Exploring The Determinants Of Rising Almond Pollination Fees

In The United States

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Senior Thesis

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1. Introduction

1.1 The Honeybee's Role Within Agriculture

Despite our long affiliation with the black and yellow insect, our understanding concerning the importance of the honeybee, aside from honey production, has developed only recently. Insects play a pivotal role in the cross-pollination of fruit bearing plants, and today honeybees are considered one of the most important pollinators of our agricultural sector. Honeybees are in fact so vital to the production of certain crops that farmers willingly hire beekeepers to place colonies on their land so that the pollination of their fields will be guaranteed. Over the last ten years, pollination fees received by beekeepers for their services have increased at an unprecedented rate, but there has not been any empirical work done explaining the motivation behind these increases. This paper focuses on explaining the determinants of rising fees associated with the pollination of the almond crops in California. Although this study is limited to a single crop type, the rising pollination fees for almonds may have a direct impact on the productive capabilities of other agricultural crops that rely on bees for pollination.

For those who may be new to the subject of beekeeping, a brief history of the evolution of the industry may be helpful. Apis mellifera, commonly known as the European honeybee, was not indigenous to the Americas. Early records show that Virginia was the first state to import honeybees in 1622, and the honeybee population gradually spread throughout the continent in the 18^{th} and 19^{th}

centuries.[1] North America does possess a small feral bee population comprised of solitary bees, such as bumblebees and leafcutter bees, but the social behavior of these bees differs significantly from that of the honeybee. A single honeybee hive can home upwards of 30,000 to 60,000 members while solitary bees congregate in the low hundreds. Honeybees were originally brought to North America for honey production, but inadequate technology made extracting honey an arduous task. However, L.L. Langstroth's invention of a specialized hive in 1852 revolutionized honey production and enabled the industry to prosper.[2] Honey production has since been viewed as the predominant function of the beekeeping industry, but honeybees perform a far greater service to the U.S. economy than simply supplying it with honey.

In order to produce honey, a honeybee will travel up to two miles away from its hive in search of nectar, which is produced by various plants.[3] After gathering nectar, the bee brings it back to the hive where it is then converted into honey by other bees. During the process of collecting nectar, honeybees contribute to the pollination of flowering plants by performing crosspollination: the carrying of pollen grains from one plant to the next. Although not all plants require cross-pollination, a vast majority of the fruits and vegetables we eat must be cross-

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[1] U.S. Department of Agriculture, *The U.S. Beekeeping Industry* (Washington, DC: GPO, 1992), 1.

[2] Donald Barrett Wooten, "The Economics of Beekeeping" (PhD diss., University of California, Davis, 1987), 34.

[3] Zachary Huang, *MSU BeeBase*, Michigan State University, http://www.cyberbee.net/

pollinated in order to reproduce. The various plants requiring cross-pollination from honeybees are show in Table 1.[4] Notice in Table 1 that many of the plants are highly dependent upon the honeybee for crosspollination: some almost exclusively. Although honeybees are not the only plant pollinators, they are much more effective than any other pollinator. Due to their large colony numbers and foraging abilities, honeybees guarantee the pollination of plants in a two mile radius surrounding their hive: a feat unmatched by solitary bees, moths, bats, birds, and even weather forces.[5]

Charles Darwin unveiled the importance of pollination to flowering plants in "The Origin of Species," but it was not until after WWI that honeybees were recognized as the "principal agents of crosspollination."[6] To demonstrate the distinction between using honeybees as opposed to natural pollinators, A.H. Hendrickson created an experiment where he encapsulated a prune tree and a hive of honeybees within a mosquito net during the tree's bloom cycle.[7] As a result, the tree produced five times more prunes than the average tree in the orchard and even needed braces on its limbs to prevent them from breaking under the sheer weight of the fruit.

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[4] Nicholas W. Calderone and Roger A. Morse, "The Value of Honeybees As Pollinators of U.S. Crops in 2000," *Bee Culture*, 2000, 8.

[5] Wooten, The Economics of Beekeeping, 20.

[6] Ibid., 51.

[7] Ibid., 55.

As literature about using honeybees for crop pollination spread, commercial pollination services grew. Renting bees for pollination was first documented in New Jersey in 1909, but other factors indicate that these services first became established in California.[8] By 1919 the value added to increased crop yields from honeybee pollination was "many times greater than that of honey and beeswax" produced in the U.S.[9] Wooten states that, "Although commercial pollination was a relatively new practice, it was already widespread by 1923."[10] This shift from solely producing honey and honey related products to offering pollination services to farmers was an important advance in the evolution of the beekeeping industry. Most of the beekeepers providing pollination services were large-scale operators who "located their hives in agriculturally well-developed areas not for the honey, but for the pollination fees".[11]

In comparison to its relatively simple origins, the beekeeping industry within America today is a complex, interrelated organization. A graphical display of all encompassing parts of the industry can be seen in Figure 1.[12] There are currently three distinctive categories of beekeepers: hobbyists, part-time, and full-time. Full-time beekeepers produce about 60% of the domestic honey supply and provide pollination services for the vast majority of crops. These individuals are primarily

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[8] Ibid., 60.

[9] Ibid., 81.

[10] Ibid., 64.

[11] Ibid., 93.

[12] U.S. Department of Agriculture, *The U.S. Beekeeping Industry*, 6.

located in California and ship their honeybees all over the state at different times of the year. Their movement is dictated by the bloom cycle of the various crops and seasonal conditions. Honey production and pollination services are the predominant sources of revenue for beekeepers today.

The need for honeybees as pollinators in commercially produced agricultural crops cannot be overstated. According to Professor Norm Gary of the University of California, "pollination is as essential to contemporary agriculture as [is] sunlight, water, fertilizer, and pesticides."[13] For the last few years we have been witnessing a steady rise in pollination fees for various crops, and Daniel A. Sumner and Hayley Boriss at the University of California have been key in identifying this rising trend.[14] However there has not been any empirical research investigating the root causes of the rising fees. The following research is meant to uncover the determinants of rising pollination fees within the U.S. almond crop, and it is hoped that this research may one day be extended to all crops utilizing honeybee pollination services.

1.2 Why Almonds?

Data for pollination fees received by beekeepers from various crops is limited and for the most part unavailable. A few state beekeeping associations do collect survey data from their members concerning hives reared, honey produced, and pollination fees received throughout the year, but these figures are neither

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[13] Wooten, The Economics of Beekeeping, 164.

[14] Hayley Boriss and Daniel A. Sumner, "Bee-conomics and the Leap in Pollination Fees," *Journal of Agricultural and Resource Economics Update* 9, no. 3 (2006): 10.

aggregated nor standardized for the entire nation. The California State Beekeepers Association has graciously provided survey data of pollination fee trends within the state for different crops, and this paper makes use of this data. Please note that this data is not publically accessible, and any replication of these figures should not be undertaken without explicit permission from the California State Beekeepers Association. Since this paper makes use of statistics from California alone, justification for why California should be considered a representative of aggregate almond pollination fees must be given. For instance, fees paid to beekeepers for apple pollination in California may differ from fees paid to beekeepers on the East Coast. A regression using apple pollination fee trends solely from California while ignoring other locations will contain sampling error. Fortunately this error can be avoided by focusing on one particular California crop, namely the almond crop.

The most important characteristic of California's almond crop is that it accounts for more than 99 percent of total U.S. production of almonds. In other words, the U.S. almond crop is located exclusively within California.[15] Without exclusivity, the issue of sampling error will not be addressed and any regression statistics utilizing this data will be biased. Another important attribute of the almond crop is that it is completely dependent upon honeybee pollination for commercial production, which can be seen in Figure 1. As a representative of

[15] Wooten, The Economics of Beekeeping, 128.

Farmer's International, a California almond producer, put it, "No bee, no crops."[16] Currently almond growers hire nearly 2/3 of all domestic honeybee colonies to meet their pollination needs. This means that virtually all of the commercial pollinators within California as well as beekeepers from out of state are hired to pollinate the almond fields. Additionally, the almond-producing sector pays more in pollination fees to beekeepers than any other agricultural producer within the U.S.

2. Variables of Interest

2.1 The Honeybee Population

In order to develop a regression model, we must consider the various independent variables that may influence almond pollination fees. By looking at the honeybee population from a labor economics perspective, it can be shown why this variable should be included in the model. Almond crops are completely dependent upon honeybee pollination in order to be produced commercially, and it is a well-established practice that one acre of almonds needs at least one, preferably two bee hives to be adequately pollinated.[17] By establishing a supply-demand analysis concerning fluctuations in the availability of honeybees for pollination services, the importance of the honeybee population with respect to pollination fees can be observed.

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[16] Representative of Farmer's International Inc., telephone communication, December 2, 2009.

[17] S.E. McGregror, *Insect Pollination of Cultivated Crop Plants*, United States Department of Agriculture, http://gears.tucson.ars.ag.gov/book.

Looking at Figure 2, the X-axis is labeled as the "Quantity of Honeybees Available for Pollination," and the Y-axis is labeled as "Pollination Fees." The Labor Demand Curve is representative of the almond farmers' collective demand for honeybees given different levels of fees they are willing to pay. It is assumed that this demand is highly inelastic, because a farmer will not plant an almond field if she/he cannot hire a hive of bees to pollinate it. The Labor Supply Curve represents the amount of hives that beekeepers rent out for pollination purposes. As pollination fees paid by farmers to beekeepers rise, beekeepers will be more willing to dedicate a greater proportion of their hives to almond pollination. Given an initial equilibrium A, labor supplied by beekeepers is equal to the labor demanded by farmers. At this equilibrium, almond farmers will pay a wage of X, and beekeepers will supply Q hives for pollination. However, holding the demand for labor constant while allowing for changes in the amount of labor supplied will have consequences on pollination fees.

For instance, say there is a dramatic decrease in the availability of honeybees; a negative supply shock to the honeybee population. This shock will cause the labor supply curve to shift leftwards establishing a new equilibrium at B. This new equilibrium will result in a higher fee X' paid out by almond farmers and a corresponding smaller quantity of honeybees available for pollination Q'. The reason for this shift from A to B is due to less hives being available for hire and farmers competing against one another for hives to pollinate their fields. Pollination fees paid to beekeepers will subsequently be bid up to a new, higher wage and this equilibrium will be higher than the original. This scenario can also be reversed given a positive labor supply shock to the honeybee population, but the importance within this analysis is seeing that the honeybee population has a role in determining pollination fees.

