Apple Pollination Costs and Strategies: Trends and Outlook

Steven W. Wilcox, David R. Just, Heather Grab, C.-Y. Cynthia Lin Lawell, D. Adeline Yeh

Abstract

The pollination choices of apple farmers have important implications for production outcomes, food supplies, and pollination resources within and beyond the farm gate. This article uses existing and new data from the US apple sector to better understand farm-level apple pollination strategies and costs.

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Tweet: Apple pollination costs increased over the past 15 years and pollination strategies vary by region. @AppliedUtah @CornellDyson @AtkinsonCenter @agsciences @adeyeh7 via @Choices_AAEA

Steven W. Wilcox (steven.wilcox@usu.edu; Corresponding Author) is Assistant Professor, Applied Economics, Utah State University.

David R. Just (drj3@cornell.edu) is Professor, Applied Economics and Management, Cornell University.

Heather Grab (hlc30@psu.edu) is Assistant Professor, Department of Entomology, Penn State University.

C.-Y. Cynthia Lin Lawell (clinlawell@cornell.edu) is Associate Professor, Applied Economics and Management, Cornell University.

D. Adeline Yeh (adeline.yeh@usda.gov) is Research Agricultural Economist, Economic Research Service, U.S. Department of Agriculture (USDA).

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Introduction

Interest in pollination has grown in recent years coincident with concerns over declines in honey bees and wild pollinators. Pollination was the focus of a 2019 *Choices* theme (Ferrier, 2019b), with articles discussing important issues pertaining to honey bee mortality (Rucker, Thurman, and Burgett, 2019), the California almond pollination market (Goodrich, 2019), the almond and beekeeping industries (Champetier, Lee, and Sumner, 2019a), the supply side of the pollination and honey markets (Champetier, Lee, and Sumner, 2019a), and federal support programs and data reporting surrounding beekeeping (Ferrier, 2019a). The majority of directly related economics literature has similarly focused heavily on beekeepers, almond growers, and the West Coast of the US; and knowledge gaps persist for important crops such as apples, particularly at the farm level (Baylis, Lichtenberg, and Lichtenberg, 2021). This article builds on the 2019 *Choices* theme by using existing and new data to draw insights on farm-level pollination strategies and costs in the commercial apple sector in the US.

Pollination is an important input for apple production. Most commercial apple varieties require some cross-pollination, and pollination by insects greatly enhances fruit set and quality (Ramírez and Davenport, 2013). Apples are not considered to be a "honey crop", as nectar from apples does not produce palatable honey, and this translates into higher pollination rental fees for apple farmers since beekeepers do not gain forage resources to produce palatable honey from pollinating apples (Rucker, Thurman, and Burgett, 2012). The pollination choices of apple farmers have important implications for production outcomes, food supplies, and pollination resources within and beyond the farm gate (Grab et al., 2018; Schmit et al., 2018; Wilcox et al., 2024a; Wilcox et al., 2024b).

We use three primary sources of data. First, we use the 2007 component of the US Department of Agriculture (USDA) Agricultural Resource Management Survey (ARMS), which provides farm-level data on apple growers that is representative at national and state levels. Pollination data is available from this survey over 2006-2007 with broadly complete data for 1,057 apple growers from 4 Eastern states (Michigan, New York, Pennsylvania, and North Carolina) and 3 Western states (California, Oregon, and Washington).

Second, we use region-level data from the USDA Cost of Pollination survey, which collects information in all 50 states on acreage pollinated, colonies used, and dollars spent for a variety of different crops from farms and ranches with at least one acre of a crop determined to be potentially pollinated by honey bees, for the years 2015-2017 and 2022-2023 (the survey was suspended during the years 2018-2021); and which aggregates the information at the regional level for 6 regions: Northeast (Region 1), Southeast (Region 2), South (Region 3), Midwest and Mountain (Region 4), Pacific Northwest (Region 5), and Pacific Southwest (Regions 6 and 7). There were 33 specific crops targeted in the Cost of Pollination sampling scheme, of which 19 were listed individually on the questionnaire. Apples are among the 19 sampled crops listed on the questionnaire. The 2015 sample size was 42,165; the 2016 sample size was 19,931; the 2017 sample size was 14,532; the 2022 sample size was 15,590; and the 2023 sample size was 15,548.

