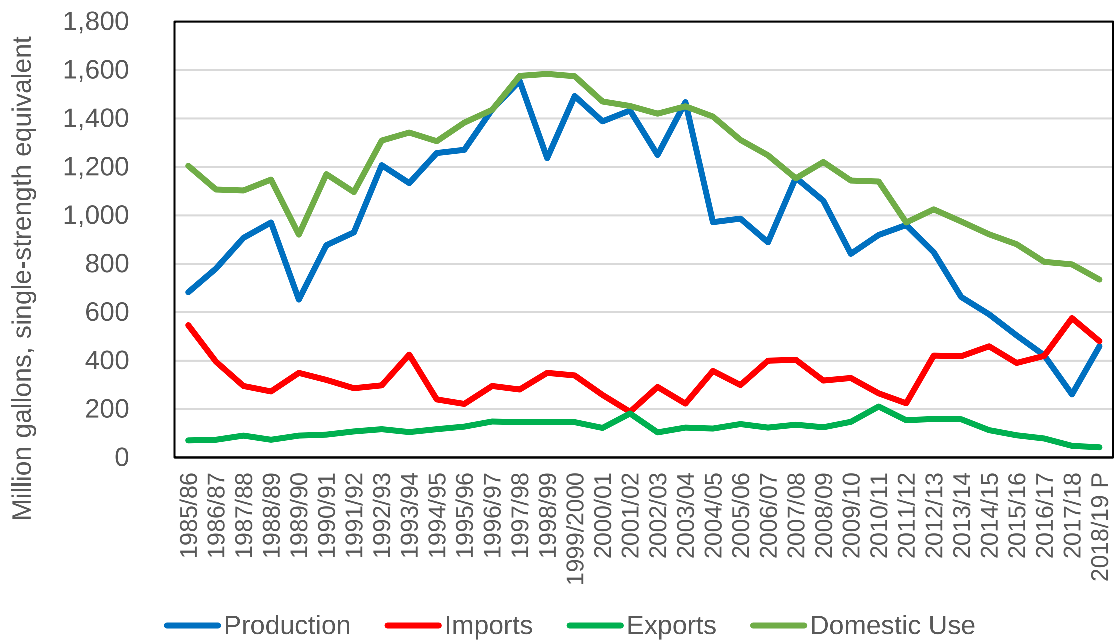


Figure 6. U.S. Orange Juice Supply and Utilization



however, lemons and other citrus exhibit a positive trend both in fresh fruit and juice consumption (not plotted).

Trade

Figures 5 and 6 plot U.S. supply, utilization, and trade of fresh market oranges and orange juice, respectively. Because of seasonal differences, the United States both exports and imports fresh oranges. U.S. imports of oranges for fresh consumption are generally small but have increased over the last 10 years. These fresh orange imports come largely from Chile, South Africa, and Mexico (U.S. Department of Agriculture, 2020c). As pest and disease mitigation increases production costs, growers struggle to compete with imports, highlighting the competitive pressures that U.S. growers face with several other major foreign citrus producers. Total supply of fresh oranges, which consists of both domestic production and imports, fluctuates considerably. Domestic consumption and exports of oranges closely follow supply fluctuations. On average, 72% of supply goes to domestic consumption and the remaining 28% of supply is exported (U.S. Department of Agriculture, 2020b), with South Korea, Canada, Japan, and Hong

Kong/China comprising the largest export destinations (U.S. Department of Agriculture, 2020c).

Juice production has steadily declined since 2000 (Figure 6), mirroring orange production (Figure 2). Domestic consumption of juice exceeds domestic production, and the excess demand is met by imports, primarily from Mexico and Brazil (U.S. Department of Agriculture, 2020c). Imports of concentrated juice from these countries are often blended with U.S. juice for domestic sales because of minimal product differentiation between regions. Increased imports of oranges and juice in the last 10 years highlight the import competition to U.S. producers as foreign suppliers fill in the gap of declining U.S. production. The United States exports a very limited amount of orange juice because of its high level of domestic consumption. Major export destinations for U.S. orange juice are Canada, South Korea, the European Union, and the Dominican Republic (U.S. Department of Agriculture, 2020c).

The United States is the leading consumer of orange juice, followed by Europe (Hart, 2004). The São Paulo region in Brazil is a major supplier of orange juice and, along with Mexican suppliers, competes for U.S. market share (Luckstead, Devadoss, and Mittelhammer, 2015). São Paulo is also the major supplier of orange juice to the European Union. Because only a few processors operate in São Paulo and Florida, they exert market power both in purchasing oranges and selling orange juice (Hart, 2004).

The orange juice markets in the United States and Europe are insulated through import tariffs. The U.S. tariff on orange juice imports is $0.2971 per single-strength gallon, and the European Union imposes an average ad valorem tariff of 20.36% (World Trade Organization, 2020). A reduction in the U.S. tariff would benefit U.S. consumers and São Paulo's producers at the expense of U.S. producers (Dhamodharan, Devadoss, and Luckstead, 2016). By contrast, trade liberalization by the European Union would cause São Paulo processors to divert their exports from the United States to the European Union; consequently, Florida orange juice producers are likely to expand their market share in the United States (Luckstead, Devadoss, and Mittelhammer, 2015).

Prices

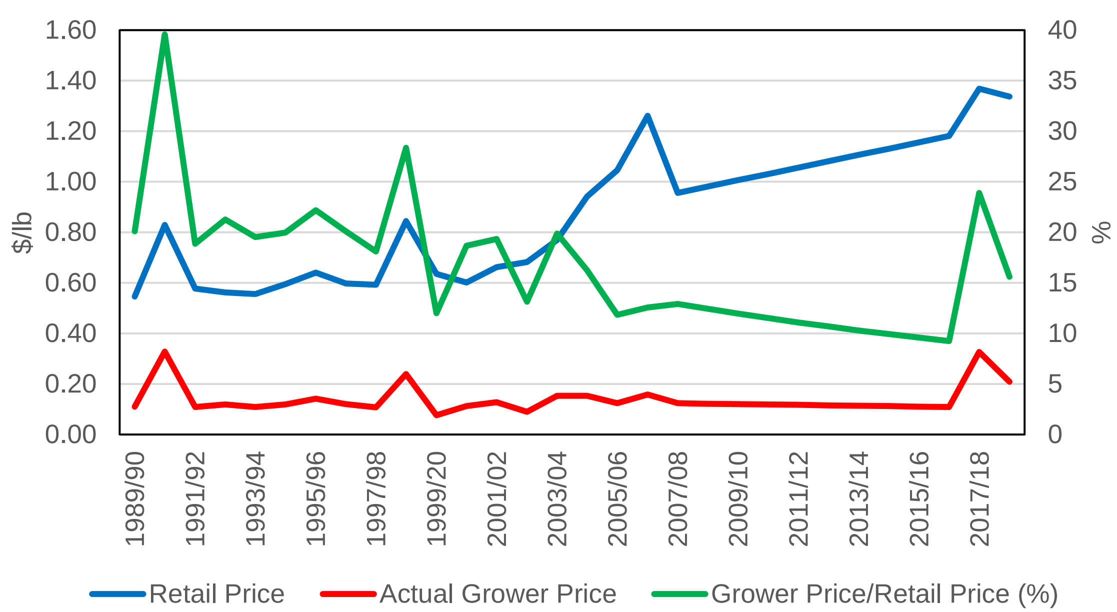
Figure 7 illustrates the trends in orange prices at the farm and retail level. Though grower prices are generally low and stable, retail prices exhibit considerable variation and a generally positive trend since 2000. Growers received an average of 20.80% of the retail price between the 1989/90 and 2002/03 seasons but only 13.10% since 2003/04. Further, increases in retail prices are not readily transmitted to growers. This can be seen between 2007/08 and 2016/17, when retail prices trended steadily upwards, but grower prices remained largely flat. This could be attributed to the fact that orange processors and buyers tend to exert oligopsony power in purchasing oranges from growers.

In summary, the steep downward trend in orange acreage and production have caused serious setbacks to the citrus industry as many growers and processors have exited the industry. This trend has provided more incentive for imports to enter the United States, further depressing the price received by growers.