There is evidence that the honeybee population has suffered a series of negative shocks in recent years. Mites, large winter die-offs, diseases, and even the recently witnessed Colony Collapse Disorder (CCD) have had devastating impacts on the honeybee population. There has been much media coverage on CCD, and some of its effects are quite alarming. For example, beekeepers expect a certain percentage of their hives to die off every year, and this percentage normally ranges within the teens to the lower twenties. However, CCD has been responsible for mortality rates ranging above 60%, which has been detrimental to beekeepers operating large operations.[18] So if there have been a steady progression of negative supply shocks to the beekeeping industry, it seems changes in the honeybee population may be a culprit in raising pollination fees. Some researchers have already made this assumption by claiming, "commercial beekeepers, crunched by huge bee losses, have boosted the fees they charge farmers to rent honeybees."[19]

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[18] Dennis VanEngelsdorp and Jerry Hayes and Jeff Pettis, *Preliminary Results: A Survey of Honey Bee Colonies Losses in the U.S. Between September 2008 and April 2009*, http://maarec.psu.edu/pdfs/PrelimLosses2009.pdf.

[19] Linda A. Johnson, "Shortage of Honeybees and Hives Creates A Buzz," *Philadelphia Inquirer*, March 6, 2006, sec. B.

2.2 Honey Prices

Beekeepers have to choose whether or not to rent their hives for almond pollination services or to use them for honey production i.e. there is an opportunity cost for pollinating almonds. When a beekeeper makes the decision to rent her/his hives out for almond pollination, the beekeeper foregoes any ability to produce saleable honey. In general, pollination services negatively effect honey production due to the manner in which hives are arranged in the field being pollinated. Hives dedicated to honey production enjoy wide, open fields of high nectar yielding plants. However, hives dedicated to pollination services do not enjoy this spatial freedom and are instead compacted into much smaller areas. The close grouping during pollination insures farmers adequate and abundant pollination for their crop.

When hives are grouped at such close proximity to one another, they compete for valuable nectar resources needed for honey production. Pollinating fruits such as oranges and blueberries provide more nectar to hives than other crops, and hives can sometimes produce surplus honey from them.[20] But almond crops differ in that they provide very little nectar for honey production. Often times colonies dedicated to almond production must be supplemented with "fake honey" or corn syrup in order to survive the grueling honey shortages that come from time spent in almond fields.[21] Therefore, one of the costs incurred by beekeepers when

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[20] Hayley Boriss and Daniel A. Sumner, "Bee-conomics," 9.

[21] Representative of Farmer's International Inc., telephone communication, December 2, 2009.

renting hives out for almond pollination is the foregone honey that could be sold in the market. According to Wooten, "The critical point occurs after the beekeepers have "saturated" a locale such that the cost of adding one additional hive is either less than the value of the increase in the total net yield of honey. In order to induce the beekeeper to bring in more colonies than this, some form of compensation, usually a rental fee, is required."[22]

We would expect that if honey prices were to increase, there would be a higher opportunity cost for the beekeeper to pollinate almond fields since they are giving up potential profit from honey sales. This higher opportunity cost must be reflected in pollination fees, because the fees serve as compensation for missed honey production. This idea is reflected in Wooten's statement, "For most crops requiring commercial pollination, the rental fee is roughly equivalent to the opportunity cost of the forgone honey production."[23]

Similar to the analysis given above concerning changes in the honeybee population, changes in the price of honey can be shown to influence the labor supply of hives dedicated to pollination services. In Figure 3, the first graph depicts the first equilibrium witnessed earlier. Labor supply is equivalent to labor demand at A, which establishes an equilibrium fee X paid to beekeepers with a quantity Q of hives supplied for pollination services. The second graph represents the labor market for honey in equilibrium at C, where the quantity of hives dedicated to honey

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[22] Wooten, The Economics of Beekeeping, 150.

[23] Ibid., 151.

production is Q* and the price received for produced honey is X*. If labor demand is held constant in both markets, we can witness how labor supply is affected by differences in honey prices and pollination fees.

If the price paid for honey production is greater than the fees paid for pollination services (X*>X), there will be an arbitrage situation. Beekeepers who originally dedicated their hives for pollination services now choose to move their hives into honey production since they can receive higher wages in the honey market. As a result the new equilibrium in the pollination market will move from A to B. This movement is caused from a leftward shift in the labor supply curve for pollination fees since beekeepers choose to stop pollinating and switch to honey production. As beekeepers leave the pollination service market, less beekeepers are available to hire for pollination services and pollination fees subsequently rise since almond farmers try to retain beekeepers to pollinate their crops. At the same time, the exodus out of pollination services results in an influx of beekeepers into the honey market, causing a rightward shift in the honey market's labor supply curve. The supply of honey production labor exceeds demand, and the prices paid for honey production fall.

The new equilibrium in the pollination market results in fewer beekeepers employed and higher fees paid for pollination. By contrast, the new equilibrium in the honey market at D results in a higher quantity of beekeepers employed for honey production and a lower price received for the honey they produce. This process will continue until wages are equalized over the two markets. This process could be reversed if the initial condition stated that pollination fees paid by farmers were higher than wages paid for honey production. Therefore, discrepancies in the price paid for honey and the fees received for pollination services can have a direct impact on determining pollination fees. Another illustration of this analysis can be seen in a One Sector-Two Good Trade Model, which is shown in Figure 4.

2.3 Almond Crop Acreage

Almond crop acreage is a crucial variable to include as a determinant of almond pollination fees, because this crop is solely dependent upon bees for production. According to Dan Sumner, "On the demand side, the main driver [of pollination fees] has been the expansion of acreage of almonds, the crop most dependent on honeybee pollination."[24] If a farmer adds additional almond acreage to her/his operations, then the farmer's demand for honeybee pollination increases in step with the added acreage. In other words, there is a 100% correlation between changes in almond crop acreage and demand for honeybee pollination services. For example, if a farmer has 100 acres of almonds, then she would need to hire 200 beehives in order to adequately pollinate her crop; otherwise acres without hives would be barren. If she increased her almond acreage to 200 acres, then she would need to hire 400 beehives and so on. This direct relationship indicates that if almond acreage increases, demand for pollination services must also increase, which in turn would have a positive effect on pollination fees. This change in pollination fees can be seen in Figure 5.

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[24] Hayley Boriss and Daniel A. Sumner, "Bee-conomics," 10.

The difference between the changes in fees in this model as opposed to the previous ones is that the new equilibrium in Figure 5 is a result of a shift in the labor demand curve, not the labor supply curve. Starting at the initial equilibrium A, the quantity of hives for pollination Q is hired at pollination fee X. If farmers add almond acres to their current operations, they will also have to hire additional hives to pollinate them. Holding labor supply constant, this increase in acreage shifts the labor demand curve to the right, because total production requires more hives. This rightward shift in the labor demand curve establishes a new equilibrium at B. Not only does this shift increase the number of hives hired for pollination, but it also increases the pollination fees paid to beekeepers. Applying the same logic, if acreage was instead decreased, the resulting equilibrium would leave the number of hives hired for pollination as well as the fees paid to beekeepers lower than they were at A.

2.4 Transportation/Input Costs

Recall that not all hives providing pollination services to the almond fields are located in California. Out-of-state beekeepers often have to ship their hives hundreds of miles in order to get them to California's almond fields, and even in-state beekeepers have sizable transportation costs. Information concerning the number of hives being shipped from different locations is unavailable, although migratory paths have been documented for in-state transportation. The migratory patterns for California beekeepers are depicted in Figure 6.[25] Besides California beekeepers, almond farmers hire additional beekeepers from areas such as North Dakota. Although labor fees associated with packing and transporting the hives may differ over regions and beekeepers, a transportation cost shared by all beekeepers is the cost of fuel. Pollination fees would necessarily have to cover transportation costs otherwise there would be no incentive for beekeepers to move their hives. For instance, if it costs a beekeeper $20 per hive to transport her bees roundtrip, but she receives $15 per hive for pollination services, she has invariably lost $5 per hive (not including foregone honey she could have produced for sale during this time).

In practice, individual contracts between farmers and beekeepers are settled after the pollination process so that these costs may be accounted for. By observing deviations in fuel prices within the model, a better understanding of the importance of transportation costs in determining almond pollination fees may be observed. Similarly, a direct input that should be covered within the pollination fees is the cost of high fructose corn syrup. As was stated earlier, hives dedicated to almond pollination need to be supplemented with corn syrup, and this cost passes directly to the farmer once pollination services are rendered.

2.5 Crop Type

Although a variable for crop type is not used within the proposed model below, it should be included for further work on this subject when dealing with

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[25] Wooten, The Economics of Beekeeping, 131.

other crops. Since some crops enable bees to produce honey while pollinating, the fees received from pollinating these crops should be lower. This statement is driven by the opportunity cost argument given above. In the case of almond pollination, almond blossoms do not provide adequate nectar for the hives to survive on. In addition, any honey produced from almond pollination is unpalatable to humans, making it unmarketable.[26] However, other crops such as blueberries and oranges provide enough nectar for hives to produce excess honey reserves. This means that beekeepers not only receive a fee for pollinating, but they may also market the honey produced from these crops. Since the opportunity cost of pollinating these higher nectar-producing fields is lower, it should be expected that pollination fees would be lower. Wooten puts it best by saying, "For crops which are both very attractive to honeybees, and benefit little from their presence, the grower [or farmer] may well charge the beekeeper an apiary fee. While this fee sometimes is simply the rental value of the land itself, more often it represents a contract for access to a valuable and restricted source of nectar."[27] This variable is not applicable to this model since all honey production is foregone when pollinating almonds; this is why honey prices do not have to be discounted in the model. Nevertheless, this variable should be considered for crops that benefit both farmer and beekeeper, because data "indicate that the average fee for pollination services

[26] Hayley Boriss and Daniel A. Sumner, "Bee-conomics," 11.

[27] Wooten, The Economics of Beekeeping, 154.

on valuable honey crops is about 50 percent below the fee for crops that do not provide nectar valuable for honey."[28]

3. Empirical Implementation

3.1 The Model

The model given below represents the original contribution of this paper and may serve as a starting point for future research concerning the determinants of pollination fees in other honeybee dependent crops. Justification for the use of specific data as a representative of the variables discussed above follows. The model states that almond pollination fees are dependent upon the overall honeybee population, honey prices, almond crop acreage, gasoline prices, and high fructose corn syrup prices.

$$\text{Almond Pollination Fee} = C + \beta_1 \text{(Honeybee Population)} + \beta_2 \text{(Honey Prices)} + \beta_3 \text{(Almond Crop Acreage)} + \beta_4 \text{(Gasoline Prices)} + \beta_5 \text{(High Fructose Corn Syrup Prices)} + \varepsilon$$

3.2 Data Sources

As stated earlier, almond pollination fees have been obtained from the California State Beekeepers Association.[29] This data was gathered by means of a

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[28] Hayley Boriss and Daniel A. Sumner, "Bee-conomics," 10.

