



**AgEcon** SEARCH  
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

*No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.*

# Are the Almond and Beekeeping Industries Gaining Independence?

Antoine Champetier, Hyunok Lee, and Daniel A. Sumner

*JEL Classifications: Q13, Q12, Q57*

*Keywords: Almonds, Beekeeping, Pollination, Self-fertile varieties*

## Introduction

The almond and beekeeping industries are bound together by the strict dependence of almond trees on insect pollination for the production of a nut harvest. Through this dependence, the extraordinary growth of almond production in California has reshaped commercial beekeeping in the United States from a declining honey-producing industry into a growing pollination service provider. Opportunities for large pollination revenues have encouraged beekeepers to shift to rearing many colonies to satisfy pollination demands in late winter rather than preparing hives for honey production in spring and summer. Thus, prior to the almond bloom season, many beehives are readied for pollination activity, contracted for delivery, and moved into the orchards.

For the best part of the last four decades of almond expansion, growth in global demand for U.S. almonds has provided growers with sufficiently high revenues to support growing demand for pollination services. The draw of honey bees to almonds, at first only present among California beekeepers, spread to beekeepers across the nation (Rucker, Thuman, and Burgett, 2012). For the past dozen years, the beekeeping industry has been able to supply expanding numbers of hives for almond pollination with little increase in real rental rates (per unit of active bee services). There are good reasons to think that this elastic response could continue in coming years (Champetier and Sumner, 2019).

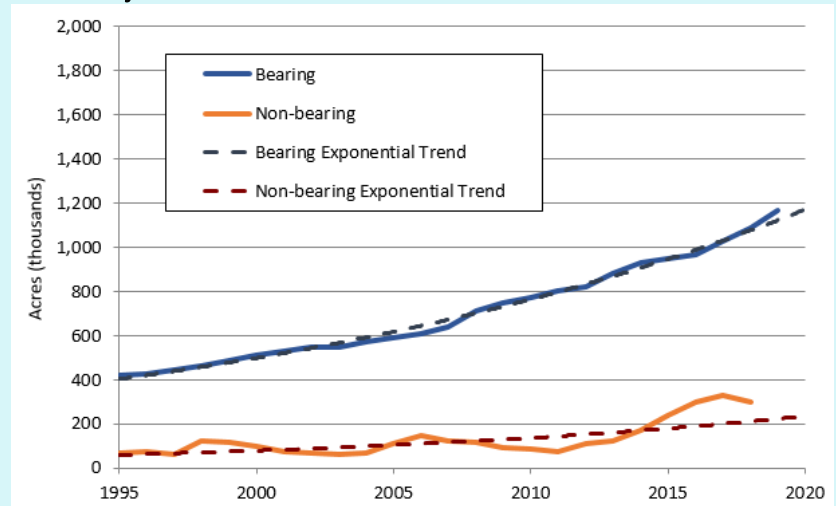
Yet the ability of the beekeeping industry to keep pace with rapid expansion of almond acreage has not always been self-evident. Concerns over pollination services becoming excessively expensive reached a peak in 2006 after almond pollination costs suddenly grew from about \$150 per acre to \$350 per acre, or \$75 to \$175 per hive at two hives per acre, in 2018 dollars (Ferrier et al., 2018). Concern about the supply of colonies for pollination services not keeping pace with the growth in acreage of pollinator-dependent crops became widespread around that time (Aizen and Harder, 2009). Economists, in contrast, argued that market forces would convey almonds growers' pollination needs to the beekeeping industry (Sumner and Boriss, 2006). Since then, a relatively calm decade of pollination market activity and only gradual change in fees have supported the notion of progressive adjustments of supply and demand for pollination services (Lee et al., 2017). Rucker, Thurman, and Burgett (2019) explain in detail how pollination markets have adapted to changes in bee health.