Pests and Disease

While many common pests and diseases inflict damage to citrus trees, since the mid-2000s, the survival of the

Figure 7. U.S. Fresh Orange Price



U.S. citrus industry has depended on the treatment of two exotic diseases: citrus greening and citrus canker.[2]

Citrus Greening

Citrus greening, also commonly known as Huanglongbing (HLB) or yellow dragon disease, was first identified in the southern Chinese province of Guangdong in 1919 (Zhang, 2019). The Asian citrus psyllid vector and infected plant materials spread the bacterium *Candidatus* Liberibacter asiaticus, which causes the disease (U.S. Department of Agriculture, 2020a). HLB is one of the most destructive plant diseases to ever enter the United States. Common symptoms include stunted and sparsely foliated trees, premature defoliation, yellow shoots, dieback of twigs, splotchy mottling of leaves, and abnormally hard fruits (U.S. Department of Agriculture, 2020a). The fruits from infected trees taste bitter, have an unusual green color, and are not suitable for fresh consumption or processing.

This incurable and lethal disease affects all citrus fruits, and infected trees generally die within a few years. Consequently, HLB has wiped out millions of acres of citrus trees throughout the world. Citrus greening reached Florida in 2005, and rapidly infected most of the state's citrus farms in a matter of three years, wreaking havoc and putting the iconic industry in peril (U.S. Department of Agriculture, 2020a). Though HLB has been detected in all citrus-growing U.S. states, it has not yet invaded commercial orchards in California (Zhang, 2019).

Because of the public-good nature of controlling this disease, degree of risk tolerance, and lack of coordinated policies, many citrus growers in Florida did not remove the infected trees, which resulted in rapid spread to most groves in Florida. As a result, citrus greening infected more than 90% of Florida's citrus trees, which reduced production for the fresh market by 21% and for the juice market by 72% (Dala-Paula et al., 2019). This led to a loss of 30,000 jobs and $4.6 million in revenues (Court et al., 2017). As a result, about 5,000 out of 7,000 growers have exited the industry since 2004, and two-thirds of citrus processors have also closed their businesses (Fears, 2019). From 2003 to 2017, the number of packinghouses fell from 79 to 26 (Singerman, Burani-Arouca, and Futch, 2018).

To mitigate the impact and spread of this disease, some growers use a four-pronged mitigation strategy—plant bacteria-free saplings, remove infected trees, control psyllids, and manage nutrition—which triples the cost of production and yields only half as much fruit (Zhang, 2019). This makes it difficult for growers to compete with imported oranges. Given the pervasive spread of HLB in Florida, these mitigation strategies so widely used in China and Brazil have had limited effectiveness. In Jiangxi, China's leading orange-producing province, 25% of crops in 2018 succumbed to this disease (Zhang, 2019). In Brazil, HLB destroyed 52.6 million of the country's sweet orange trees, a third of the country's total, between 2004 and 2019. If these two countries had not implemented the preventive measures, the destruction would have been more severe.

California growers and policy makers have been assessing the experience of Florida, China, and Brazil and taking preventative measures to avoid extensive destruction to citrus groves. California currently spends $40 million annually to implement mitigation strategies to control the disease's spread (Zhang, 2019). Without such strategies, the U.S. citrus industry would be decimated, which would not only adversely impact growers and allied industries but also cause consumers to become heavily reliant on imports.

Though HLB is currently incurable, scientists have recently made progress toward a solution. A natural antimicrobial peptide developed from Australian fingerlimes, an exotic but close relative to oranges, shows great promise in killing the bacterium *Candidatus* Liberibacter asiaticus (Allen, 2020). The application of this antibiotic to infected trees improves HLB symptoms as new, healthy foliage growth occurs. The peptide acts as a vaccine against the disease in young trees. While this peptide will be environmentally safe, cost effective, and one of several other peptides under development, commercialization may still be several years away (Allen, 2020; Bernstein, 2020). Scientists have also turned to gene editing in recent years but have not yet found a solution (Zhang, 2019). Another bright spot in tackling this disease is the Sugar Belle® orange variety, which is known to be tolerant of citrus greening because the trees grow a healthy dose of new phloem after being infected (Deng et al., 2019).

Citrus Canker

Citrus canker is another highly contagious bacterial disease originating in Asia that infected U.S. citrus in the early part of the twentieth century. The symptoms of this disease include corky and scabby lesions on fruit, leaves, and twigs; branch dieback; and death of the tree in severe cases. Dark and water-soaked lines surround the lesions, and younger leaves are more susceptible to infection (University of California Agricultural and Natural Resources, 2020). Among citrus fruits, lime and grapefruit trees have been the worst hit by this disease. While the disease was initially eradicated in the United States, it resurfaced in the 1990s and is a continuing threat (Cooksey and Hoddle, 2020). Though citrus canker is commonly found in Australia, Brazil, Southeast

[2] Other common pests and diseases include citrus black spot, sweet orange scab, armillaria root rot, bacterial blast, citrus nematode, dothiorella blight, *phytophthora* gummosis, *phytophthora* root rot, and sooty mold (University of California Agricultural and Natural Resources, 2020).

Asia, and the southeastern part of the United States, it has not yet spread to California. The 1995 outbreak in Florida led to the removal of 16 million trees (Cooksey and Hoddle, 2020). However, legal challenges by residential owners of backyard trees between 1995 and 2004 stymied the tree eradication program carried out by the USDA and Florida Department of Agriculture and Consumer Services. Further, the 2004–2005 hurricane season caused the disease to spread rapidly throughout Florida's citrus-growing regions (Irey et al. 2006); the USDA deemed complete eradication to be impossible and abandoned the tree removal program. Since all trees in the range of 260 acres surrounding a single infected tree have to be removed, the cure became worse than the disease for Florida citrus growers (Lowe, 2009). In all, 87,000 acres of citrus trees were destroyed; the government spent $600 million on eradication efforts and $700 million to compensate growers between 1995 and 2006 (Lowe, 2009).

With rampant spread of HLB and citrus canker, Florida growers have abandoned 64,000 acres of orange groves. Unfortunately, these abandoned groves have become enormous bastions of both diseases.

Major Winter Freeze Incidents

Winter freezes also cause extensive damage to citrus groves. Particularly, if citrus groves endure below-freezing temperature even for a short period of time, fruits and foliage are likely to be damaged. Freeze-hit fruits can drop from trees and rot on the ground. Temperatures below 28oF, even for a few hours, can be detrimental to fruit, and ice formation in citrus tissues affects both trees and fruits. Frozen, but not spoiled, fruits are often used for juice production.

U.S. citrus groves, unlike those in Brazil, are susceptible to winter freezes. In the 1980s, four winter freezes occurred in Florida: 1981, 1983, 1985, and 1989. The freezes in 1985 and 1989 were particularly severe, killing both young and mature trees across Florida (Florida Citrus Mutual, 2017). Winter freezes in 1997 (*New York Times*, 1997), 2010 (Fletcher, 2010), and 2012 (Josephs, 2012) also caused extensive crop damages. California citrus groves are also beset by winter freezes. Frosts in 1990 and 1998 caused extensive crop losses, and a deep freeze lasting more than seven days in December 2013 decimated California citrus groves (Gorman, 2013). A late-season freeze in February 2019 had a mild impact on California citrus crops (Fresh Fruit Portal, 2019).

While the persistent decline in orange production (see Figure 2) is the result of the two exotic diseases and more imports, the year-to-year variation in production is due to pests, diseases, and winter freezes. Research has been ongoing in developing cold-hardy citrus varieties to mitigate the winter-freeze losses (Inch et al., 2014).

Labor Issues

Florida citrus growers adopted machine harvesting until the mid-2000s, but they stopped machine harvesting to minimize undue stress on infected trees following the devastation caused by citrus greening disease (Onel and Farnsworth, 2016). With much of the harvesting of citrus fruits done by hand, citrus growers have increasingly turned to H-2A workers to mitigate the problems associated with hiring undocumented workers due to aggressive enforcement of immigration policies and the dearth of domestic farmhands. The new E-Verify law that takes effect on January 1, 2021 will compound citrus producers' labor woes (Lambert et al., 2020). Of the total guest workers employed in Floridan agriculture, 85% work in citrus groves (Luckstead and Devadoss, 2019). Simnitt, Onel, and Farnsworth (2017) observe that more than 80% of the citrus grove labor force is made up of guest workers. About 91% of citrus workers are from Mexico. This highlights the difficulty of growers to find alternate labor sources and the unwillingness of domestic workers to perform hard labor.

As the survey by Simnitt, Onel, and Farnsworth (2017) found, employers can help avoid labor shortages by ensuring good housing accommodations for guest workers, maintaining a positive working environment (by treating workers fairly and valuing their work), and paying workers in a timely manner.