A third source of data is the 2022 Northeast Apple Growers Survey, a survey we designed and implemented among apple farmers in the Northeastern US, which includes responses from 21 apple growers in New York and 1 apple grower in Connecticut, and which focuses on the 2019-2021 production years.

How Do Apple Farmers Pollinate Their Apple Trees?

Apple farmers in the US use one or more of the following options for pollination: (i) owning honey bee colonies (for pollinating apple trees, producing honey, or providing pollination services); (ii) renting or purchasing bees (such as buckets of bumble bees) during the bloom period; (iii) relying on local domesticated pollinators (such as local colonies of honey bees); (iv) relying on local wild pollinators; or (v) relying on a combination of local domesticated and wild pollinators (Kahlke, 2019; Biltonen, 2020; Wilcox et al., 2024b). According to nationally representative USDA ARMS data going back to 2006-2007 (from 1,057 growers) and the 2022 Northeast Apple Growers Survey (from 22 growers), adoption of these strategies varies as follows:

- ***Owning bees:*** Nationally, only 3% of apple growers in 2006-2007 owned their own honey bee colonies; among sampled apple growers in Eastern states (Michigan, New York, Pennsylvania, and North Carolina), the average was closer to 4% of growers who own their own honey bee colonies. Among the non-representative sample of 22 Northeast apple growers who responded to the 2022 Northeast Apple Growers Survey, 22.7% reported owning honey bees and also using their own colonies for pollination.

- ***Renting bees:*** Nationally, 74% of apple growers rented honey bees for pollination over 2006-2007, with growers in Eastern states (Michigan, New York, Pennsylvania, and North Carolina) being less likely to rent bees (65%) than growers in Western states (California, Oregon, and Washington) (81%). Among the non-representative sample who responded to the 2022 Northeast Apple Growers Survey, 50% reported renting honey bees for pollination.

- ***Wild pollination:*** Nationally, 25% of apple growers reported never renting honey bees over 2006-2007, with growers in Eastern states being more likely to never rent bees (33%) than

Western state counterparts (18%). Among the non-representative sample who responded to the 2022 Northeast Apple Growers Survey, 27.3% reported never renting honey bees, purchasing bees, or owning honey bees. Growers who never rent honey bees, own honey bees, or purchase bees are unique because the implication is that these growers may be relying exclusively on local wild pollinators – though contributions from local domesticated pollinators cannot be ruled out.

- ***Purchasing bees:*** In the available data from 2006-2007, there is no data on single season purchase of bees for pollination. Among the non-representative sample who responded to the 2022 Northeast Apple Growers Survey, the only purchases of bees reported appear to have been occasional purchases to replace hives among growers who own bees (and therefore not single season purchase for pollination purposes). Those who reported higher frequency of purchasing bees also indicated that they had experienced higher hive mortality rates in recent years (40% among those who owned bees).

- ***Other pollination strategies:*** There are reports that growers may also pollinate apples by hand, using new drone-based technology, or other kinds of mechanical methods. In the 2022 Northeast Apple Growers Survey, one grower reported using such strategies at some point, though in the years of focus for the survey (2019-2021 production years) this sole grower reported relying on honey bee rental.

There are currently no known suitable data to determine if apple growers have substantially changed their general pollination strategies since 2006-2007. Nevertheless, for the Northeastern states and New York in particular, honey bee rental seems to be the predominant strategy for how to pollinate apples during the bloom period. Figure 1 captures the predominant pollination strategies among the respondents to the 2022 Northeast Apple Grower Survey.

[Place Figure 1 here]

How Much Pollination Do US Apple Farmers Use?