Despite only moderate recent fee increases, growers and researchers have pursued efforts to reduce almond pollination costs. Such efforts include both improved pollination practices and technological innovation. The rest of this article explores the adoption of self-fertile almond varieties, which require much smaller pollinator densities than varieties conventionally grown in California. We describe varietal planting trends and discuss economic issues surrounding the adoption of self-fertile varieties. We highlight an important economic trade-off between savings in pollination and other cultivation costs and quality-related price premiums for almond nuts.

## Overview of Almond Acreage Growth

The growth of the California almond industry has been impressive. Figure 1 illustrates this growth by showing the exponential increase in bearing almond acreage from 1995 to 2018 (almond trees start bearing a commercial harvest after 3–4 years). According to the latest *California Almond Acreage Report* (California Department of Food and Agriculture, 2019), 1,090,000 acres were bearing in 2018. While the acreage of nonbearing orchards has ebbed and flowed following almond price fluctuations, the upward trend of nonbearing acres reflects a sustained pace of long-term expansion. While planting of new orchards seems to have slowed recently, nonbearing acreage has for several years been above what is needed for replacement of old orchards. As a result of this planting activity, almond acreage is likely to reach 1.4 million acres within a few years.

**Figure 1. Bearing and Non-Bearing Acreages for Almonds with Simple Trend Projections**



Source: California Department of Food and Agriculture (2019). Trends are authors' calculations.

Understanding the impact of almond acreage expansion on the demand for pollination services is straightforward if current patterns continue. Honey bees are placed at a stocking density of about two hives per acre of almond trees. The number of honey bee colonies in the United States, as measured by the Census of Agriculture in December 2017, was 2.9 million hives. Therefore, pollinating 1.1 million bearing acres required about 76% of U.S. honey bees. Pollinating 1.4 million acres would require 97% of the hives measured in the 2017 Census at the current stocking density.

Demand for almond pollination outgrew supply from California and West Coast–based beekeepers years ago and now draws three out of four colonies from across the U.S. (Rucker, Thurman, and Burgett, 2012). The trend seems set to continue and may include additional hives located in regions that are not currently major honey bee suppliers (Champetier and Sumner, 2019). Goodrich, Williams, and Goodhue (2019) argue that Florida, Georgia, and Texas will likely contribute to further expansion of almond pollination service provision.

## Pollination Costs Are as High as Irrigation and Harvest Costs

Before 2005, pollination costs were a relatively small share of total almond production costs. Following the sudden increase in pollination fees from 2004 to 2006, and with the number of colonies per acre of almonds unchanged, the cost share of pollination has risen significantly. This pattern is clearly visible in Table 1, which reports sample cost shares of pollination in California from 1998 through 2019. The share of pollination costs varied between 6% and 8% from 1997 to 2003. The cost rose to nearly 10% in 2008 and 20% by 2016. The other major operating cost components for almonds are irrigation costs—which differ by region and vary from year to year—and harvest costs, which are more stable.

**Table 1. Sample of Cost Shares for Pollination, Harvest and Irrigation in Total Operating Costs in Micro-Sprinkler Irrigation in North and South San Joaquin Valley**

Year	Pollination Cost Share (%)	Harvest Cost Share (%)	Irrigation Cost share (%)	San Joaquin Valley Location
1998	6.7	19.2	13.1	North
2002	7.7	22.7	22.7	North
2003	7.6	18.7	30.8	South
2008	10.1	15.9	27.7	South
2011	13.0	16.0	10.8	North
2012	15.6	23.8	10.3	North
2016	20.0	17.7	22.1	North
2019	15.8	20.1	15.8	North

*Note: The dashed line delineates the periods before and after the almond pollination fee hike for 2004–2006. The grey shadings highlight the high irrigation cost shares for the Southern San Joaquin Valley relative to the North.*

*Source: University of California Co-Operative Extension and UC Agricultural Issues Center Sample Cost and Returns Studies, years and locations indicated, all micro-sprinkler irrigated and not organic. Shares are authors' calculations.*

## Potential Responses to High Pollination Fees per Colony

High pollination costs caused increased attention to tracking and managing pollination services. Because pollination activity may differ greatly across hives, growers have adopted new standards for hive strength in pollination contracts. Goodrich, Williams, and Goodhue (2019) describe in detail how frame counts have become common practice in almond pollination contracts, with six and eight bee-covered frames being the reference standards. Unfortunately, the lack of historical record for frame counts limits our ability to fully assess how almond growers have increased active bee densities per hive while hive densities remain constant.