Discussion and Implications

The citrus industry has been experiencing hard times as production has been declining since the mid-1990s. As a result, many have gone out of business and exited the industry. Pests and disease and weather incidences seem to threaten the livelihood of citrus growers, particularly in Florida. California growers can learn from the problems that Florida growers are experiencing to safeguard their groves. Unless significant progress is made in research and development to control diseases such as citrus canker and citrus greening and develop freeze-hardy varieties, the U.S. citrus industry will continue its downward trend in production and succumb to foreign competition. To prevent this declining trend and reverse the course of falling acreage and production, continued support for research and development, removal of abandoned citrus groves, and support for growers that have been adversely affected by citrus greening are crucial.

Since progress in mechanization has slowed, growers depend heavily on workers. Labor shortages and high wage rates are serious problems that increase production costs and cut into citrus growers' profits. As the number of undocumented and domestic workers in the citrus industry has sharply declined, growers now mainly rely on guest workers. Consequently, growers must adapt to worker shortages, rising wages, and the high cost of guest workers. Growers should be aware of evolving immigration policies and proactive in addressing labor-supply issues.

Citrus growers also face intense competition from imports from foreign countries, where the cost of production is considerably lower than in the United States. This makes it even more imperative for U.S. growers to innovate by developing varieties that are pest and disease resistant and cold hardy so that growers can effectively implement mechanized harvesting methods.

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Issues Facing the Californian Fruit Sector

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The value of fruit production in California has grown to over $18 billion, making up to two-thirds of the total value of U.S. fruit farming in 2018. This increase provides consumers a variety of fruits available all year around; however, Americans' daily fruit consumption is still lower than the level recommended in the 2015–2020 *Dietary Guidelines for Americans*. Fruit farming receives minimal assistance relative to commodity crops, but Farm Bill supports reducing farming risks and government programs encouraging more fruit consumption have gradually increased in recent decades.

California fruit growers must now deal with issues that raise their production costs and decrease their farm revenue significantly. The main issues noted by the California Fresh Fruit Association (2020) are water curtailment, groundwater requirements, immigration policies, labor regulatory compliances, invasive pests, and food safety compliance. However, opinions on how to solve issues tied to: water, environment, immigration and labor policies are very diverse. Unprecedented drought conditions over 2011–2017, increasing levels of soil salinity, and political polarization further compound these problems. We summarize California fruit farming trends and analyze current and potential issues affecting the sector by assessing factors related to trade, policy, labor, water access, climate, pests and disease, and financial risks.

Importance of Fruit Farming in California

Among U.S. states, California receives the highest total gross farm value for all commodities. Fruit production accounts for 37.6% of California's total gross farm value (Table 1). Figure 1 demonstrates the changes in total gross value of all crops and fruit faming from 2009 to 2018. In the last decade, gross farm value increased from $35.2 billion to $48.4 billion, while fruit production values increased from $9.9 billion to $18.2 billion. Total fruit acreage has fluctuated around 1.5 million acres in California since 2009 (Figure 2). Nevertheless, we witness a noticeable decline in stone fruit, raisin, and orange acreages, while wine grape, berries, and mandarin acreages have increased. Although this study does not analyze the reasons behind these changes, we note that demand and new markets are often major factors for growers switching to new crops.

California is commercially the sole producer of six fruits (dates, figs, raisin grapes, kiwifruit, olives, and clingstone peaches) and leads other U.S. states in the production of 22 other fruits (CDFA, 2020b). In this study, we divide selected high-value fruits into five major categories: grapes (wine, raisin, table, and others), citrus (oranges, tangerines, grapefruits, and lemons), berries (strawberries, raspberries, and blueberries), stone fruits (peaches, nectarines, prunes/plums, apricots, and cherries), and avocados. Figure 3 shows the gross farm value of production of selected fruits in California. Grape farming in California creates over $7 billion in value. Berries and citrus are worth above $3 billion each, followed by $2 billion in stone fruit production statewide. Avocado, olive, and apple/pear production are valued at $0.7 billion. In 2012, a sharp increase in unit prices for table and wine grapes significantly raised the total farm value for grapes, which is attributed to the grape shortage resulting from a growth in demand (Bailey, 2012).

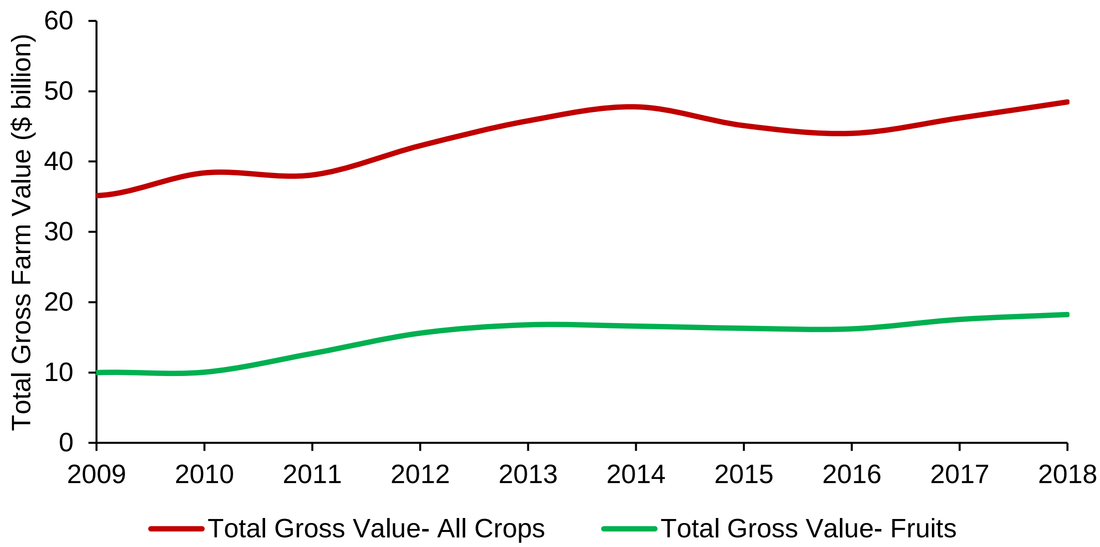
The value of Californian fruits utilized for domestic consumption has exhibited sustained growth, from $10 billion in 2009 to $13 billion in 2018. California also leads the nation in expanding fruit exports, from $3.4 billion in 2009 to $4.7 billion in 2018 (Figure 4). The value of California fresh fruit exports is one-fourth of its total agricultural exports though it may not grow further because of increasing domestic demand. Half of the fresh fruits consumed domestically consist of imported fresh fruits—mainly bananas, avocados, table grapes, and berries, valued in 2018 at $2.2 billion, $2.4 billion, $1.6 billion, and $2.9 billion, respectively—which makes the United States a net fruit importer since 1970s (Johnson, 2016). Moreover, per capita U.S. fruit consumption has not changed significantly in past decades and experienced a small decline from 254 pounds in 2009 to 241 pounds in 2018 (USDA, 2020). Therefore, we suggest that the growth in demand is mainly driven by U.S. population increase.

Table 1. Total Gross Farm Value of Agricultural Crop Production in California, 2018

Commodity Group	Total Value (in $1000)	Percentage
Fruits	18,242,251	37.63%
Nuts	10,691,252	22.06%
Vegetables	9,825,213	20.27%
Field and seed	5,872,205	12.11%
Nursery products, flowers, and foliage	3,842,385	7.93%
All crops	48,473,306	100.00%

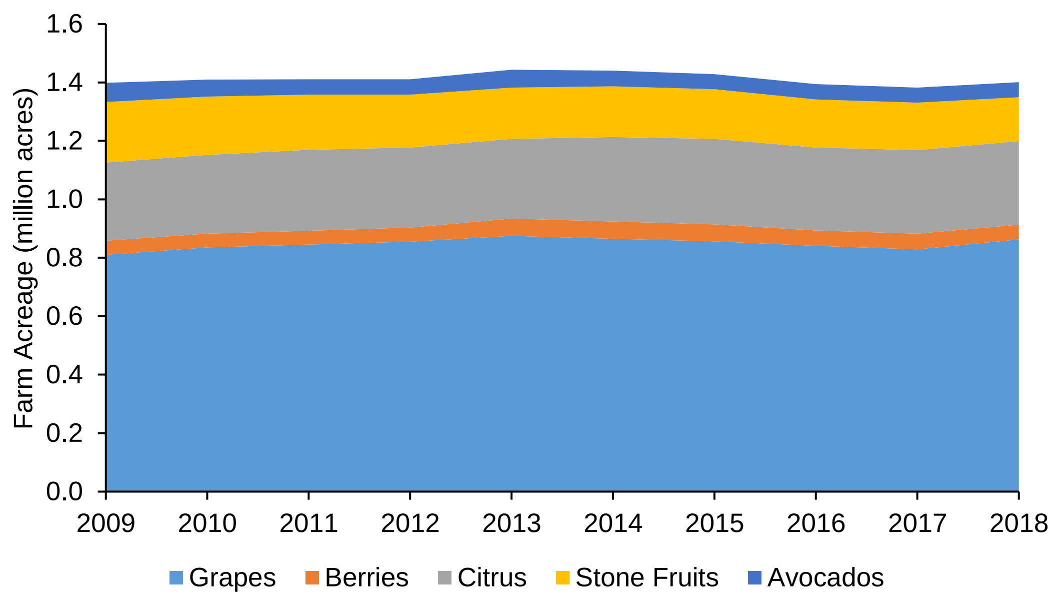
Note: Following the USDA's classification, this study includes melons in the vegetable category, not the fruit category.
Source: CDFA (2020b).