[29] California State Beekeepers Association, Inc., *Survey Data to Member Beekeepers*, 2009.

survey to the members of the association from 2000-2008. This means that there are only nine data points available for use in the regression model; the problems associated with this lack of data are discussed in section 3.3.

The survey conducted by the California State Beekeepers Association divides the state into three distinct regions: Kern-Madera, Merced-San Joaquin, and Sacramento-North. Under each region are listed various almond pollination fees including the highest fee, the lowest, and the average fee per hive received by all beekeepers in the area. The number of hive rentals per region is given as well, and by dividing each region's hive rentals by the total number of hive rentals in the state, a weight can be established for each region. By taking the average fee for each region, multiplying it by the region's respective weight, and then adding together the weighted almond fee for each region; we obtain the weighted average almond fee per hive for the entire state. The reason for doing this calculation is due to there being different average fees for each area. This data has been graphed and can be seen in Figure 7.

The data used to represent the honeybee population comes directly from the United States Department of Agriculture's (USDA) yearly figures of the nation's honey producing bee colonies.[30] Even though some hives may not be dedicated solely to honey production, they still produce saleable honey. For instance, a beekeeper dedicating hives to queen bee rearing still produces marketable honey

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[30] United States Department of Agriculture, *Sugar and Sweeteners Yearbook Tables*, http://www.ers.usda.gov/briefing/sugar/data.htm.

even though honey production is not the beekeeper's primary goal. This honey functions as additional income to the beekeeper, and Figure 8 demonstrates how all types of beekeepers receive income from honey production.[31] The USDA chooses not to subdivide beehives according to their intended use but acknowledges that the distinction of honey-producing colonies encompasses all types of hives. This makes the USDA's figures of honey producing colonies a strong representative of the domestic honeybee population, and this data is represented graphically in Figure 9.

The USDA also provides yearly data concerning the market price of honey, and the average world market price (in cents per pound of honey) has been utilized.[32] Since 1950, "The U.S. Government has supported the price of honey…by providing market price stability to honey producers to encourage them to maintain honeybee populations sufficient to pollinate important agricultural crops."[33] However, those price supports and subsidies have been tapered off such that the U.S. domestic price of honey has started reflecting world prices. Although some government programs are still in effect to aid domestic producers, U.S. beekeepers do participate in exporting honey to the world market. The trend of this data can be observed in Figure 10.

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[31] Wooten, The Economics of Beekeeping, 134.

[32] United States Department of Agriculture, *Sugar and Sweeteners Yearbook Tables*, http://www.ers.usda.gov/briefing/sugar/data.htm.

[33] United States Department of Agriculture, *Honey Background for 1995 Farm Legislation*, (Herndon, Virginia: GPO, 1995), 3.

The USDA produces yearly figures for U.S. almond crop acreage and this data is utilized within the regression model.[34] The changes in acreage over time can be seen in Figure 11. In addition, the U.S. Energy Information Administration provides historic data concerning gas price fluctuations.[35] Since beekeepers vary in their choice of shipping method, different types of gasoline can be used. For instance, one beekeeper may choose to move her hives via tractor-trailer, which utilizes diesel fuel, while another beekeeper may move her hives by a vehicle fueled by unleaded gasoline. For this reason, the combined price for all grades and formulations of gasoline was used. Overall trends for all U.S. gasoline prices can be seen in Figure 12. U.S. prices for high fructose corn syrup were taken from the USDA and fluctuations have been graphed in Figure 13.[36]

3.3 Econometric Methods

The econometric method used to approximate the influence the U.S. honeybee population, world honey prices, almond acreage, gasoline prices, and high fructose corn syrup have on almond pollination fees is the simple linear regression model. Since pollination fees are a summation of separate individual costs, the model should be regressed under linear conditions.

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[34] United States Department of Agriculture, *Fruit and Tree Nut Yearbook Spreadsheets Files*, http:// usda.mannlib.cornell.edu/ MannUsda/ viewDocumentInfo.do?documentID=1377.

[35] United States Energy Information Administration, *Retail Gasoline and Diesel Prices*, http://tonto.eia.doe.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm.

[36] United States Department of Agriculture, *Sugars and Sweeteners Yearbook Tables*, http://www.ers.usda.gov/Briefing/Sugar/Data.htm.

There is, however, a point of clarification that needs to be made before any analysis or regression work is performed. As stated earlier, data for U.S. almond pollination fees is only available for years ranging from 2000 to 2008. Unfortunately this lack of data makes the regression results highly questionable, and they should in turn be viewed with an appropriate degree of caution. Ideally we would like to have more historical data so that the regression could be deemed statistically sound, but this simply is not an option. The results that follow are preliminary, and as more data is gathered over time this model may be deemed more or less reliable.

The data used for each variable is regressed for the same year except for honey producing colonies. This variable has been lagged for one year, and the reason for this is due to the timing of almond pollination. Almonds are pollinated at the beginning of the year, specifically February. The amount of hives available for hire in February will depend upon the size of the honeybee population in December of the prior year. If honey-producing colonies were used in the regression for the same year, then the honeybee population calculated at the end of the year would have to remain constant from February to December. Since this is not the case, the prior year's honey producing colonies are used.

The error term is assumed to be normally distributed and independent of the regressors in the equation. Costs not accounted for in the variables but that are encompassed in the error term are labor costs. These are costs associated with individuals moving the hives to the almond fields and maintaining them during the pollination cycle. This data is not available since it constitutes personal income, and it is assumed that labor costs vary for each independent beekeeper. Although labor costs directly influence pollination fees, there is no fundamental basis for assuming labor costs have been increasing at an elevated rate. However, for the sake of argument and sound modeling practice, these costs were taken into consideration.

In addition to running a linear regression on the raw data, a linear regression using the log difference between years has been utilized as well. As seen in the graphical representations of the variables over time, some variables trend alongside each other. Trending is a negative attribute in data, because it biases regression results. If an independent variable and the dependent variable increase over time, this does not necessarily mean that the independent variable is causing the increase in the dependent variable. However, log-adjusted data represents the percentage change in each variable. Regression results become more robust if a percentage change in an independent variable reflects similar percentage changes in the dependent variable. This indicates that not only are the variables moving in the same direction, but they are also changing by the same rate over time. In addition, nominal prices are represented in the almond fees, honey prices, gasoline prices, and high fructose corn syrup prices. Therefore, another regression has been performed using figures adjusted by the Consumer Price Index (CPI).[37]

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[37] United States Department of Labor, *Consumer Price Index*, http://www.bls.gov/cpi/.

3.4 Estimation Results

The regression results for the simple linear model above are shown in Table 2. According to the results, honey prices, bearing acreage, and high fructose corn syrup prices were not statistically significant at the 5% level. However, the intercept term, honey producing colonies, and U.S. all grades and formulations for gasoline prices were significant at this level. On this basis we can drop the statistically insignificant variables and rewrite the model as:

$$\text{Almond Pollination Fee} = C + \beta_1 \text{ (Honeybee Population)} + \beta_2 \text{ (Gasoline Prices)} + \varepsilon$$

The results for the rewritten model can be seen in Table 3. Again, caution must be exercised when interpreting these results since we lack sufficient data. However, examining the signs of the coefficients may provide insight as to whether or not the supply and demand analysis given above was accurate. The coefficient for honey producing colonies is negative, and this sign is what was expected. As honey producing colonies decrease, i.e. the honeybee population falls, there should be a positive influence on pollination prices. It was thought that an increase in gasoline prices would increase contractual inputs. In other words, a rise in gasoline prices would subsequently raise fees paid by farmers in order to cover beekeepers' transportation costs. The positive coefficient for gasoline prices is indicative of this expectation as well.

The regression results for the log difference between years are also consistent with the above analysis (Table 4 shows the results of this regression). Note that the coefficient for honey producing colonies is negative while the coefficient for gas prices is positive: following the expectations of the proposed hypothesis. Looking at the regression results obtained using CPI adjusted data, which are given in Table 5, we find the same relationship.

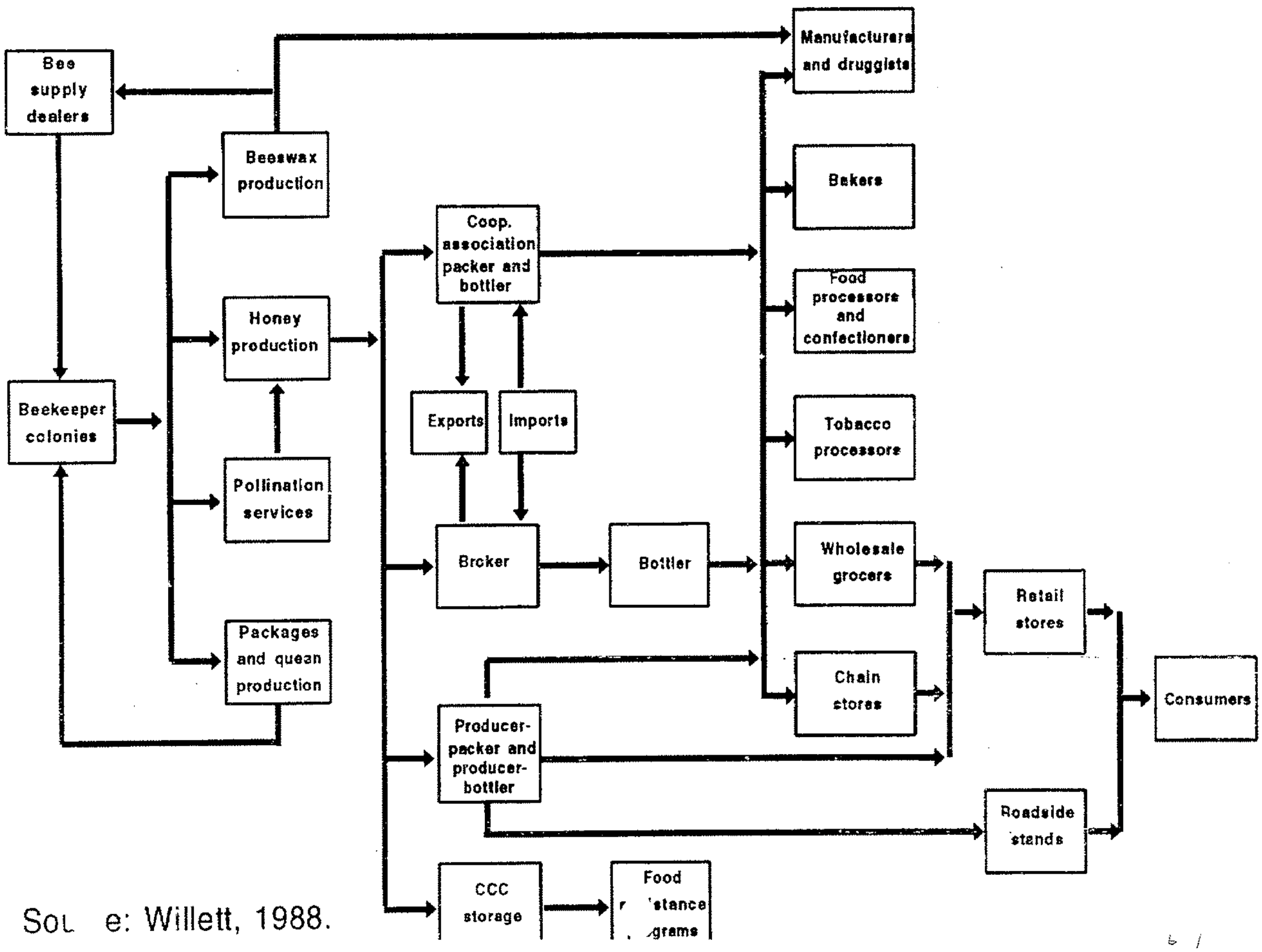
4. Conclusion and Prospects for Future Research