Almond growers have also attempted to reduce reliance on honey bees by experimenting with other insect pollinators. Given the early bloom of almonds, wild pollinators cannot be relied upon for the large expanses of almond areas and the high pollinator densities required. However, other managed species have been explored. For instance, the blue orchard bee can be successfully managed for cherry and apple pollination (Bosch and Kemp, 2001) and was the focus of large research and development efforts for almond pollination. Integrated pollination management, which combines honey bees with other species like the blue orchard bee, has also received significant attention (Koh et al., 2017). So far, however, blue orchard bees have not been cost-effective for almonds. After a decade of searching for alternative pollinators, using honey bees remain the only widespread practice among commercial almond growers.

A third approach to reducing the number of honey bee colonies needed in almond production is through the development of almond varieties (or cultivars) that require much less insect pollination. Most almond trees planted in California in the last several decades have been self-sterile varieties and thus require pollen to be moved across trees of different varieties to obtain a commercial harvest. The strict dependence of Californian varieties of almond trees on insect pollination is idiosyncratic. Many varieties traditionally cultivated outside the United States, in Spain for instance, are much less pollinator-dependent.

To reduce dependence on honey bees, plant breeding programs in California have developed two commercial varieties, 'Independence' and 'Shasta', that produce relatively high yields with hive-stocking rates of less than half

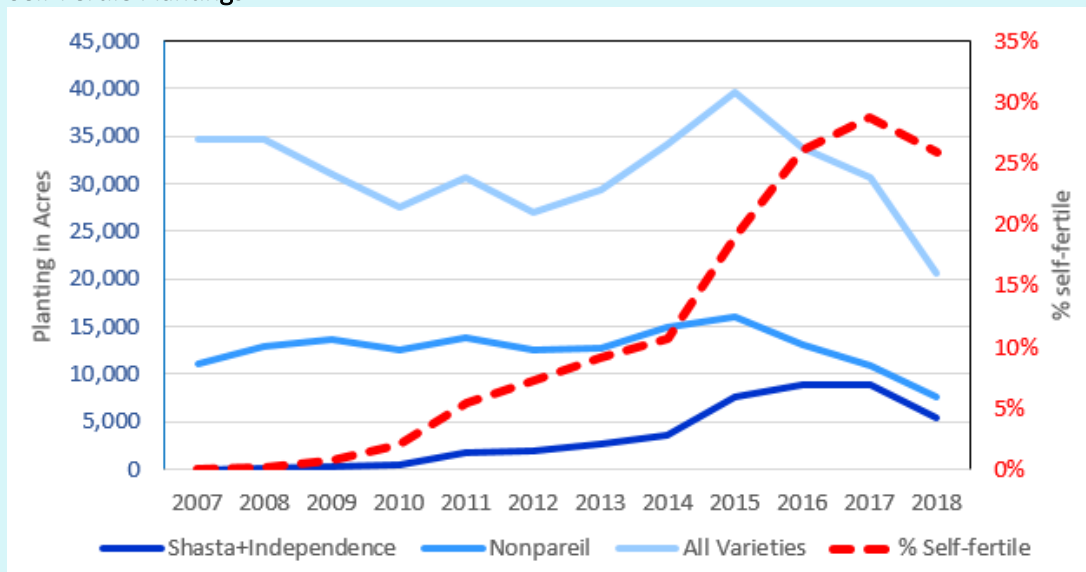
the conventional two hives per acre used for standard varieties. The new varieties are self-fertile, meaning that they can be pollinated from the same variety to bear fruit. A low stocking density of around one honey bee hive for two acres is recommended for commercial yields with self-fertile varieties (Parsons, 2017). At the current rental rate of nearly \$200 per hive, this may represent savings of up to \$300 per acre (from 2 hives per acre to 0.5 hive per acre).