Figure 1. Total Gross Farm Value of Agricultural Crop and Fruit Production in California, 2009-2018



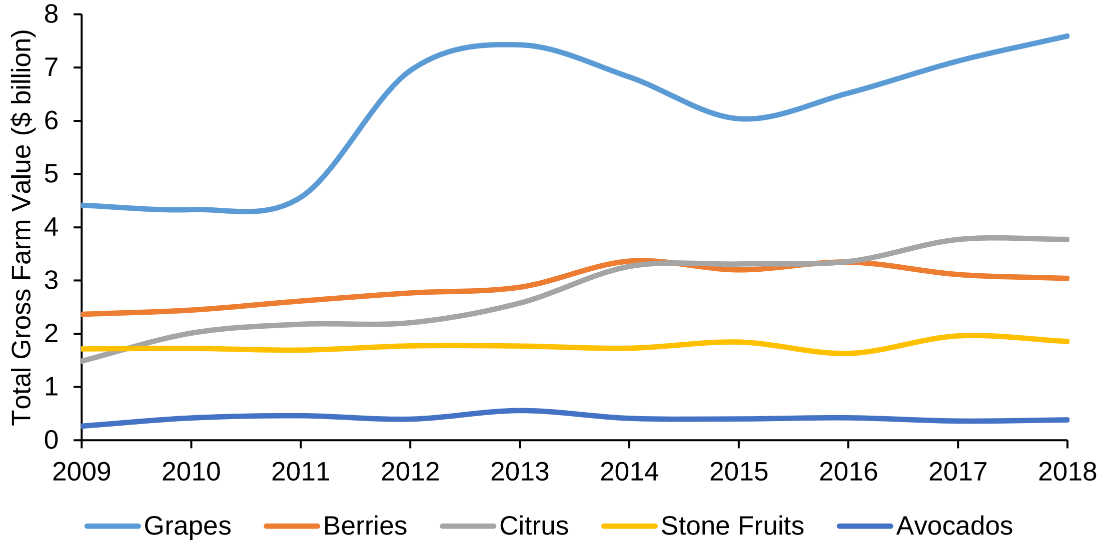
Source: CDFA (2020b).

Figure 2. Stacked Farm Acreage Chart of Selected Fruit Categories in California, 2009-2018



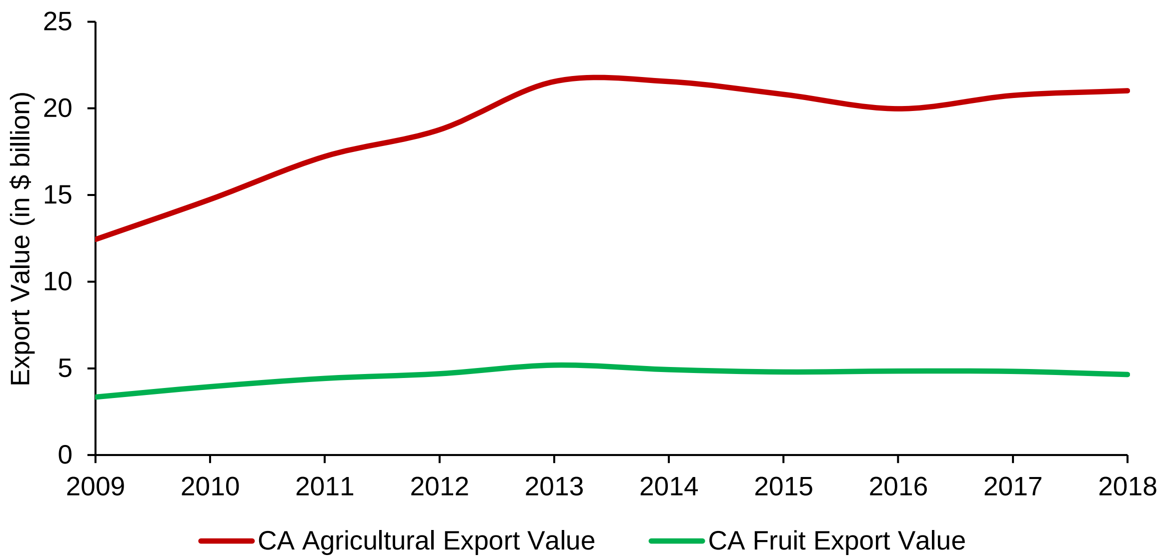
Source: CDFA (2020b).

Figure 3. Gross Farm Value of Selected Fruit Categories in California, 2009-2018



Source: CDFA (2020b).

Figure 4. Total Agricultural Export Values, and Fruit and Products Exports in California, 2009-2018



Source: CDFA (2020a).

Issues and Trends in Fruit Farming in California

Fruits are an important part of a healthy diet and have been shown to reduce the risk of many chronic diseases, such as type 2 diabetes, some cancers, and obesity (CDC, 2018). The 2015–2020 *Dietary Guidelines for Americans* recommend that adults should consume 1.5–2.0 cups of fruit per day. However, CDC surveys in 2015 show that only 12.2% of respondents met the daily fruit intake recommendations (Lee-Kwan et al., 2017). Federal programs such as Food and Nutrition Service nutrition programs and the fresh fruit and vegetable program encourage all children and adults regardless of their sociodemographic groups to consume more fruits.

The USDA also provides assistance to producers and marketers of fresh fruits. Federal Crop Insurance and Disaster Assistance programs reduce yield risk, Market Access and Technical Assistance for Specialty Crops programs help producers access foreign markets, Federal Marketing Orders standardize grade and quality, and several specialty crop grants and farmers' market programs support research and promotion.

California fruit growers, however, deal with many issues resulting from federal policies and state regulations. Based on the California Fresh Fruit Association's annual top-ten issues list, the main issues repeatedly facing the fruit industry in the past few years include groundwater regulation, water supply availability, immigration policies,

Table 2. Economic Impacts of Issues in Fruit Farming in California

Issues in Fruit Farming	Issue Caused By	Expected Impact 1	Current Level 2	Percentage Impact 3
Water curtailment	Shrinking snowpack in Sierra Nevadas and drought	>36,000 fallow acres	1,500,000 acres	>2.4% decline in acreage
Groundwater regulation	Sustainable Groundwater Management Act	260,000 fallow acres	1,500,000 acres	17.3% decline in acreage
Labor shortage	Federal immigration policies	$500 million additional labor cost	$2.3 billion labor cost	22% increase in labor cost
Labor regulation	California minimum wage law	$390 million additional labor cost	$2.3 billion labor cost	17% increase in labor cost
Invasive Pests	Invasive pests			
	Berry/cherry farming	$660 million farm value reduction	$3.3 billion gross value	20.0% loss in farm value
	Citrus farming	$740 million farm value reduction	$3.7 billion gross value	20.0% loss in farm value
Food safety	U.S. Food Safety Modernization Act	$240 million additional cost	$18 billion revenue	1.32% cost of compliance decreased from revenue
Trade disruption	Retaliatory tariffs on U.S. products	$190 million export revenue loss	$4.7 billion export value	4% decline in U.S. agricultural export value

Note: Expected impact calculated by authors. Dollar amounts are at the 2018 level. Percentage impact (column 3) is calculated by dividing the value in column 1 by the value in column 2.

changing labor standards, food safety compliance, and invasive pest issues (CFFA, 2020). This study estimates the potential impact of these issues on the fruit industry based on previous impact studies (Babcock, 2018; Bolda, Goodhue, and Zalom, 2010; Bovay, Ferrier, and Zhen, 2018; Howitt et al., 2015; Martin, Hooker and Stockton, 2017; Richard, 2018; Sunding and Roland-Holst, 2020). Table 2 reports the expected impact of these issues.