Because of the small amount of time series data available, estimates of the percentage influence of each variable on pollination fees would not be reliable and have therefore not been computed. We can, at best, say there is no empirical evidence so far as to discredit the proposed model. Concluding that the variables have been empirically proven to be causal instruments would be misleading. This paper has instead argued theoretically for the use of certain variables to depict almond pollination fees. The results of the regressions act as preliminary evidence for the use of these variables, specifically the use of honey producing colonies and gasoline prices, to explain current increases in almond pollination fees. This paper also provides a structural basis to question the claims that pollination fees are equivalent to forgone honey production and that increases in crop acreage are the primary determinants of increased pollination fees; there is reason to believe that these factors are not the primary causes for increased fees.

There are many opportunities available for future research in this area of the beekeeping industry. Although this paper has focused on almond pollination fees, there are many other crops in which pollination fees are received by beekeepers. Extending this analysis and model to other crops could prove helpful in determining fees for various crop sectors. The limitations of this research were due primarily to constraints in the data; there was a lack of data concerning historical pollination fees, and a lack of data over various crop sectors. If pollination fees can be gathered for other crops and aggregated, this model can be a starting point for analysis. The variable crop type was not used for the analysis of almond fees, but would be instrumental in crops where beekeepers are able to produce salable honey after providing pollination services. Information concerning how much honey can be obtained from different crops after pollinating would be extremely helpful in future assessment as well.

Appendix

Figure 1: The U.S. Beekeeping Industry



Source: U.S. Department of Agriculture, *The U.S. Beekeeping Industry*, 6.