The potential cost savings of using self-fertile varieties are not limited to reduced stocking densities of honey bees. Planting these varieties eliminates the need to manage rows of “pollinator” or pollen donor varieties in between rows of the main variety. The mix of varieties in alternate rows complicates orchard cultivation practices such as spraying or fertilizing. Harvest is also complicated by planting patterns, especially when varieties must be kept segregated. Self-fertile varieties can be planted in uniform blocks with homogeneous management. Based on the almond cost studies published by the University of California Agricultural Issues Center, initial investments for orchard establishment are similar for self-sterile and self-fertile varieties, which means that operating costs and revenues are the main drivers of adoption (Duncan et al., 2016).

## Increasing Acreage Planted to Self-Fertile Varieties

The potential for pollination and other cost savings is reflected in a growing portion of almond acreage in California planted with ‘Independence’ or ‘Shasta’ varieties. Adoption rates for these and other varieties can be tracked with data on plantings by variety provided in the *California Almond Acreage Reports* published by the California Department of Food and Agriculture. Figure 2 shows the acres in new plantings for which variety is known (covering about 70% of bearing acreage) from 2007 through 2018 along with plantings of self-sterile varieties as well as ‘Nonpareil’, the most popular self-sterile variety.

**Figure 2. Plantings of Nonpareil, Independence and Shasta Varieties (acres) and Percentage of Self-Fertile Plantings**



Source: California Department of Food and Agriculture (2019). Percentages of self-fertile varieties are calculated as the percentage of ‘Independence’ and ‘Shasta’ plantings in total state (all varieties) plantings.

The adoption of self-fertile varieties began to grow around 2010, with a rapid acceleration in 2015 and continued growth in 2016. In eight years, self-fertile varieties reached more than 25% of new plantings, second to ‘Nonpareil’. The small dip in the share of self-fertile plantings from 2017 to 2018 might be indicative of a future slow-down in adoption. However, it is too soon to know whether adoption has peaked.

Despite the recent importance of self-fertile varieties in new plantings, the effect on total demand for honey bee pollination services for almonds remains small. As of 2018, of the almond acres for which a variety was known, about 5% were planted with self-fertile varieties (California Department of Food and Agriculture, 2019), and much of that was still nonbearing acreage planted within the last three years. Lee et al. (2018) simulated the impacts of the continuing adoption of self-fertile varieties in the long run. The scenario simulating a widespread adoption that reached 11% of bearing acreage, caused a 13% decline in pollination fees per hive. However, with a productive lifespan of almond trees of 25 years, the transition to self-fertile varieties would be a matter of decades rather than years.