Water Curtailment and Groundwater Regulation

The snowpack from the Sierra Nevadas is a crucial water source for fruit growers. The runoff from melted snowpack replenishes reservoirs during dry months in California's San Joaquin Valley (SJV), where most of California's tree fruits are produced. More of the precipitation falls as rain rather than snow due to warmer winters in the past few years; as a result, the reservoirs cannot contain all the runoff water for later months. In the last decade, California has also suffered a long-term drought, which has further limited allocation of water to SJV growers.

Combined with drought and La Niña years, water service contractors in the SJV have received ever-declining water allocations of their contract total. Howitt et al. (2015) estimate that the drought and limited water allocation may result in the fallowing of over 36,000 acres of orchards and vines. Since total fruit farming in

California is about 1.5 million acres, we estimate at least a 2.4% decline in total land dedicated to fruit farming.

The Sustainable Groundwater Management Act (SGMA), which will take full effect by 2040, provides a framework for long-term sustainable groundwater management in California. The SGMA requires water agencies to halt overdraft and bring groundwater basins into balanced levels of pumping and recharge. This state regulation may lead some growers to pull their land from agricultural production or keep their land fallow. Sunding and Roland-Holst (2020) suggest that the SGMA may lead to a decline of 260,000 acres in harvested acreage for tree fruits and vines in the SJV, or 17.3% of California fruit acreages leaving production.

Immigration Policies and Labor Regulations

Over 60% of crop workers in California are unauthorized or undocumented (Martin, Hooker, and Stockton, 2017). Additionally, studies show that the rate of substitution between domestic and immigrant labor is fairly low, and it is not plausible to assume that wage-induced substitution will attract domestic labor into agriculture (Wei et al., 2019). Current immigration policies are removing unauthorized foreigners and limit H-2A guest workers, who are the significant workforce for U.S. agriculture. Therefore, farm labor shortages are becoming a severe problem in California. Another issue fruit farmers face is the rising cost of labor due to strict state regulations and increasing minimum wage. For instance, California minimum wage legislation set the new level to $15/hour by 2024, raising gradually from $10/hour in 2016 (Hill, 2018; Scheiber and Lovett, 2016).

California fruit and tree nuts establishments employ 100,000 full-time equivalent (FTE) employees, who receive around $3 billion total wage (Martin, Hooker, and Stockton, 2017). Richard (2018) suggests that removing 50% of undocumented farmworkers would increase the salary by 22% to replace them with domestic workers. IMPLAN (2017) data show that fruit farming employs three times more workers than does tree nut farming. Therefore, we assume 75,000 FTE employees in fruit farming, receiving $2.3 billion wage payment. Thus, the salary increase will account for additional $500 million annual labor cost for fruit farmers.

California fruit industry mostly employs seasonal farmworkers who generally receive minimum wage; Martin, Hooker and Stockton (2019) calculated a noticeable gap between the average earnings of FTE employees and the average earnings of actual farmworkers. The study reports that the primary workers share of FTE is 50% for all agriculture and 53% for fruit farming, but it does not provide a breakdown by employment type. Therefore, we assume that half of farmworker earnings have been paid to seasonal workers at minimum wage since 2016. At the new $15 minimum wage level, labor cost for California fruit farmers will increase by $390 million per year in 2018 price level.

Invasive Pests, Food Safety and Trade Disruption

California fruit production has suffered from invasive pests. For instance, the spotted wing drosophila (SWD) is a pest of berry and stone fruits first detected in 2008 in California and now found along the entire west coast of the United States. Another well-known pest problem in California is Asian citrus psyllid, a vector of the bacterial disease Huanglongbing (HLB), also known as citrus greening (Warnert, 2012). HLB has caused devastating damage in Florida, infecting 80% of citrus trees (Singerman and Useche, 2016). In California, HLB was first detected in 2012. Current and possible invasive pests have become one of the biggest concerns for fruit growers.

Bolda, Goodhue, and Zalom (2010) estimate that SWD may cause 20% yield reduction in berry and cherry production in California. We calculate a $660 million decline in gross crop value for berry and cherry farming given $3.3 billion total value of these fruits in 2018. Babcock (2018) assumes that Asian citrus psyllid invasion and HLB could reduce citrus yields by 20%. Based on our calculations, we expect to see a $740 million decline in gross production value.

The food safety modernization act (FMSA)—the first-ever food safety requirements for farms producing fruits and vegetables, established science-based standards for growing, harvesting, packing, and holding produce—will be fully implemented by 2024 for small and very small businesses (FDA, 2019). The FMSA established many produce rules, including for agricultural water

Table 3. Number of Fruit and Tree Nut Farms in California

Farm Size	Area Operated	Average Sales Value	Number of Farms
Very small	1.0–69.9 acres	$59,319	24,742
Small	70.0–139 acres	$378,948	3,359
Large	≥140 acres	$2,428,893	6,986

Source: USDA (2017).

quality, soil amendments of animal origin, worker health and hygiene, animal intrusion, sanitary standards, and record-keeping requirements (Bovay, Ferrier, and Zhen, 2018).

Fruit growers are generally small or very small farms, and the costs of complying with the FMSA have already begun to impact fruit growers. Table 3 shows that there are 24,742 very small, 3,359 small, and 6,986 large farms in California (USDA, 2017). The Agricultural Census reports the size of fruit and nuts farms by acreage. The table combines several farm sizes into three general ranges based on total annual average sales: very small farms (1.0–69.9 acres and <$250,000 average sales); small farms (70–139 acres and <$500,000 average sales); and large farms (>140 acres and >$500,000 average sales). Bovay, Ferrier, and Zhen (2018) estimate that the cost of compliance with FSMA for California fruit and vegetable producers will be 1.32% of their revenue. We estimate that, by 2024, fruit growers in California may bear additional costs of $240 million.

Export markets provide opportunities for fruit growers to expand their market opportunities. Favorable export prices may also increase growers' revenues and improve crop quality and grade. However, China recently imposed retaliatory tariffs on U.S. fresh and processed fruits. The USDA projects a 4% decline in U.S. agricultural exports due to continuation of these tariffs (Regmi, 2019). If conditions persist, we estimate an annual loss of $190 million in export revenues when we apply a 4% decline to California fruit exports.

Summary

California will remain the largest fruit growing state in the United States due to its favorable climate and farmers' expertise in fruit production. However, industry growth might halt due to strict state regulations and federal policies. Since government programs aim to increase per capita intake of fruits, California fruit growers might require additional assistance to tackle the many issues that increase their production costs and decrease their revenue. The industry might benefit from innovative research and promotion programs, which can decrease production costs and open new markets which will allow fruit industry to reach consumers from all demographics. The industry would benefit highly from expanded crop insurance programs, favorable farm labor and immigration policies, export promotion and market expansion efforts, and incentives for agricultural research and development.

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CHOICES

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Trends and Issues Relevant for the US Tree Nut Sector

Serhat Asci and Stephen Devadoss

JEL Classifications: Q10, Q11, Q20
Keywords: Demand analysis, Sustainable groundwater management, Trade, U.S. tree nuts