Measures of the intensity of pollination use at the farm level are not widely available. As an input choice in commercial settings, managed pollination is the most readily measurable form of pollination use with existing data, though entomologists have successfully measured the relative prevalence of wild versus managed pollinators and studied comparative efficacy of pollination between wild and domesticated pollinators in commercial settings for apples and many other crops (Garibaldi et al., 2013; Blitzer et al., 2016; Park et al., 2016; Russo et al., 2017). The earliest available data for apple growers at the farm level comes from 2006-2007 USDA ARMS data, specifically for the number of honey bee colonies distributed per acre at the random apple block level. The 2022 Northeast Apple Grower Survey also collected farm-level data on the number of bee colonies distributed per acre. The following comparison of the available data on stocking densities highlights interesting variation across growers in how intensively they use honey bee colonies:

- ***Number of colonies rented:*** Nationally, among those who rented honey bees in 2006-2007, apple growers rented 17.26 colonies on average for pollination at the block level. Among this sample, Eastern growers rented fewer colonies (15.11) on average compared with Western growers (18.62). Within the un-representative sample from 2022 Northeast Apple Grower Survey, the average number of colonies rented among those who rented was 85 colonies.

- ***Colonies rented per acre:*** The measure used here is the total colonies deployed divided by the number of bearing apple acres at the block level. On a per acre basis at the national level in 2006-2007, among those who rented honey bees, apple growers used 1.87 honey bee colonies per acre on average. The Eastern growers in this sample had higher stocking densities on average (2.22 colonies per acre) than growers in Western states (1.65 colonies per acre); though for New York and Pennsylvania (the states closest to the sample population for the 2022 Northeast Apple Grower Survey) the average was closer to the national average at 1.85 colonies per acre. Within the un-representative sample from the 2022 Northeast Apple Grower Survey, among those who rented bees, the average colonies per acre was 1.48. Notably, these block-specific data show much higher stocking densities than aggregate statistics from the USDA Cost of Pollination survey suggest. For example, the implied stocking density (ratio of colonies used to paid pollinated acres) in 2017 for Region 1 (Northeast) and Region 5 (Northwest) are 0.51 and 0.93 colonies per acres, respectively. Reasons for the discrepancy between estimated stocking densities at the regional versus block level are not precisely known, but may reflect that regional estimates do not account for block-specific variation.
- ***Colonies owned per acre:*** Within the un-representative sample from the 2022 Northeast Apple Grower Survey, the intensity of bee colony use per acre differed markedly depending on if a grower owned or just rented bees. Among those who owned bees, the effective number of average colonies per acre was 0.24 colonies per acre. Comparable data at the block level is not available in the 2007 USDA ARMS.

The USDA ARMS data suggests that apple growers in Eastern states who rent bees use managed pollination more intensively than apple growers in Western states. Within the un-representative sample from the 2022 Northeast Apple Grower Survey, however, those who rented bees used

managed pollination less intensively on average than their regional counterparts have in recent years.

How Much Does Pollination Cost for Apple Farmers?

The range of potential costs for pollinating apples for commercial purposes are not very well tracked across the range of potential pollination strategies. The most widely captured dimensions of costs are costs for renting bees in pollination service markets; costs for beekeeping among honey producers are also captured by the USDA ARMS data. Potential costs for single-season purchase, wild pollination investments and maintenance, and alternative approaches (such as drones, hand labor, mechanical) are not well understood.

- ***Costs for honey bee rental over 2006-2007:*** After adjusting for inflation, the USDA ARMS data indicate that the average national price of renting honey bees over 2006-2007 was $46.19 per colony (in real 2017 US dollars). The respective average cost for growers in Eastern states was $50.73 per colony, compared to $42.61 per colony for growers in Western states. The average price for New York and Pennsylvania (the states closest to the sample population for the 2022 Northeast Apple Grower Survey) over 2006-2007 was $51.83. Among apple growers who reported using honey bees for pollination in the USDA ARMS data, we estimate that 7% of total operating costs are from pollination; the respective proportion of total costs from pollination for growers in Eastern states is 10%, compared to 5% for growers in Western states.
- ***Price per colony in the Northeast and Northwest over 2015-2023:*** According to the USDA Cost of Pollination survey, which collected information from farms and ranches in all 50 states on the average price paid by operations to use a colony for pollination (which does not include