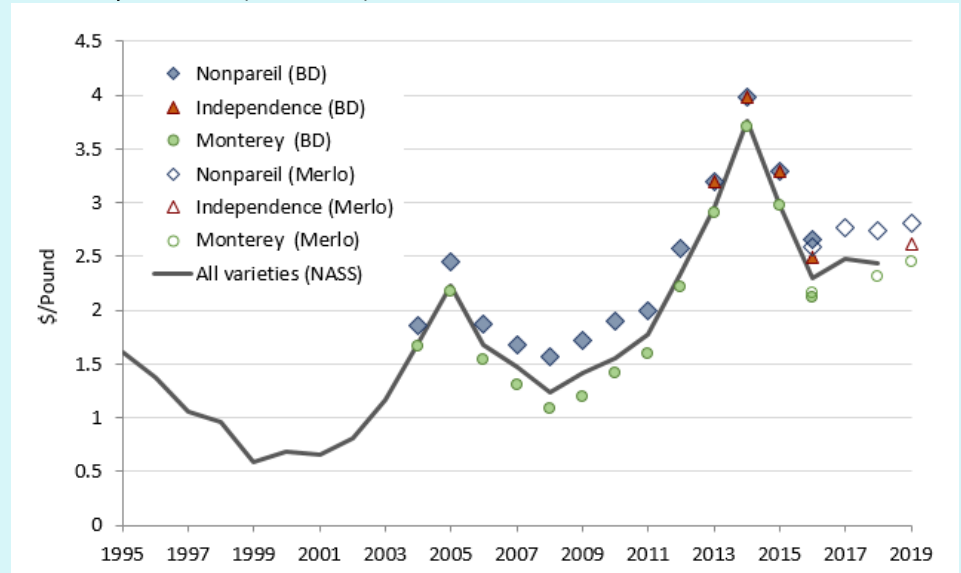
Clearly, adoption of self-fertile varieties can contribute to slowing the growth in demand for pollination services from the almond industry. The planting of self-fertile almond varieties is relatively new, however, and the costs and returns of adopting self-fertile varieties are only starting to become better understood. On the revenue side, variety-specific prices per pound of self-fertile almonds, a key driver for adoption rates, are just becoming available.

## Relative Prices of Self-Fertile Varieties

Quality attributes of almonds are crucial determinants of market prices. Larger kernels generally garner higher prices, but characteristics related to taste and color also receive price premiums. Easily observable nut characteristics may indicate a likely price range, but pricing by variety is complex and prices for new varieties only become known after sufficient quantities have been in the market.

Figure 3 shows the average price of almonds (in 2018 dollars) as well as prices for three specific varieties—‘Nonpareil’, ‘Independence’, and ‘Monterey’—from two industry sources for crop years 2007–2018. While the average market price varied from year to year, price differences between almond varieties were more stable. The price of ‘Nonpareil’ almonds was consistently above prices of other varieties. ‘Monterey’, considered a mid-range variety, sold for an average of 40 cents per pound below ‘Nonpareil’, with the difference ranging between 30 and 50 cents per pound. The average price across all varieties has remained between these two

**Figure 3. Prices for All Almond Varieties and for Nonpareil, Independence, and Monterey Varieties (USD 2018)**



Source: California Department of Food and Agriculture (2019), Blue Diamond (BD) Payment History in filled markers (2004–2016), Merlo Farming Group (Merlo), Almond Price Overview in hollow markers (2016–present). GDP deflator for United States from World Bank database.

variety-specific prices. Other varieties, such as ‘Mission’, have lower prices than ‘Monterey’. Relative prices for these established varieties are well known to growers and buyers.

Market prices for ‘Independence’ almonds were available starting in 2013, when the crop was still very small. The red triangles in Figure 3, representing ‘Independence’, start in 2013 and coincide with ‘Nonpareil’ for the first three years. Due to the large size of their kernels, ‘Independence’ prices were initially listed as a premium nut, along with ‘Nonpareil’. In 2016, Blue Diamond, the large almond marketing co-operative, bought ‘Independence’ almonds for prices about 6% less than ‘Nonpareil’ prices and about 18% more than ‘Monterey’ prices (Blue Diamond, 2018a). In 2019, an almond broker listed the price of ‘Independence’ almonds at about 6% below ‘Nonpareil’ and about 7% above ‘Monterey’ almonds. ‘Independence’ is now considered a distinct category from ‘Nonpareil’ as reflected in handler’s requirement that growers segregate and deliver the two varieties separately (Blue Diamond Growers, 2018b).