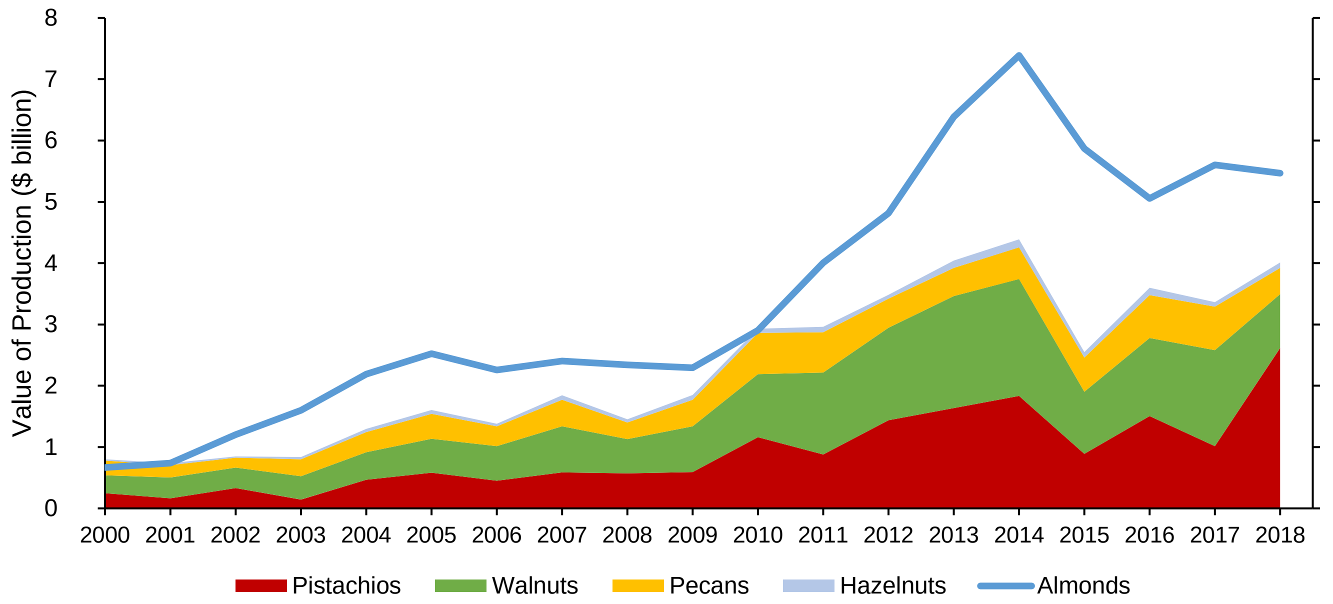
The United States is the second largest producer of tree nuts worldwide. Commercial tree nuts produced in the United States include almonds, pistachios, walnuts, pecans, hazelnuts, and macadamias. California is the sole producer of almonds, walnuts, and pistachios, accounting for 94% of the total U.S. tree nut production value. Pecans are produced in several states; from largest to lowest, the main commercial producers are New Mexico, Georgia, Texas, Arizona, and Oklahoma. Oregon is the main hazelnut-producing state, while the state of Washington only contributes 1% of total production. Total farm revenue for U.S. tree nut farming has expanded significantly, from $1.5 billion in 2000 to $9.5 billion in 2018 (USDA, 2020a). U.S. tree nuts are mainly exported to other countries, but the domestic demand for tree nuts is also steadily growing, supported by their promotion as nutritious and healthy snacks by government programs, marketing boards, and trade associations. However, environmental concerns, water shortage issues, labor shortfall, and trade issues challenge the sustainability of continued expansion in the United States. This article examines trends in tree nut supply, international trade, domestic demand, and current and future potential issues in the U.S. tree nut sector. This study further simulates changes in consumer spending on tree nuts and discusses potential policies to eliminate problems associated with increasing demand and sustainable tree nut supply in the United States.

Tree Nut Production in the United States

Almonds are one of the most valuable crops, not only in California but for the nation (CDFA, 2020; USDA, 2020a). Pistachios and walnuts generate significant farm revenues in the long run; however, it is possible to observe a drop in revenue for some years because of the alternate-bearing characteristics of these crops (CDFA, 2020; UC Davis, 2020). Figures 1 and 2 illustrate trends in the value and utilized production of major commercial tree nuts in the United States from 2000 to 2018. Almond crop values have significantly increased, from $0.67 billion to $5.47 billion from 2000 to 2018, and the quantity of almonds produced has grown threefold over the same period. Almond crop values and utilized production are much higher than those of all other tree nut varieties combined. Between 2000 and 2018, pistachios increased the most in value (10.7 times higher in 2018 compared to 2000) and utilized production (4.3 times higher in 2018 compared to 2000). Walnuts and pecans have also shown noticeable growth in both crop values and utilized production quantities since 2000. Although hazelnuts constitute a small share of total tree nut production, the value of hazelnut production has increased 4.6 times in this period, demonstrating the third largest value growth behind pistachios and almonds.

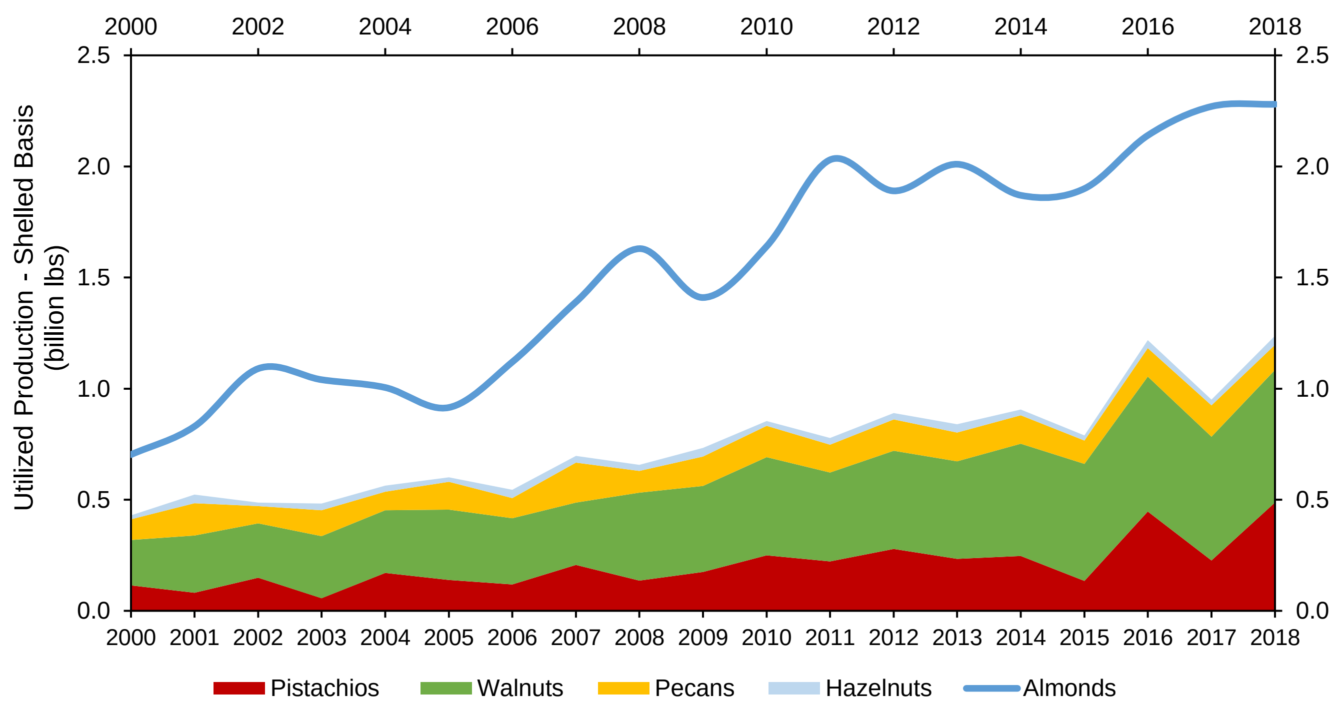
Annual per capita utilization of tree nuts has steadily increased since 2000, and consumption growth is mostly associated with the rising domestic utilization of almonds and pistachios in the United States (Figure 3). Annual per capita utilization of almonds increased from 0.8 pounds to 2.3 pounds, and the per capita utilization of pistachios went up from 0.2 pounds to 0.5 pounds between 2000 and 2018 (USDA, 2020a). On the other hand, per capita utilization for walnuts and pecans stayed around 0.5 pounds, and the per capita utilization for hazelnuts was the lowest at less than 0.1 pounds (USDA, 2020a). The increase in per capita consumption of almonds and pistachios can be attributed to the successful efforts of the Almond Board of California and American Pistachio Growers in marketing and boosting consumer demand (Almond Board, 2020; American Pistachio, 2020; Goodhue, Martin and Simon, 2018). Since 2008, over 50% of annual tree nut production has been directed toward export markets (Figure 4). For example, in the last decade, 70% of U.S. almond production and 75% of U.S. hazelnut production have been destined for export markets (USDA, 2020b). The United States is the largest almond producer and exporter in the world and one of the largest producers and exporters of pistachios and walnuts (CDFA, 2020). The figures show that pecan exports have increased significantly since 2000 while the domestic consumption of pecans has remained relatively unchanged. During this period U.S. pecan imports surpassed its exports as