colonies owned by the operation or used on a nonmonetary basis), the price per colony for apple growers in the Northeast (Region 1) in the years 2015, 2016, 2017, 2022, and 2023, after adjusting for inflation, were $66.38, $71.15, $72.17, $77.31, and $66.26 (in real 2017 US dollars), respectively. In contrast, in the Northwest (Region 5), the respective prices in 2015, 2016, 2017, 2022, and 2023 were $54.15, $52.42, $51.90, $49.42, and $48.67 (in real 2017 US dollars).

- ***Costs and revenues for bee owners in the Northeast over 2019-2021:*** According to data from the 2022 Northeast Apple Grower Survey, none of the bee owners appear to be large-scale honey or pollination service providers. Commercial profits seemed to be a very minor component of their operations. Among those who reported owning bees, a few reported minor profits over 2019-2021; others reported minor losses. After adjusting for inflation, the average total costs for owning and managing honey bees among those who owned honey bees was $935.78 with an average cost per colony of $87.80 per colony (in real 2017 US dollars).

- ***Costs for honey bee rental in the Northeast over 2019-2022:*** According to data from the 2022 Northeast Apple Grower Survey, after adjusting for inflation, the average total costs for honey bee rental among those who rented honey bees was $7,162.88 with an average price per honey bee colony of $87.80 per colony (in real 2017 US dollars). Real prices also increased slightly during the height of the COVID pandemic by $0.91 per colony according the 2022 Northeast Apple Growers Survey. Growers who responded to the 2022 Northeast Apple Grower Survey reported a range of costs for pollination from under 1% to as high as 5% of total operating costs. On average this subset of growers reported that pollination accounted for only 1.65% of total operating costs.

- ***Actual and perceived trends in pollination costs:*** Figure 2a plots the available data on the inflation-adjusted cost to rent honey bees per colony. Although a perfect match between states represented in available data over time is not possible, reasonable comparisons between Eastern and Western states in Figure 2a show that costs have increased since 2006-2007, and also that the amount of cost increase varies by region. Apple farmers in Western states experienced a relatively small increase in inflation-adjusted costs of $6.44 per colony between 2006-2007 and 2022-2023 (Region 5 average real price over 2022-2023 minus Western states average real price over 2006-2007). In contrast, apple growers in Eastern states experienced a much larger increase of approximately $21.06 to $35.97 per colony over the same period (Region 1 average real price over 2023-2022 minus Eastern states average real price over 2006-2007; and 2022 Northeast Apple Growers Survey average real price over 2021-2019 minus average real price for Pennsylvania and New York over 2006-2007). Figure 2b presents results for the views of growers who responded to the 2022 Northeast Apple Growers Survey regarding their perceptions of the trend of pollination costs over the last 10 years. Growers who responded to the 2022 Northeast Apple Growers Survey expressed a variety of opinions regarding the arc of changes in pollination costs over time.

Although we cannot speak comprehensively to the range of potential changes in pollination costs over the last 15 years or so, the available data does suggest important trends in pollination costs that can currently be tracked with reasonable accuracy. Of particular note is the significant increase in inflation-adjusted cost to rent honey bees per colony since 2006 for Eastern states compared to Western states (see Figure 2a). There are initial indications that this increasing trend in prices may be waning, though it is unclear where costs will go moving forward. This observed real price increase for seasonal honey bee rental costs runs contrary to the views of most growers who

responded to the 2022 Northeast Apple Growers Survey that pollination costs have stayed the same or declined over the last 10 years (see Figure 2b).

[Place Figure 2 here]

What Pollination Strategy Should Apple Farmers Use?