Some observers note that ‘Independence’ has relatively high yields, so a loss in price per pound may be partially or entirely offset by a higher yield (Parsons, 2017). Using the 2018 average yield of 2,280 pounds per acre, a loss of \$0.18 in price premium between ‘Independence’ and ‘Nonpareil’ (year 2018 in Figure 3) amounts to forgone revenue of \$410 per acre (or 7% of revenue). This potential loss in revenue is above the \$300 per acre of cost savings on pollination calculated above. However, the average prices per acre should account for the fact that some rows of lower-priced varieties must be planted as pollination donors in ‘Nonpareil’ orchards. Moreover, operation costs will also likely be slightly higher when the block is not of a uniform variety. Therefore, the economic gain from ‘Independence’ has been compelling for some growers. Overall, the largest impediment to planting the ‘Independence’ variety may simply be the relatively little evidence about how relative prices, yields, and costs may persist over the life of an orchard.

## Concluding Remarks

Almond pollination demands services from most commercial honey bees in the United States. As almond acreage continues to expand, the demand for pollination services from honey bees will continue to grow unless the number of hives per acre falls. The relatively high cost of pollination, between 15% and 20% of almond operating costs, provides an incentive to reduce the use of honey bees. One of the few promising ways to accomplish this may be through further adoption of self-fertile almond varieties, such as ‘Independence’. However, the economics of adoption of self-fertile almonds remains uncertain and, even if planting continues to be significant, its impact on pollination demand will be gradual and take decades to be fully realized.

## For More Information

Aizen, M. A., L.D. Harder. 2009. “The Global Stock of Domesticated Honey Bees Is Growing Slower than Agricultural Demand for Pollination.” *Current Biology* 19(11): 915–918.

Blue Diamond Growers. 2018a. “Blue Diamond Payment History 1997-2016.”

Blue Diamond Growers. 2018b. *2018 Crop Delivery Information*. Available online: <http://bluediamondgrowers.com/wp-content/uploads/2018/07/2018-Quality-Adjustment-Schedule-FINAL-7-05-18.pdf>

Bosch, J., and W.P. Kemp. 2001. *How to Manage the Blue Orchard Bee as an Orchard Pollinator*. Handbook Series 5. Beltsville, MD: Sustainable Agriculture Network, National Agricultural Library.

California Department of Food and Agriculture. 2019. *2018 California Almond Acreage Report*. Available online: [https://www.nass.usda.gov/Statistics\\_by\\_State/California/Publications/Specialty\\_and\\_Other\\_Releases/Almond/Acreage/201904almac.pdf](https://www.nass.usda.gov/Statistics_by_State/California/Publications/Specialty_and_Other_Releases/Almond/Acreage/201904almac.pdf)

Champetier, A., and D.A. Sumner. 2019. “Economics of the Supply Functions for Pollination and Honey: Marginal Costs and Supply Elasticity.” *American Journal of Agricultural Economics*, forthcoming.