Figure 2: The Effects Of A Changing Honeybee Population On Pollination Fees

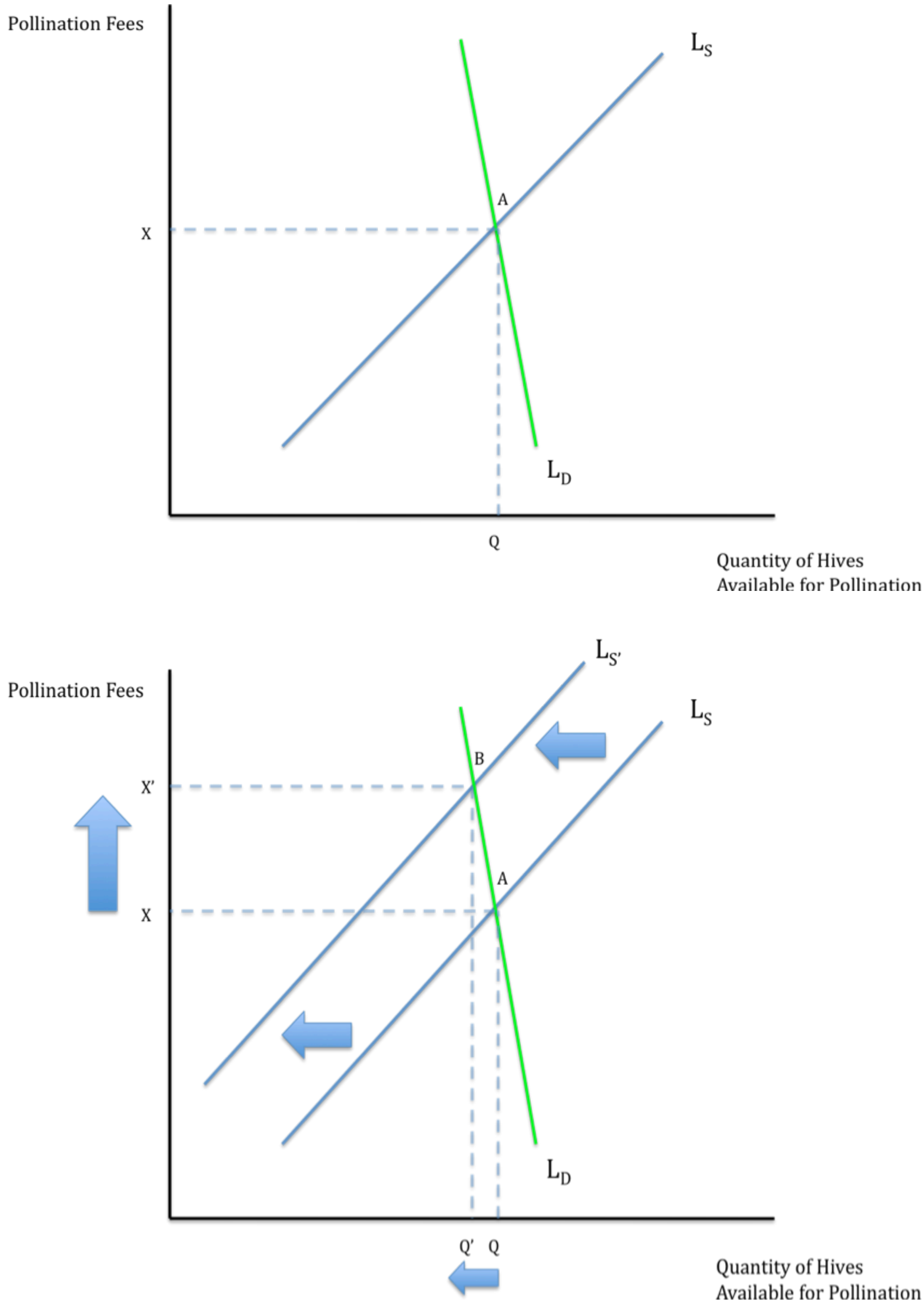


Figure 3: Honey Price Effects On Pollination Fees

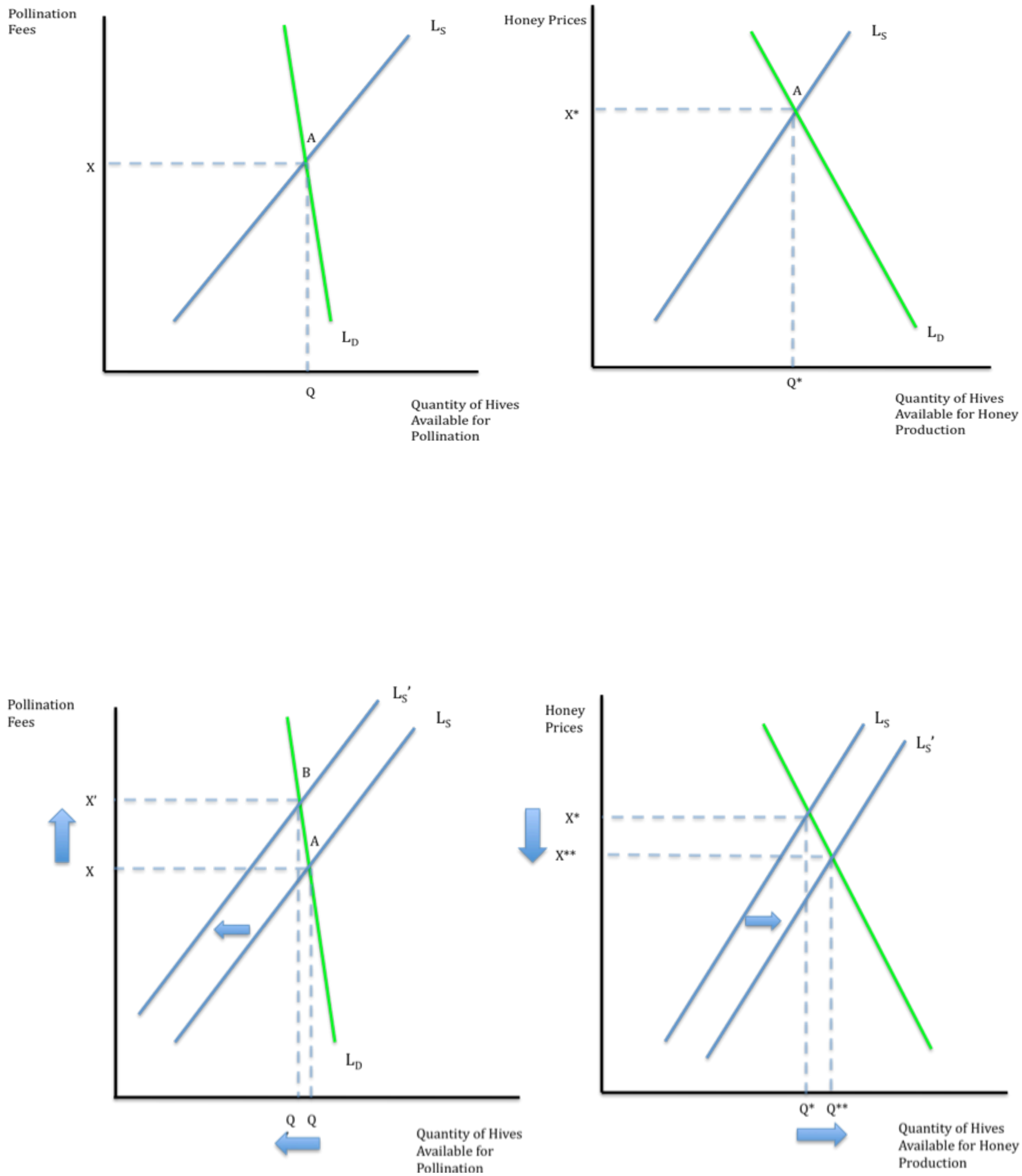
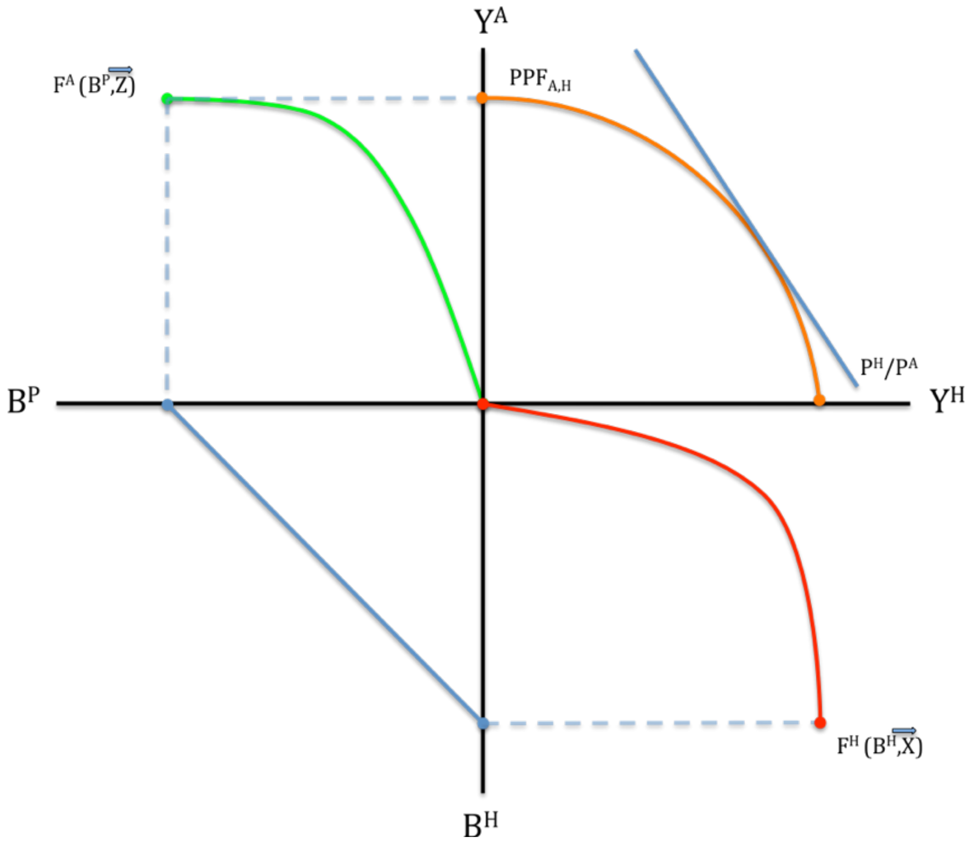
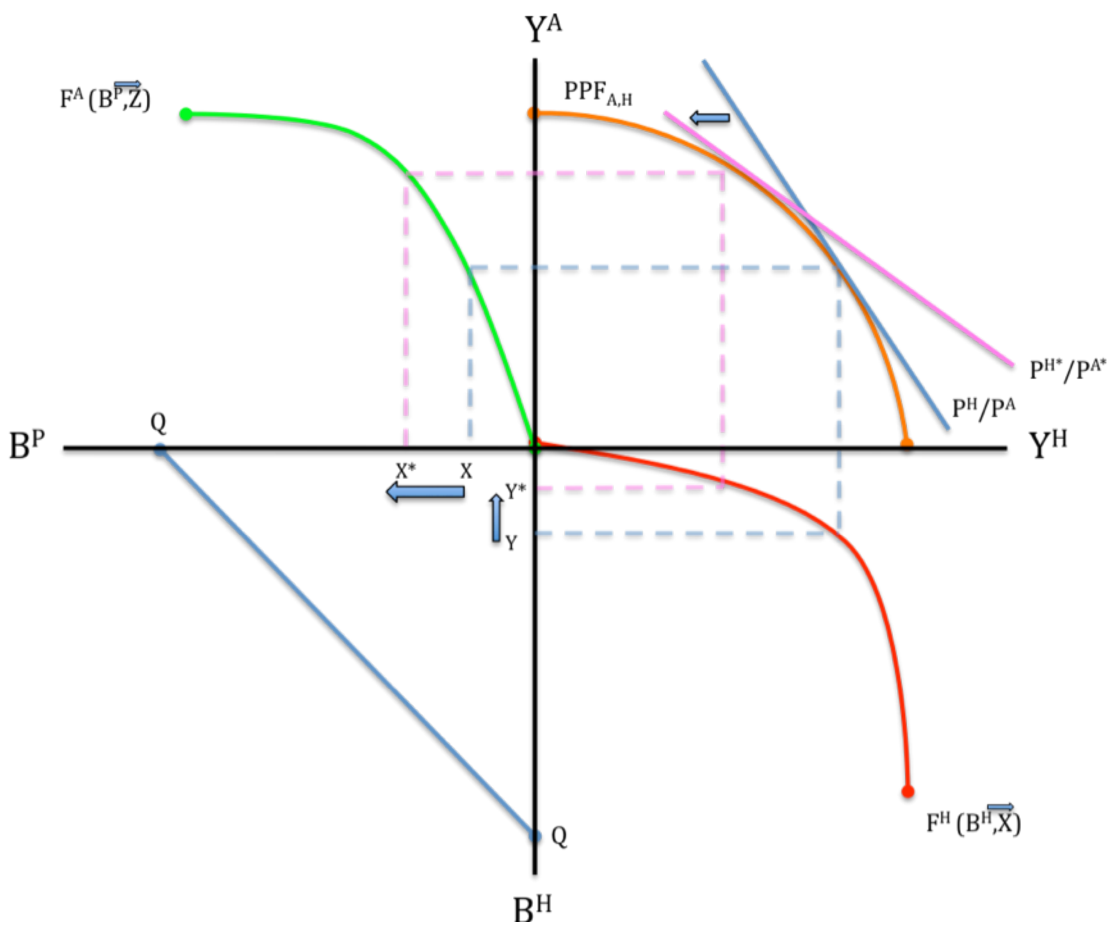


Figure 4: One Sector–Two Goods Trade Model[38]



[38] The axes are defined as: output of almonds (Y^A), output of honey (Y^H), bees in the honey sector (B^H), and bees in the pollination sector (B^P). In the first graph, the bottom left quadrant represents all hives in the economy used for honey production, pollination services, or a combination of the two. When the line intersects B^P, this indicates that all hives are dedicated to pollination services. When the line intersects B^H, this indicates that all hives are dedicated to honey production. The upper left and bottom right quadrants represent the production functions of almonds and honey respectively. Each graph is a function of honeybee hives and a given vector that encompasses various inputs specific to the good being produced. Vector Z and vector X have not been rigorously defined since they are outside the scope of this analysis. Based upon the production functions of the two goods, a production possibility frontier ($PPF^{A,H}$) is established, which is given in the upper right quadrant. The line tangent to the $PPF^{A,H}$ represents the relative price of honey (P^H) to the price of almonds (P^A). When the relative price changes, the slope of the line tangent to the $PPF^{A,H}$ also changes; the second graph depicts this change. Note that the number of bees originally dedicated to pollination were X and those for honey were Y, where Q= X+Y (Q is equal to the total number of hives in the economy). P^{H*}/P^{A*} is less than P^H/P^A, meaning that the relative price of honey to the price of almonds has decreased. Intuitively this means that beekeepers will be enticed to move hives from honey production to almond production since the price of almonds has increased. This is witnessed by following the new tangency point where P^{H*}/P^{A*} intersects the $PPF^{A,H}$ to the production functions of the two goods. At these new levels of production, X* hives will be dedicated to pollination services and Y* will be dedicated to honey production. Note that Q = X* + Y* = X + Y, but X* > X and Y* < Y.