Recent data and research strongly suggest that wild pollinators are more effective than managed pollinators (such as honey bees) at providing reliable and complete fruit set in apples and other crops (Garibaldi et al., 2013; Blitzer et al., 2016; Park et al., 2016; Russo et al. 2017). The available data and anecdotal evidence clearly indicate there are apple operations that are doing quite well without renting honey bees, with the likely implication that they are relying on local wild stocks of pollinators (Kahlke, 2019; Biltonen, 2020; Wilcox et al., 2024a; Wilcox et al., 2024b). Other work by entomologists has suggested that apple production may be pollination-limited in some settings (Reilly et al., 2020).

Especially for farms with sufficient local wild pollinators, given the pollination efficiency and production benefits of wild pollination, and given rising costs for honey bee rental, there may be value in working to enhance the habitat for wild pollinators to benefit farm operations. Some examples of ways to enhance the habitat for wild pollinators include setting aside land for planting wildflower strips, or other natural cover. For farms that may not currently have sufficient wild pollinators for apple production, however, it may be very costly to improve the wild pollination habitat to the point that they are able to rely heavily on wild pollination.

The optimal pollination strategy for a given apple farmer may depend on very local conditions, however. If sufficient wild pollinators are present, it may be unnecessary to use

managed pollination. On the other hand, in many cases wild pollination stocks may be insufficient to even consider such a strategy. Moreover, according to data from the 2007 USDA ARMS, apple farmers who rent honey bees have higher yields on average than those who do not rent bees (Figure 3). In other cases, a mixed strategy may be wise whereby apple growers make investments in local wild stocks but continue to rely on managed pollination to some extent.

[Place Figure 3 here]

A key factor determining wild pollinator abundance and sufficiency for pollination purposes is likely to be local pollinator habitat. To characterize this dimension, we generated summary data for each respondent to the 2022 Northeast Apple Growers Survey using a sophisticated web-based tool called Beescape that was created by entomologist Dr. Heather Grab and a number of other collaborators to help growers and other stakeholders assess the quality of their landscapes for supporting bees and other pollinators. For each farm/respondent, for the randomly selected apple block that they reported on in the 2022 Northeast Apple Grower Survey, we examined: a map indicating the approximate center of their block; a map of land cover types within a 1-mile buffer around the center of their block; a characterization of the proportion of different land cover types; and a temperature profile for the location. Within a 1 mile buffer around the center of all randomly selected apple blocks from farms sampled in the 2022 Northeast Apple Grower Survey, the most predominant cover types are forest cover and pasture and hay. The farms in the 2022 Northeast Apple Grower Survey vary in the quality of their landscapes for supporting pollinators, and therefore vary in whether they may have sufficient local wild pollinators for successful fruit set without relying on supplementary pollination.

Conclusion

This article uses existing and new data from the US apple sector to better understand farm-level pollination strategies and costs. We find that although US apple farmers seem to predominantly rely on honey bee rental, non-negligible proportions of growers seem to rely solely on wild pollination. Apple farmers in Eastern states also use pollination more intensively at the block level. We also show that apple pollination costs have risen substantially in the last 15 years or so for farmers in Eastern states, but less so for farmers in Western states.

Many apple farmers are likely making very good pollination input decisions based on hard-earned knowledge gleaned from many years of on-farm experimentation. Other farmers may also be engaged in less than optimal use of pollination resources based on conventional wisdom, which may translate into negative impacts to yield and profits, or negative impacts to the broader local environment. For example, results from a recent farm-level survey of UK farmers showed significant variation in interest and understanding of the impact of pollinators on commercial crops, and many respondents did not consider they had a pollinator deficit in terms of crop quality, quantity, or financial impacts (Fraser, Fountain, and Holland, forthcoming). As pollination costs are rising for the apple sector, honey bees as "cheap insurance" may not remain as cheap as they have in the past, apple farmers may find value in thinking carefully about pollination now and in the future. Moving forward, it seems important that economists remain engaged in these issues to provide apple farmers, and pollination-dependent agriculture broadly, with better information to inform farm-level pollination decisions.