Figure 1. Value of Major Tree Nut Production in the United States, 2000-2018



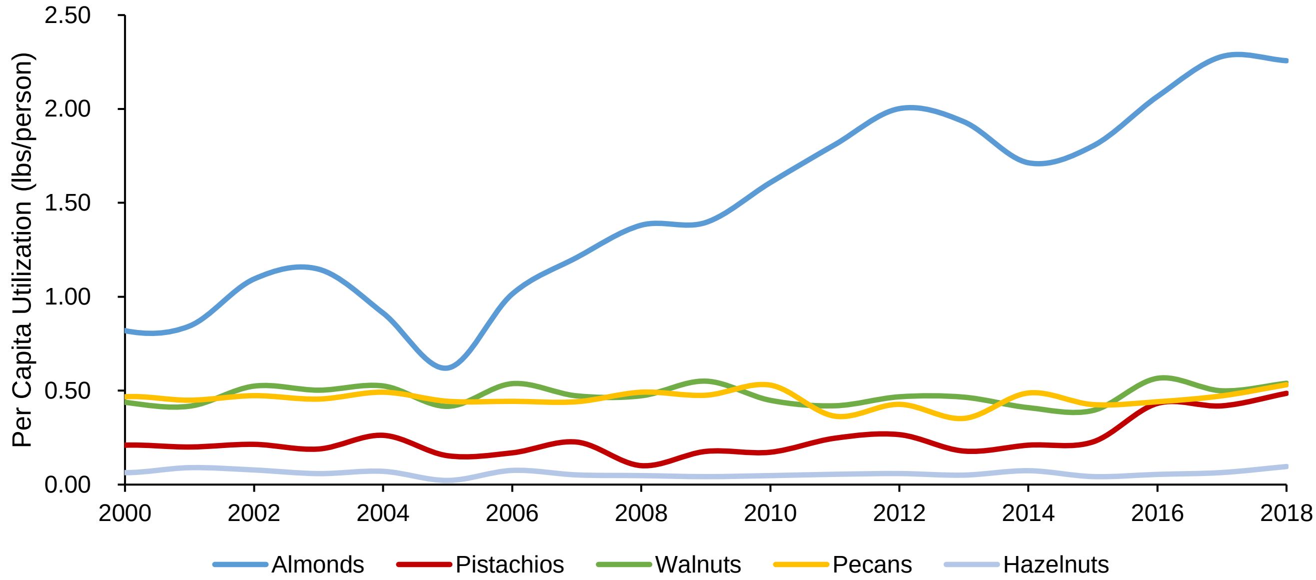
Note: Because of the large almond production value, it is represented by the entire area under the blue line; the values of other tree nuts are illustrated by colored areas stacked on one another.
Source: USDA (2020a).

Figure 2. Utilized Production of Major Tree Nuts in the United States, 2000-2018



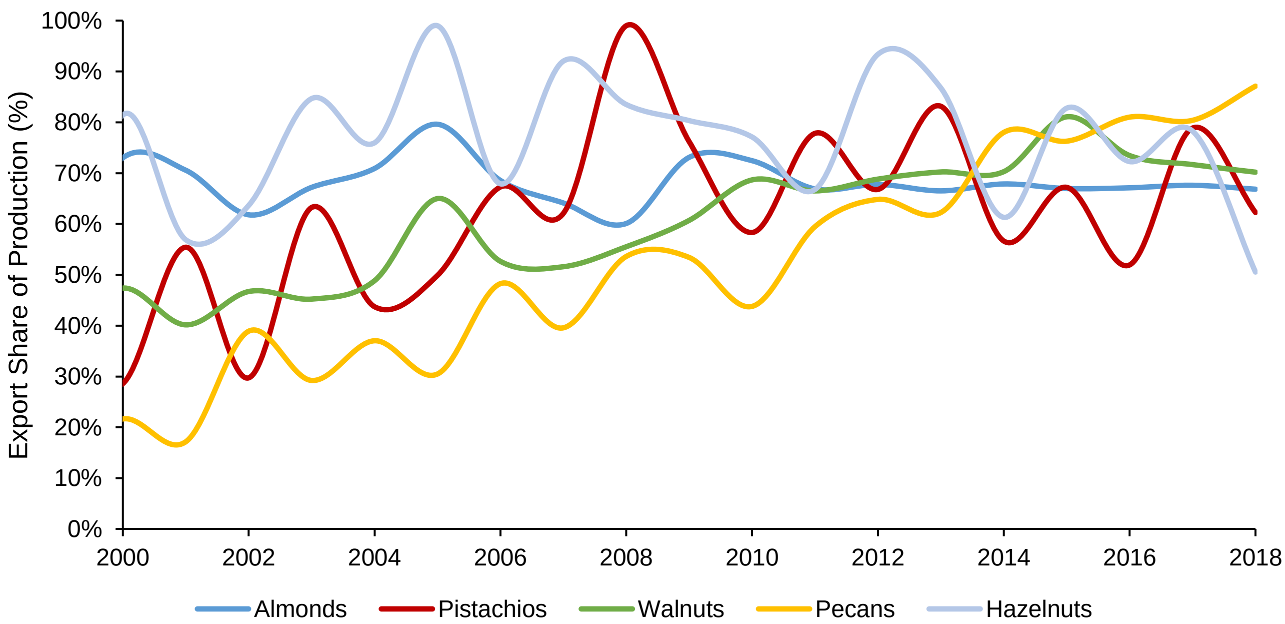
Note: All the production figures are specified in shelled basis. Because of the large almond production, it is represented by the entire area under the blue line; all the other tree nuts are illustrated by colored areas stacked on one another.
Source: USDA (2020a).

Figure 3. Per Capita Utilization of Major Tree Nuts in the United States, 2000-2018



Note: All quantities are converted into shelled-nut basis.
Source: USDA (2020a).

Figure 4. Export Share of Major Tree Nut Production in the United States, 2000-2018



Source: USDA (2020a).

the increased production was not sufficient to fulfill both export and domestic demands. The United States also imports large quantities of hazelnuts to meet demand from the confectionary and chocolate industries (Hazelnut Marketing Board, 2020).

Issues and Trends in U.S. Tree Nut Farming

The growth of domestic and international demand for U.S. tree nuts has led to the replacement of traditionally grown crops in the U.S. with tree nuts (Goldhamer and Fereres, 2017). Although the nutritional value of tree nuts—which provide plant-based protein, fats, fiber, and micronutrients—is appreciated by an increasing number of consumers, increased tree nut production has become an issue of debate because of the consumptive use of water in production (Fulton, Norton, and Shilling, 2019). Multiyear drought conditions in California and other southern states, combined with groundwater management regulations, put mounting pressure on tree nut growers. For instance, the Sustainable Groundwater Management Act (SGMA), a response to rapid decline in groundwater levels in California, regulates groundwater pumping to keep water levels stable and limits groundwater access for many tree nut growers. A current study estimates that the act will cause a yield decline of about 20% in California tree nut production by 2060 (Sunding and Roland-Holst, 2020). Shrinking snowpack in the Sierra Nevada, combined with long periods of drought in California, have led to a decline in surface water allocations for San Joaquin Valley growers. In 2020, the Sierra Nevadas accumulated only 50% of their seasonal average snowpack by April as a result of the warmer winter, leading the Bureau of Reclamation to announce only a 15% initial allocation of contract water supply for some water districts in California (USBR, 2020).

Immigration policies create labor shortfalls for many specialty crop operations. Additionally, state labor requirements and mandates result in stricter and costlier labor regulations and a rising minimum wage. While most tree nuts are mechanically harvested in the United States, tree nut farming is still considered a labor-intensive endeavor (Martin, 2018). Thus, studies suggest that stricter immigration policies and labor regulations would increase labor costs for tree nut farming by 22% or more (Martin, 2017; Richard, 2018). The reliance of the U.S. tree nut industry on export markets makes these crops susceptible to international trade issues. Several countries—including China, Turkey, and India—have imposed retaliatory tariffs on U.S. tree nuts since 2018. The United States has suspended free trade agreement negotiations and pulled out of free trade agreements such as the Transatlantic Trade and Investment Partnership (T-TIP) and the Trans-Pacific Partnership (TPP). These agreements were expected to increase trade revenues for the industry, but the products are diverted to other export markets (Heron, 2016). A current study estimates that the trade divergence of almonds to other export destinations because of Chinese retaliatory tariffs may decrease total industry revenue by 0.43% (Asci et al., 2020).