Y^A
F^A (B^P,Z)
PPF_A,H
P^H*/P^A*
P^H/P^A
B^P
Q
X*
X
Y*
Y
Y^H
Q
F^H (B^H,X)
B^H

Figure 5: How Changes In Almond Acreage Influence Pollination Fees

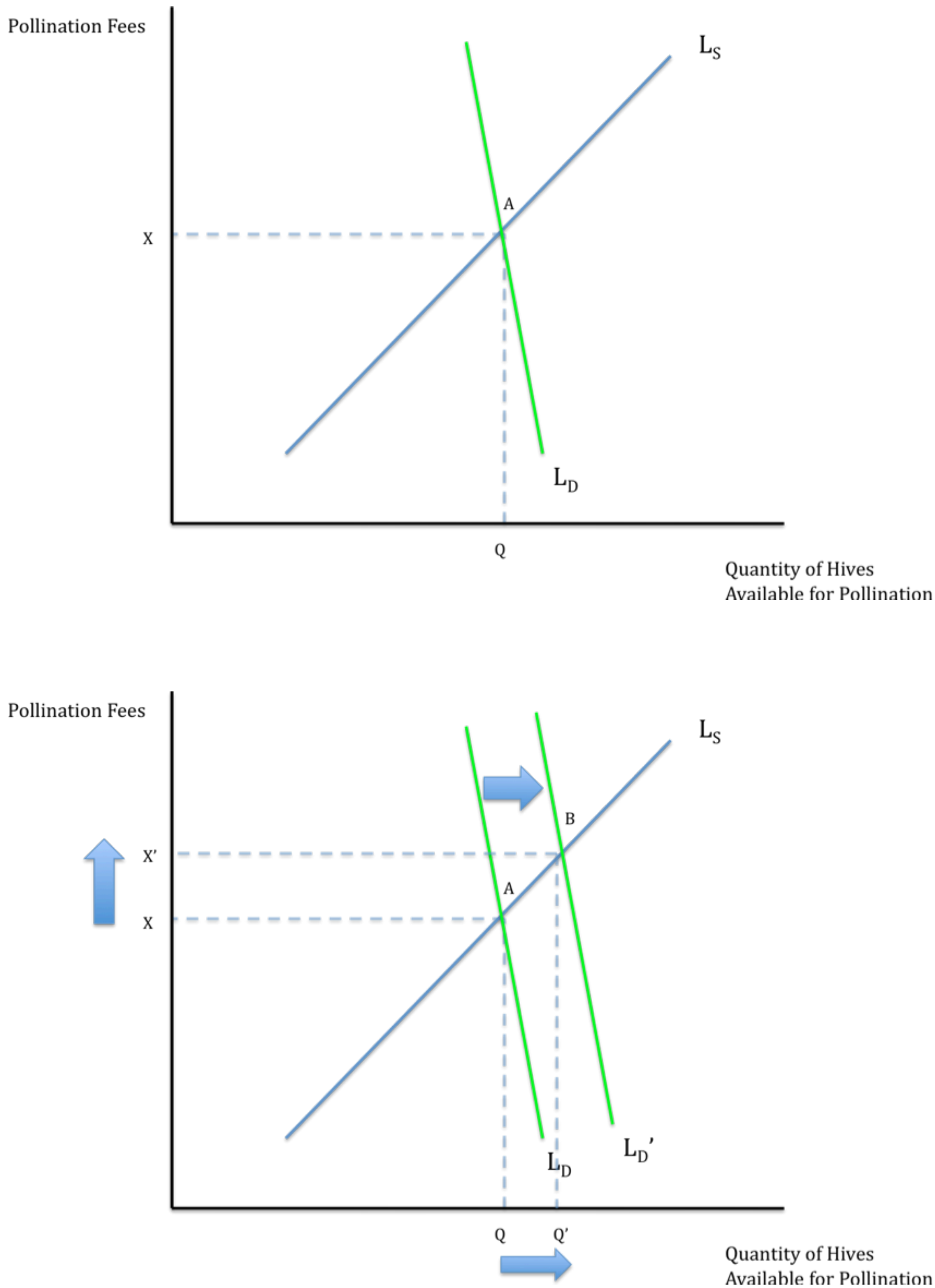
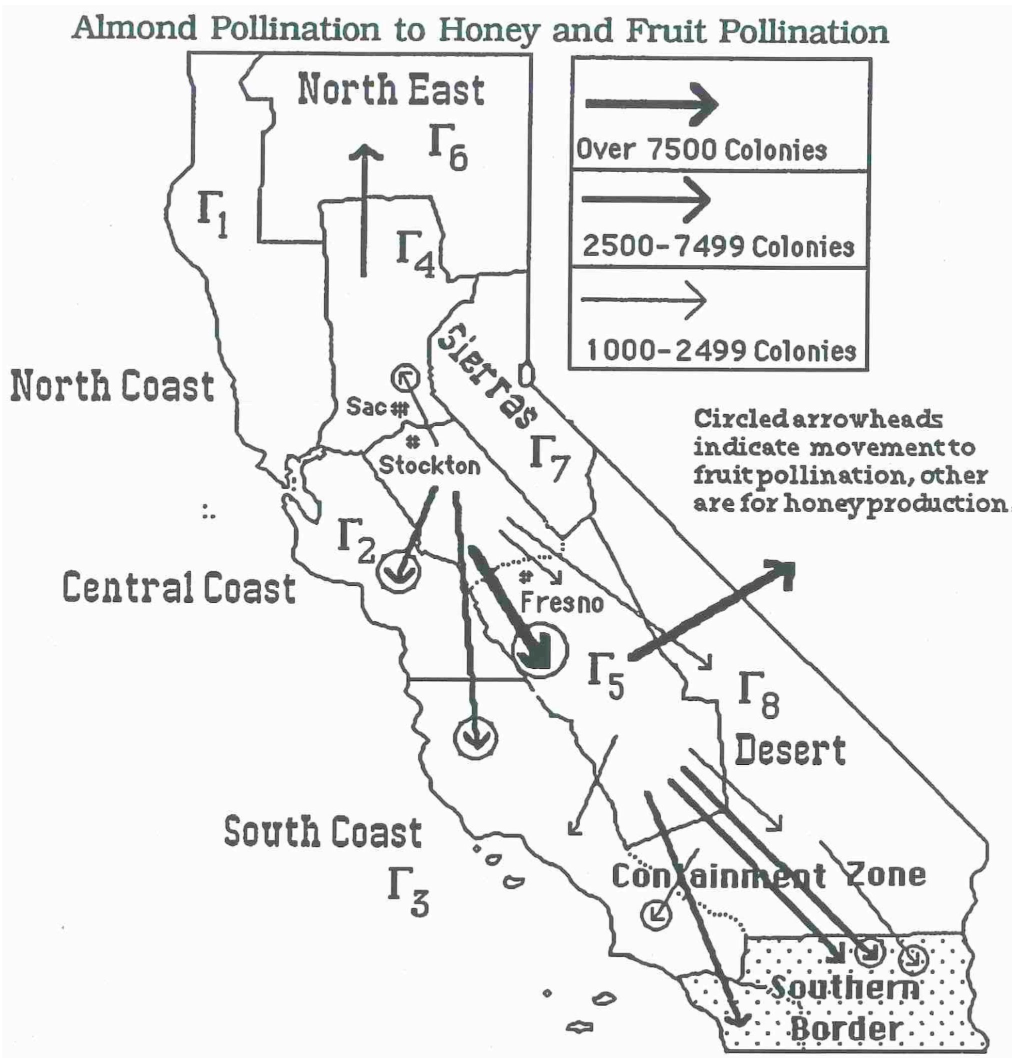
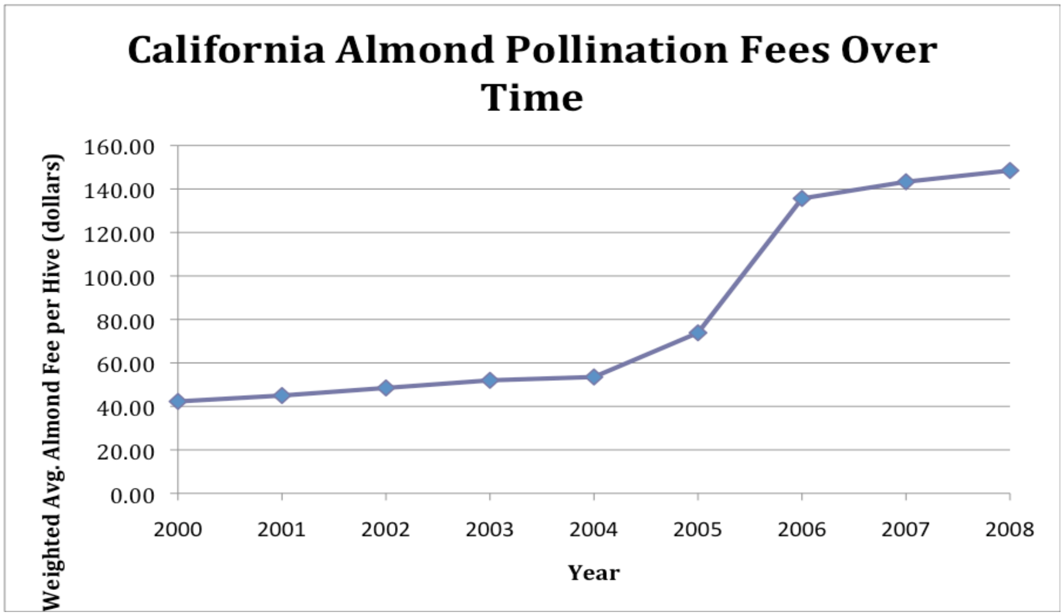


Figure 6: Migratory Paths Of California Beekeepers From Almond Pollination To Honey Production



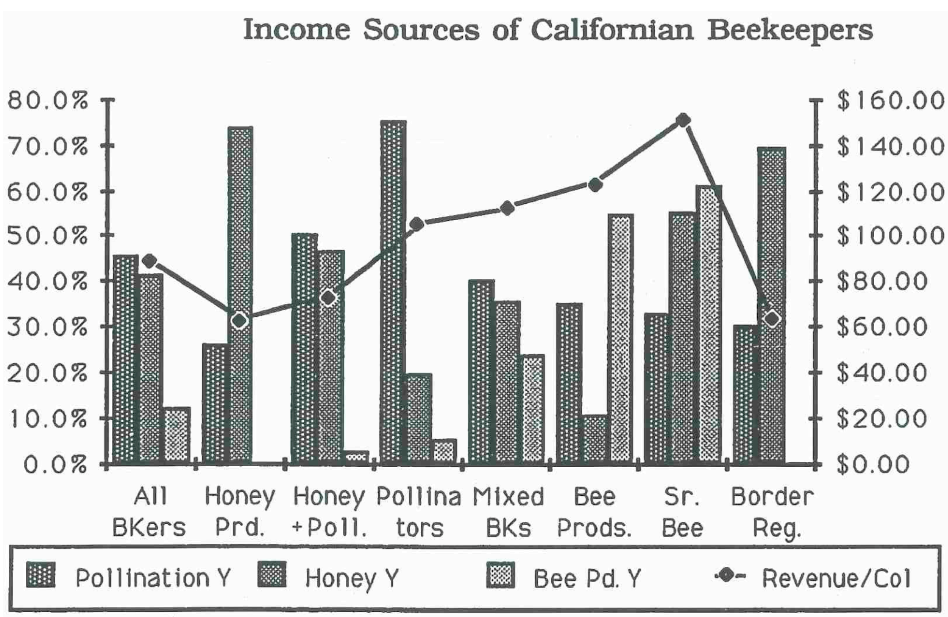
Source: Donald Barrett Wooten, "The Economics of Beekeeping" (PhD diss., University of California, Davis, 1987), 131.

Figure 7: Almond Fees Over Time



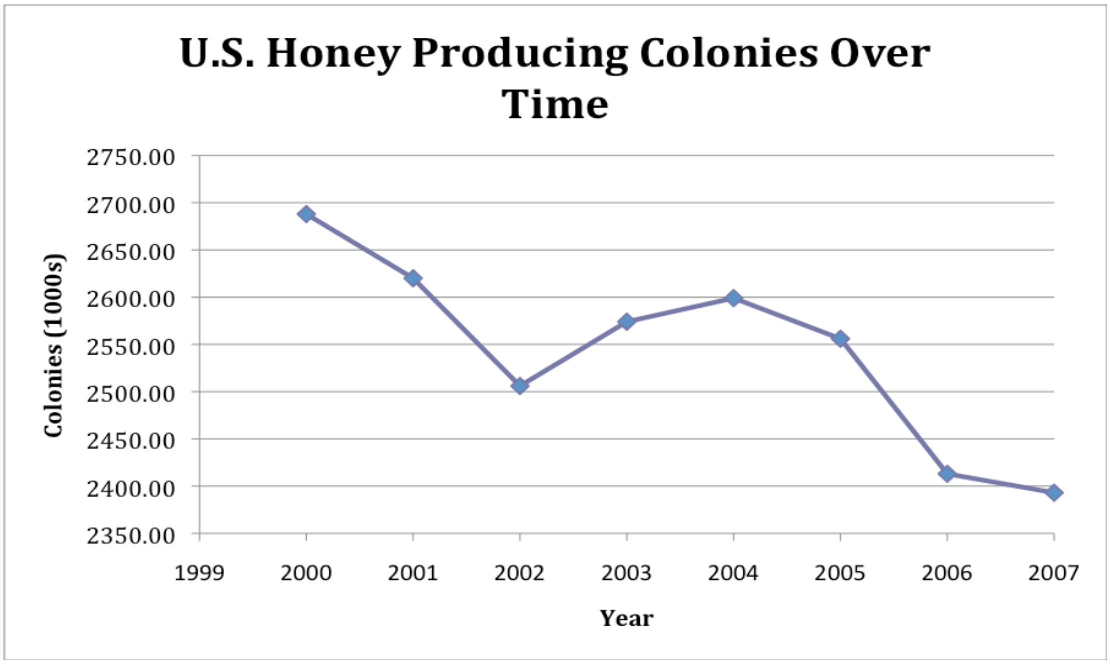
Data Source: California State Beekeepers Association, Inc., *Survey Data to Member Beekeepers*, 2009.