For More Information

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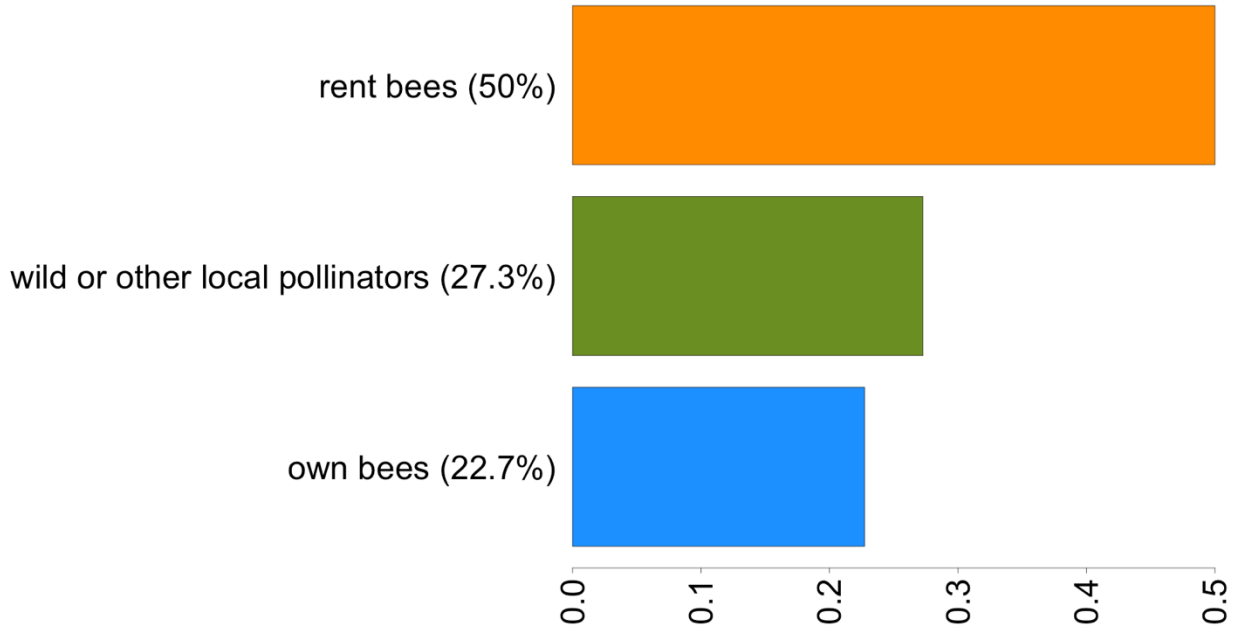
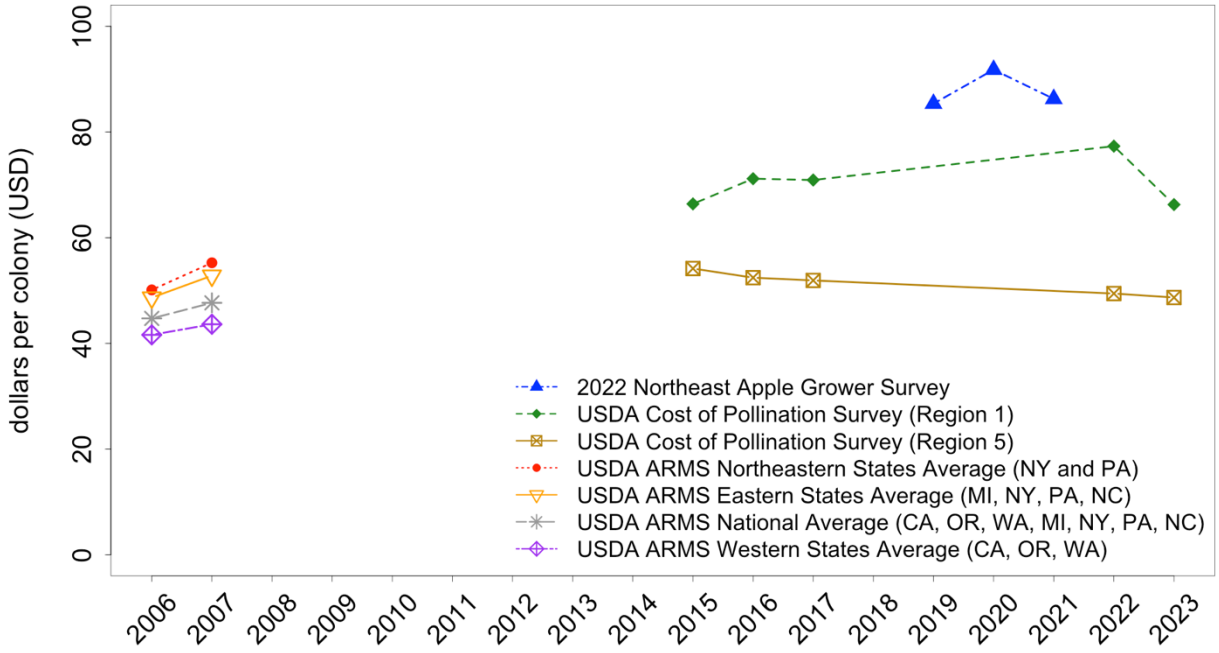
***Figure 1*. Pollination Strategies of Respondents to the 2022 Northeast Apple Grower Survey.**