Government nutrition assistance programs and the 2014 and 2018 Farm Bills encourage consumers to consume more fresh produce and nuts and to prepare healthier meals to meet the Dietary Guidelines for Americans (USDHHS and USDA, 2015). Consumers are also increasingly more concerned about eating healthier foods. Tree nuts are considered to be healthy foods due to their rich protein, fiber, and other essential nutrient content. Increasing health consciousness is driving the adoption of nut consumption in diets across the globe. Moreover, the use of tree nuts in bakery, confectionery, dairy, breakfast cereals, sports nutrition, and personal care products has also been growing in recent years. The fruit and nut farming industry is expected to continue growing over the next five years, consumer demand and government programs targeting consumption of tree nuts will likely contribute to this growth.

Demand Analysis of U.S. Tree Nuts

In the last decade, U.S. per capita tree nut consumption has increased significantly (USDA, 2020a). The main driver of changes in favorable consumer preferences for nuts is the promotion of tree nuts' dietary benefits by marketing boards, trade associations, and government programs. In this section, we estimate the responsiveness of U.S. consumer demand for tree nuts to changes in prices and food expenditure using an economic concept called "elasticity." Holding other prices and expenditures constant, elasticity measures the effect of a change in a tree nut price or its expenditure on quantity demanded of that tree nut. Next, we use these elasticity estimates to analyze how the general promotion of tree nuts through various government programs or marketing board efforts would affect consumer demand for specific types of tree nuts (USDA, 2020c). Using annual data on unit export prices and domestic consumption quantity between 1996 and 2018, we analyze the domestic consumer demand patterns for five U.S. tree nuts: almonds, pistachios, walnuts, pecans, and hazelnuts. We use export prices for this analysis because we lack annual consumer prices for tree nuts. Since most of the U.S. tree nut production is also destined for export markets, we can assume that these prices are closer to the domestic consumer prices, except the value addition from individual packaging, further processing, and retailing in the tree nut supply chain. A general differential demand model conforming to economic regularity conditions was used to estimate price and expenditure elasticities in Table 1. For detailed technical information on estimating such demand systems as well as calculating price and expenditure elasticities, readers can refer to Schmitz and Seale (2002) and Asci et al. (2016).

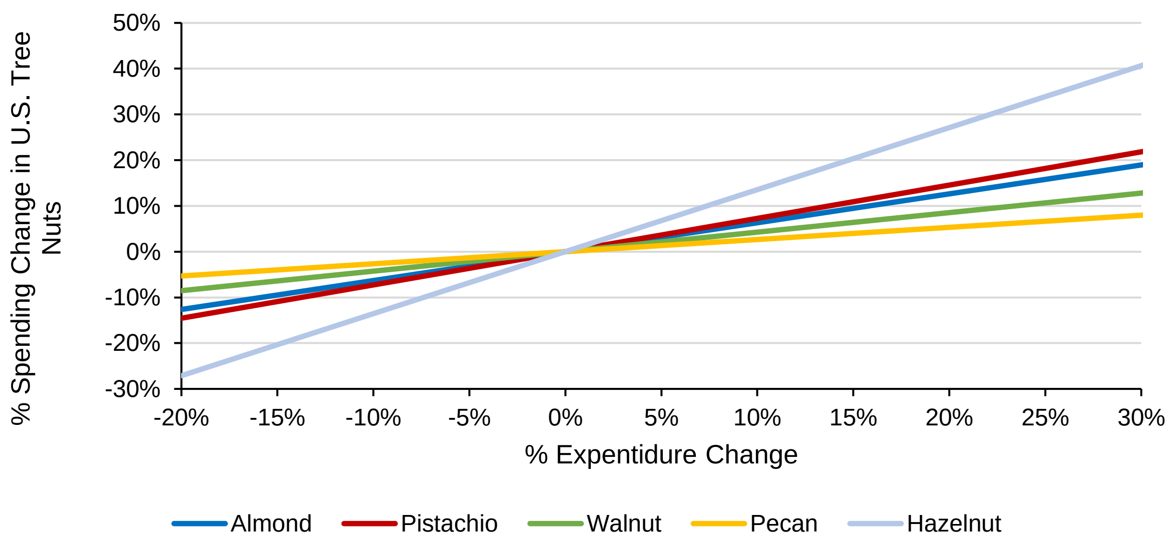
The own-price elasticities are reported along the diagonals, and they explain the percentage change in domestic quantities of nuts consumed when the price of the same nut changes by a percentage point. The sign of all own-price elasticities are negative as expected due to the law of demand; however, they are not statistically different from zero. The cross-price elasticities are reported on off-diagonals and explain the percentage change in domestic quantities of nuts consumed when the price of an alternative nut changes by a percentage point, holding total expenditures on tree nuts constant. Positive cross-price elasticities indicate that two varieties

Table 1. Estimated Price and Expenditure Elasticities of Demand for Major Tree Nuts, 1996-2018

	Price Elasticities					Expenditure Elasticities
	Almond	**Pistachio**	**Walnut**	**Pecan**	**Hazelnut**	
Almond	-0.12	0.04	0.10*	-0.07	0.06*	1.26*
	(0.12)	(0.08)	(0.06)	(0.09)	(0.03)	(0.19)
Pistachio	0.19	-0.33	-0.07	0.41	-0.20	1.45*
	(0.40)	(0.43)	(0.22)	(0.26)	(0.16)	(0.51)
Walnut	0.22*	-0.03	-0.16	-0.03	0.00	0.85*
	(0.12)	(0.09)	(0.10)	(0.12)	(0.05)	(0.23)
Pecan	-0.09	0.10	-0.02	-0.08	0.09*	0.53*
	(0.11)	(0.06)	(0.07)	(0.15)	(0.03)	(0.30)
Hazelnut	1.03*	-0.71	-0.03	1.25*	-1.29	2.71*
	(0.57)	(0.56)	(0.39)	(0.43)	(1.02)	(0.82)

Notes: Asterisks (*) denote the elasticities are statistically significant at 10% level. Numbers in parenthesis are approximate standard errors. Elasticities are calculated at mean values of data. Expenditure elasticities are computed conditional on total tree nut expenditures. Price elasticities are the so-called "Slutsky" variation.

Figure 5. Simulated Effects of Expenditure Changeson Quantity Demanded, 2018 Prices and Quantities



Source: Calculated by authors using the expenditure elasticity estimates.

of nuts are substitutes from the consumer's point of view, while negative cross-price elasticities indicate complementarity among different tree nuts. The following combinations of nuts have positive and statistically significant cross-price elasticities at the 10% level: almonds–walnuts, almonds–hazelnuts, and pecans–hazelnuts. Conditional expenditure elasticities reported in the last column of Table 1 indicate the expected percentage change in spending for a tree nut variety when the total expenditures for all nuts change by a percentage point. All expenditure elasticities, except for that of pecans, are positive and statistically significant at the 1% level. The expenditure elasticity for pecans is significant at the 10% level. Hazelnuts have the highest expenditure elasticity, 2.71, followed by pistachios, almonds, walnuts, and pecans. Therefore, U.S. consumers spend relatively more on hazelnuts as their total spending on tree nuts increases.

Lastly, we simulate possible effects of federal nutrition programs and favorable promotions on the quantity demanded of each tree nut using the estimated elasticities reported in Table 1 (Figure 5). The chart shows the simulated percentage change in spending for each type of U.S. tree nut with respect to the percentage change in total nut expenditures, holding prices constant. When we observe a 30% increase in consumers' total expenditure on tree nuts, spending on hazelnuts, pistachios, and almonds increases by 40%, 21%, and 19%, respectively, while spending on walnuts and pecans increases only slightly. On the other hand, if total U.S. expenditures on tree nuts decreased, hazelnuts would be impacted most negatively, followed by pistachios, almonds, walnuts, and pecans.

Summary

Overall, demand for tree nuts continues to grow in the United States and around the world. Consumers' growing interest in the nutritional benefits of tree nuts, expanding use of tree nuts in various processed food items, and promotional campaigns by government programs and trade associations to encourage tree nut consumption are the main drivers for this increasing demand. The United States dominates total world production of almonds and pecans and is a major global producer of pistachios and walnuts. However, major export competitors—including Australia, Iran, Turkey, and Chile—are adding more acreage for tree nut production. The U.S. tree nut industry is prone to showing negative long-term response to changes in government regulations and trade policies. Therefore, tree nut operations may shift out of states with high regulations and costs into states with fewer regulations and other bureaucratic restrictions on water and labor. Taken together, our analysis suggests that the growing consumer interest and promotional campaigns can significantly increase domestic spending on tree nuts to varying degrees depending on the type of tree nut. Growing demand for tree nuts will likely lead to additional land allocation for domestic tree nut production, increased tree nut imports, or both.

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