Figure 8: Sources Of Income Received By California Beekeepers



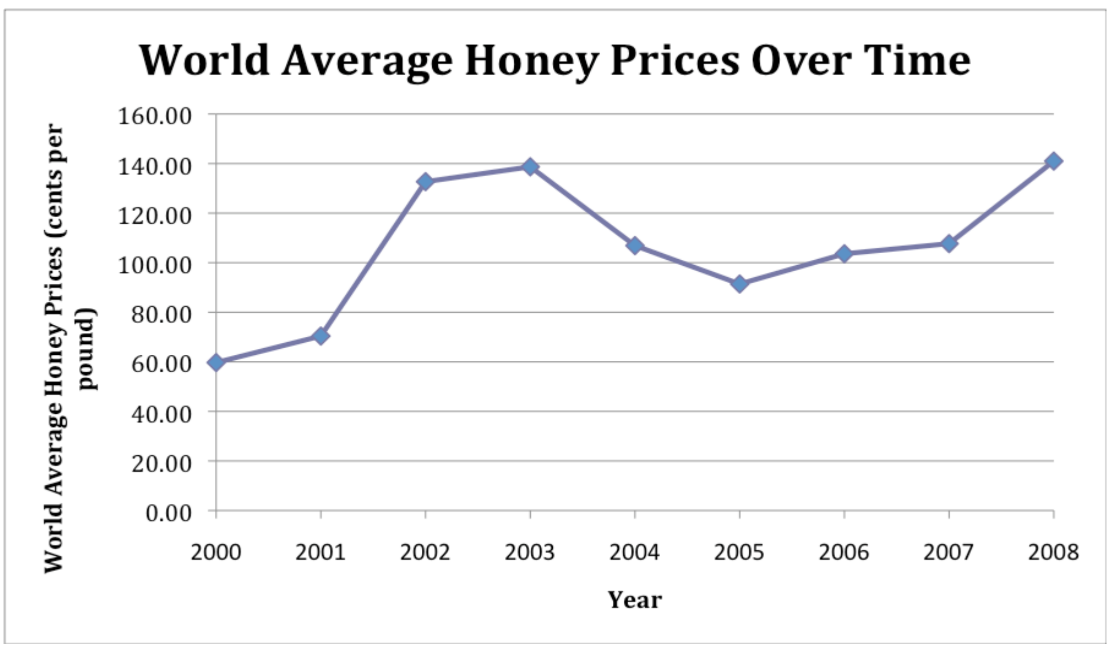
Source: Donald Barrett Wooten, "The Economics of Beekeeping" (PhD diss., University of California, Davis, 1987), 131.

Figure 9: Population Changes In U.S. Honey Producing Colonies



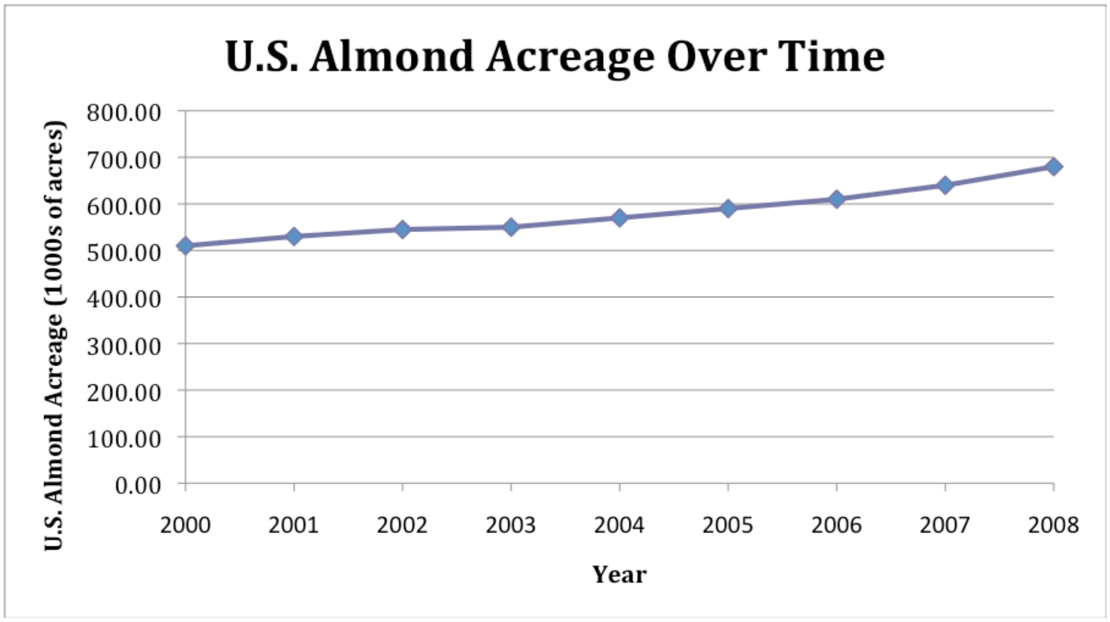
Data Source: United States Department of Agriculture, Sugar and Sweeteners Yearbook Tables, http://www.ers.usda.gov/briefing/sugar/data.htm.

Figure 10: World Honey Prices Over Time



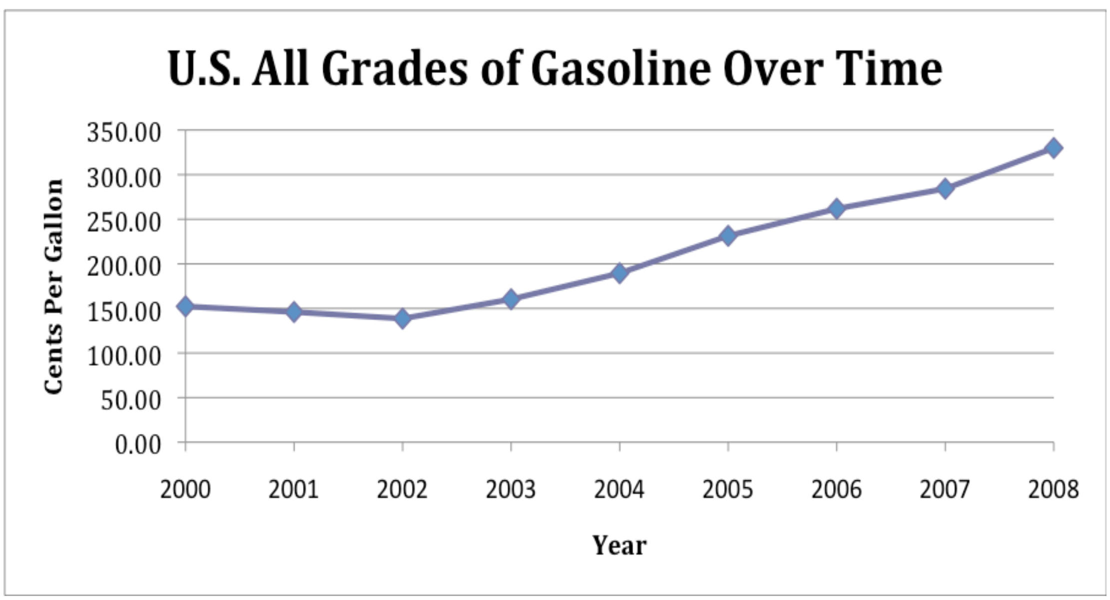
Data Source: United States Department of Agriculture, Sugar and Sweeteners Yearbook Tables, http://www.ers.usda.gov/briefing/sugar/data.htm.

Figure 11: U.S. Almond Acreage Changes Over Time



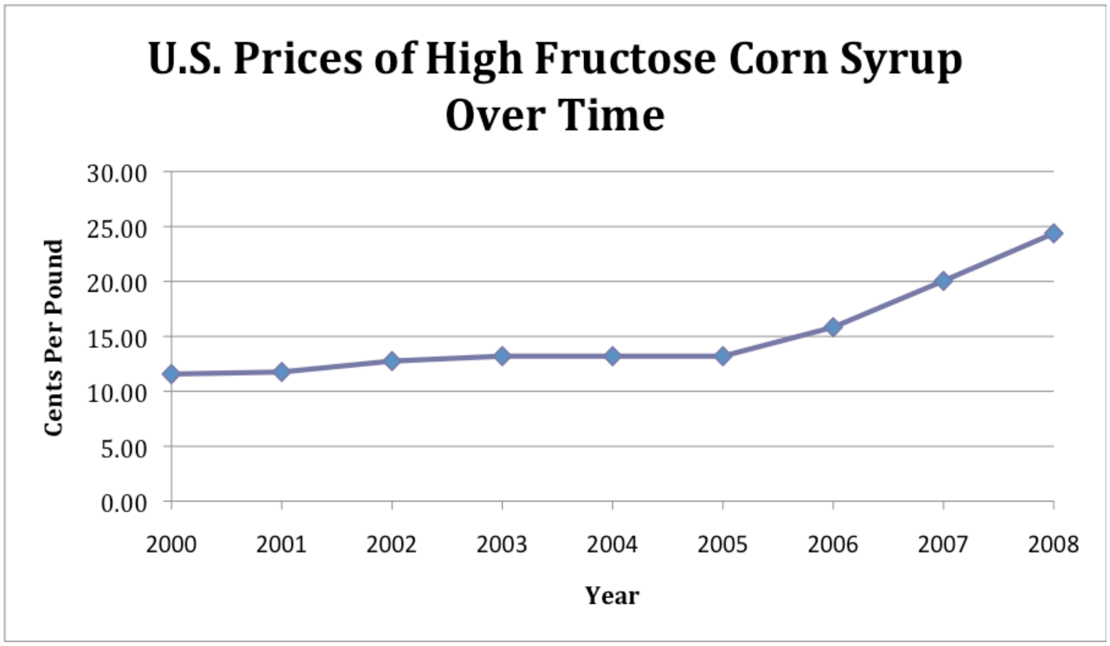
Data Source: United States Department of Agriculture, Fruit and Tree Nut Yearbook Spreadsheets Files, http:// usda.mannlib.cornell.edu/ MannUsda/ viewDocumentInfo.do?documentID=1377.