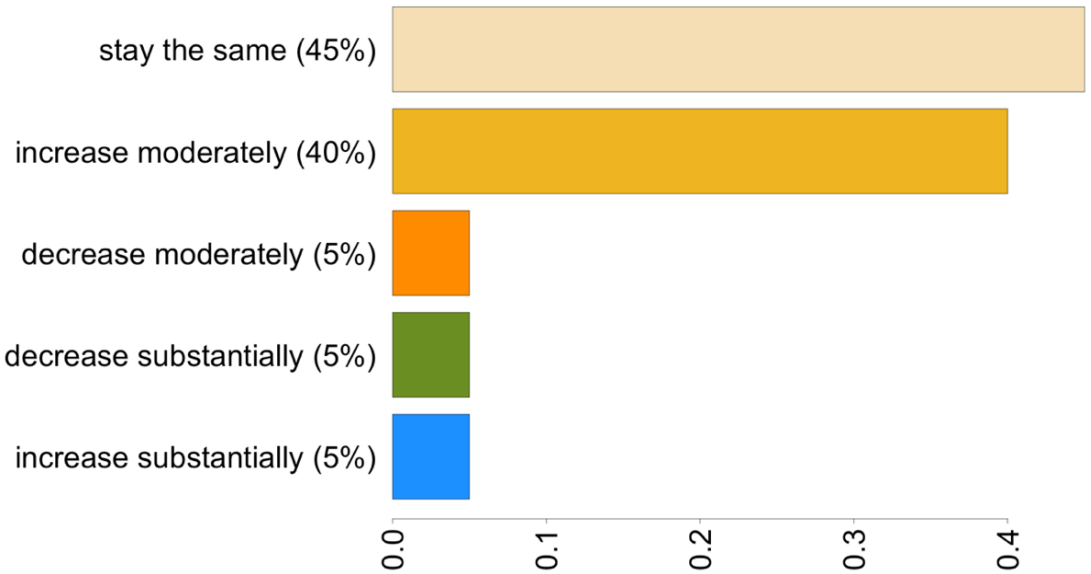
Source: 2022 Northeast Apple Grower Survey.

***Figure 2*. Actual and Perceived Trends in Pollination Costs.**

(a) Trends in the real cost of honey bee rental spanning 2006 – 2023.