- Doll, D. 2012, June 30. "Independence Almond: Some Observations. Almond Doctor." Available online: <http://thealmonddoctor.com/2012/06/30/independence-almond-some-observations/>.
- Duncan, R.A., B.A. Holtz, D.A. Doll, K.M. Klonsky, D.A. Sumner, C.A. Gutierrez, and D.E. Stewart. 2016. *Sample Costs for to Establish and Orchard and Produce Almonds. San Joaquin Valley North*. University of California Cooperative Extension and UC Agricultural Issues Center. Available online: [https://coststudyfiles.ucdavis.edu/uploads/cs\\_public/35/d7/35d70394-71d5-4d58-bbc4-d0a11f6b372c/16almondssjvnorthfinaldraft42716.pdf](https://coststudyfiles.ucdavis.edu/uploads/cs_public/35/d7/35d70394-71d5-4d58-bbc4-d0a11f6b372c/16almondssjvnorthfinaldraft42716.pdf)
- Ferrier, P.M., R.R. Rucker, W.N. Thurman, and M. Burgett. 2018. *Economic Effects and Responses to Changes in Honey Bee Health*. Washington, DC: U.S. Department of Agriculture, Economic Research Service, Economic Research Report ERR-246, March.
- Goodrich, B.K., J.C. Williams, and R.E. Goodhue. 2019. "The Great Bee Migration: Supply Analysis of Honey Bee Colony Shipments into California for Almond Pollination Services." *American Journal of Agricultural Economics* 101(5): 1353–1372.
- Koh, I., E.V. Lonsdorf, D.R. Artz, T.L. Pitts-Singer, and T.H. Ricketts. 2017. "Ecology and Economics of Using Native Managed Bees for Almond Pollination." *Journal of Economic Entomology* 111(1): 16–25.
- Lee, H., A. Champetier, D.A. Sumner, and J. Bond. 2017. "Bee-Conomics Revisited: A Decade of New Data Is Consistent with the Market Hypothesis." *ARE Update* 20(5): 1–4. University of California Giannini Foundation of Agricultural Economics.
- Lee, H., D.A. Sumner, and A. Champetier. 2018. "Pollination Markets and the Coupled Futures of Almonds and Honey Bees: Simulating Impacts of Shifts in Demands and Costs." *American Journal of Agricultural Economics* 101(1): 230–249.
- Merlo Farming Group. 2019. "Almond Price Overview." Available online: <https://www.merlofarminggroup.com/almonds> [Accessed June 29, 2019].
- Parsons, C. 2017, June 14. "A Closer Look at the Self-Fertile Independence Almond Variety" *FarmProgress* Available online: <https://www.farmprogress.com/tree-nuts/closer-look-self-fertile-independence-almond-variety> [Accessed June 30, 2019].
- Romero, D. 2016, March 26. "With Bees in Trouble, Almond Farmers Try Trees That Don't Need 'Em." *The Salt*. Capital Public Radio. Available online: <http://www.npr.org/sections/thesalt/2016/03/23/471437025/with-bees-in-trouble-almond-farmers-try-trees-that-dont-need-em>.
- Rucker, R.R., W.N. Thurman, and M. Burgett. 2012. "Honey Bee Pollination Markets and the Internalization of Reciprocal Benefits." *American Journal of Agricultural Economics* 94(4): 956–977.
- Rucker, R.R., W.N. Thurman, and M. Burgett. 2019. "Colony Collapse and the Consequences of Bee Disease: Market Adaptation to Environmental Change." *Journal of the Association of Environmental and Resource Economists* 6(5): 927–960.
- Sumner, D.A., and H. Boriss. 2006. "Bee-conomics and the Leap in Pollination Fees." *Agricultural and Resource Economics Update* 9(3): 9–11.
- U.S. Department of Agriculture. 2017. *Census of Agriculture*. Washington, DC: U.S. Department of Agriculture, National Agricultural Statistics Service.



#### Author Information

Antoine Champetier ([antoinechampetier@ecoeconomodeling.com](mailto:antoinechampetier@ecoeconomodeling.com)), is an independent economics consultant. Hyunok Lee ([hyunok@primal.ucdavis.edu](mailto:hyunok@primal.ucdavis.edu)) is Economist, Department of Agricultural and Resource Economics, University of California, Davis, and a member of the Giannini Foundation of Agricultural Economics, Davis, CA. Daniel A. Sumner ([dasumner@ucdavis.edu](mailto:dasumner@ucdavis.edu)) is Frank H. Buck, Jr. Distinguished Professor, Department of Agricultural and Resource Economics, University of California, Davis; Director, University of California Agricultural Issues Center; and a member of the Giannini Foundation of Agricultural Economics, Davis, CA.

**Acknowledgments:** The authors thank the editor and an anonymous reviewer for helpful comments.

---

©1999–2019 CHOICES. All rights reserved. Articles may be reproduced or electronically distributed as long as attribution to Choices and the Agricultural & Applied Economics Association is maintained. Choices subscriptions are free and can be obtained through <http://www.choicesmagazine.org>.