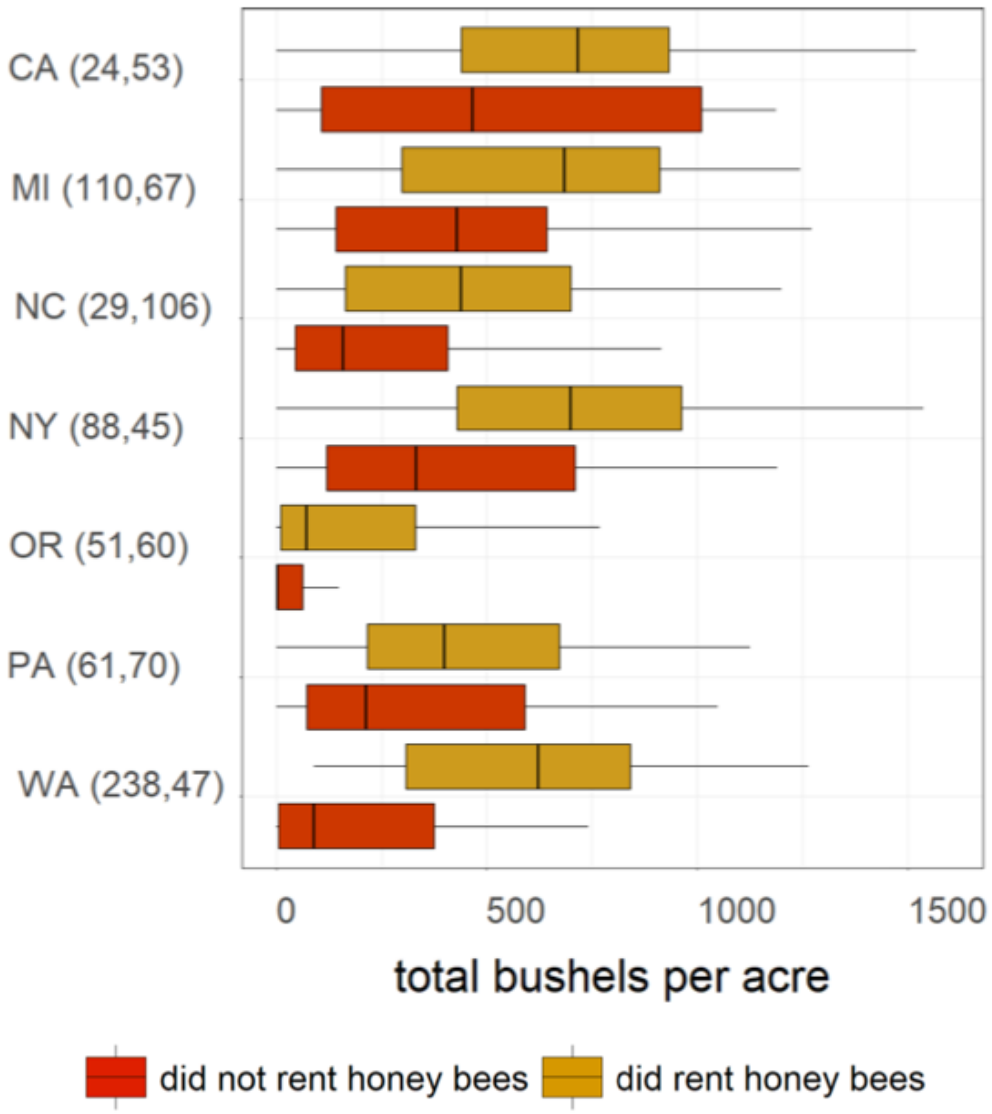


***(b)* Perceptions of respondents to the 2022 Northeast Apple Grower Survey regarding how pollination costs have changed over the last 10 years.**



Note: Costs are adjusted for inflation using a price deflator from the US Federal Reserve.
Source: 2007 USDA ARMS; 2022 Northeast Apple Grower Survey.

Figure 3. **Apple Yield by Pollination Strategy (2007 USDA ARMS).**



Notes: Figure shows a weighted boxplot for total apple yield in bushels per acre by state and by whether an apple farmer rented honey bees or not. Numbers in parentheses indicate the sample size per state, broken down by the number who reported renting honey bees and the number who reported not renting honey bees. For example, WA (238, 47), indicates that, of the apple farmers sampled in Washington State, 238 reported renting honey bees, while 47 reported not renting honey bees. *Source:* 2007 USDA ARMS.