Figure 12: U.S. Gas Price Changes Over Time



Data Source: United States Energy Information Administration, Retail Gasoline and Diesel Prices, http://tonto.eia.doe.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm.

Figure 13: U.S. Corn Syrup Price Over Time



Data Source: United States Department of Agriculture, Sugars and Sweeteners Yearbook Tables, http://www.ers.usda.gov/Briefing/Sugar/Data.htm.

Table 1
Crops Dependent On Honeybee Pollination

crop	1996-1998 V= U.S. Average Value[d] ($ millions)	1985 v= U.S. Annual Value[e] ($ millions)	D= Dependence On Insect Pollination	P= Proportion Of Pollinators That Are Honey Bees[f]	V x D x P= Annual Value Attributable To Honey Bees ($ millions)
Fruits and Nuts					
almond	959.2	360.6	1.0	1.0	959.2
apple	1,502.6	915.6	1.0	0.9	1,352.3
apricot	37.8	28.1	0.7	0.8	21.2
avocado	254.6	176.4	1.0	0.9	229.2
blueberry	151.3	104.6	1.0	0.9	136.1
wild	31.3				
cultivated	119.9				
brambleberry	[j]64.8	51.8	0.8	0.9	46.7
cherry					
sweet	242.4	101.0	0.9	0.9	196.3
tart	43.4	62.9	0.9	0.9	35.1
citrus					
grapefruit	297.4	308.5	0.8	0.9	214.1
lemon	268.2	168.1	0.2	1.0	53.6
lime	5.8	19.9	0.3	0.9	1.6
orange	1,869.8	1,459.3	0.3	0.9	504.9
tangelo	16.4	34.4	0.4	0.9	5.9
tangerine	112.5	49.4	0.5	0.9	50.6
temple	12.4	26.2	0.3	0.9	3.4
cranberry	294.9	189.9	1.0	0.9	265.4
grape	2,704.6	959.1	0.1	0.1	27.0
kiwifruit	18.1	16.7	0.9	0.9	14.6
macademia	41.6	30.5	0.9	0.9	33.7
nectarine	108.1	68.7	0.6	0.8	51.9
olive	70.2	53.6	0.1	0.1	0.7
peach	426.0	307.4	0.6	0.8	204.5
pear	291.2	201.0	0.7	0.9	183.5
plum/prune	243.6	192.4	0.7	0.9	153.5
strawberry	900.1	450.8	0.2	0.1	18.0
Vegetables and Melons					
asparagus	183.2	163.7	1.0	0.9	164.9
broccoli	483.8	239.3	1.0	0.9	435.4
carrot	467.5	206.4	1.0	0.9	420.7
cauliflower	233.5	169.1	1.0	0.9	210.2
celery	230.1	189.5	1.0	0.8	184.1
cucumber					
fresh	* 205.0	82.6	0.9	0.9	166.1
pickled	* 141.8	123.6	0.9	0.9	114.9
muskmelon					
cantaloupe	* 395.7	164.4	0.8	0.9	284.9
honeydew	* 91.7	58.1	0.8	0.9	66.0
onion	735.3	347.2	1.0	0.9	661.7
pumpkin	[i]200.0	60.2	0.9	0.1	18.0
squash	[j]240.5	192.4	0.9	0.1	21.6
vegetable seed	[j]61.0	48.8	1.0	0.9	54.9
watermelon	286.6	149.8	0.7	0.9	180.5
Field Crops					
alfalfa					
seed	[g]109.0	114.8	1.0	0.6	65.4
hay	7,647.9	4,719.0	1.0	0.6	4,588.8
cotton					
lint	[j]4,556.8	3,645.4	0.2	0.8	729.1
seed	* 803.9	348.3	0.2	0.8	128.6
legume seed	[j]34.1	27.3	1.0	0.9	30.7
peanut	* 1013.7	1,003.4	0.1	0.2	20.3
rapeseed	* 0.4	1.8	1.0	0.9	0.4
soybean	16,490.7	10,571.3	0.1	0.5	824.5
sugarbeet	[j]951.5	761.2	0.1	0.2	19.0
sunflower	* 455.4	251.5	1.0	0.9	409.9
TOTAL ALL	**47,107.2**	**29,976.0**	**1996-1998 avg. sum =**		**14,563.6**

8 Pollination 2000

Source: Nicholas W. Calderone and Roger A. Morse, "The Value of Honeybees As Pollinators of U.S. Crops in 2000," *Bee Culture*, 2000, 8.

Table 2
Linear Regression Results

Linear Regression

Regression Statistics	
R	0.9972
R Square	0.9943
Adjusted R Square	0.9849
Standard Error	5.656
Total Number Of Cases	9

Weighted Avg. Almond Fee (dollars) = 1003.4421 - 0.2580 * Honey Producing Colonies -Lagged 1 Year- (thousands of colonies - 0.0471 * Honey Prices (cents per pound) - 0.8304 * Bearing Acreage (1000 Acres) + 0.7815 * U.S. All Grades All Formulations Retail Gasoline Prices (Cents per Gallon) + 3.6478 * U.S. Prices for High Fructose Corn Syrup (Cents per Pound)

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	5.	16808.5831	3361.7166	105.0837	0.0014
Residual	3.	95.9725	31.9908		
Total	8.	16904.5557			

	Coefficients	*Standard Error*	*t Stat*	*p-level*
Intercept	1003.4421	191.4031	5.2426	0.0104
Honey Producing Colonies -Lagged 1 Year- (thousands of colonies)	-0.258	0.0387	-6.6744	0.0051
World Honey Prices (cents per pound)	-0.0471	0.1406	-0.3354	0.981
U.S. Bearing Acreage (1000 Acres)	-0.8304	0.3171	-2.6187	0.072
U.S. All Grades All Formulations Retail Gasoline Prices (Cents per Gallon)	0.7815	0.2116	3.6937	0.0283
U.S. Prices for High Fructose Corn Syrup (Cents per Pound)	3.6478	1.4003	2.605	0.0729

Residuals

Observation	*Predicted Y*	*Residual*	*Standard Residuals*
1	44.7869	-2.5069	-0.7238
2	40.99	4.	1.1549
3	52.8461	-4.3574	-1.2581
4	49.4597	2.5277	0.7298
5	50.7148	2.8064	0.8102
6	78.6786	-4.8297	-1.3944
7	131.7697	3.8661	1.1162
8	144.785	-1.4706	-0.4246
9	148.5332	-0.0355	-0.0102

Table 3
Linear Regression Results For Reformulated Model

Linear Regression-Dropped Variables

Regression Statistics	
R	0.9817
R Square	0.9637
Adjusted R Square	0.9515
Standard Error	10.1184
Total Number Of Cases	9

Weighted Avg. Almond Fee (dollars) = 426.5674 - 0.1723 * Honey Producing Colonies -Lagged 1 Year- (thousands of colonies + 0.4387 * U.S. All Grades All Formulations Retail Gasoline Prices (Cents per Gallon)

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	2.	16290.2647	8145.1323	79.5564	0.0000
Residual	6.	614.291	102.3818		
Total	8.	16904.5557			

	Coefficients	*Standard Error*	*t Stat*	*p-level*
Intercept	426.5674	154.2146	2.7661	0.0223
Honey Producing Colonies	-0.1723	0.0556	-3.1005	0.0135
U.S. All Grades Gasoline Prices	0.4387	0.0807	5.4391	0.0008

Residuals

Observation	*Predicted Y*	*Residual*	*Standard Residuals*
1	30.1877	12.0923	1.38
2	39.1415	5.8485	0.6674
3	55.5395	-7.0508	-0.8046
4	53.342	-1.3546	-0.1546
5	61.8446	-8.3234	-0.9499
6	87.6368	-13.7879	-1.5735
7	125.6157	10.0201	1.1435
8	138.9333	4.3811	0.5
9	150.323	-1.8252	-0.2083

Table 4
Log Difference Linear Regression Results

Ln Adjusted Linear Regression

Regression Statistics	
R	0.9349
R Square	0.874
Adjusted R Square	0.8236
Standard Error	0.0863
Total Number Of Cases	8

LNA Weighted Avg. Almond Fee (dollars) =- 0.0918 - 7.0479 * LNA Honey Producing Colonies -Lagged 1 Year- (thousands of colonies + 1.7040 * LNA U.S. All Grades All Formulations Retail Gasoline Prices (Cents per Gallon)

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	2.	0.2582	0.1291	17.3406	0.0056
Residual	5.	0.0372	0.0074		
Total	7.	0.2954			

	Coefficients	*Standard Error*	*t Stat*	*p-level*
Intercept	-0.0918	0.0566	-1.6216	0.1658
LNA Honey Producing Colonies -Lagged 1 Year- (thousands of colonies	-7.0479	1.2483	-5.6459	0.0014
LNA U.S. All Grades All Formulations Retail Gasoline Prices (Cents per Gallon)	1.704	0.3976	4.2861	0.005

Residuals

Observation	*Predicted Y*	*Residual*	*Standard Residuals*
1	0.0168	0.0453	0.6215
2	0.1331	-0.0582	-0.7983
3	-0.0326	0.1023	1.4029
4	0.1252	-0.0962	-1.3185
5	0.3662	-0.0442	-0.6064
6	0.5243	0.0837	1.1472
7	0.1074	-0.0523	-0.717
8	0.0159	0.0196	0.2686

Table 5
CPI Adjusted Linear Regression Results

CPI Adjusted Linear Regression

Regression Statistics	
R	0.9788
R Square	0.9581
Adjusted R Square	0.9441
Standard Error	0.048
Total Number Of Cases	9

Weighted Avg. Almond Fee (dollars) = 2.1884 - 0.0009 * Honey Producing Colonies -Lagged 1 Year- (thousands of colonies + 0.4503 * U.S. All Grades All Formulations Retail Gasoline Prices (Cents per Gallon)

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	2.	0.3163	0.1581	68.5304	0.0001
Residual	6.	0.0138	0.0023		
Total	8.	0.3301			

	Coefficients	*Standard Error*	*t Stat*	*p-level*
Intercept	2.1884	0.7152	3.0598	0.0143
Honey Producing Colonies -Lagged 1 Year- (thousands of colonies	-0.0009	0.0003	-3.5411	0.0072
U.S. All Grades All Formulations Retail Gasoline Prices (Cents per Gallon)	0.4503	0.0927	4.857	0.0014

Residuals

Observation	*Predicted Y*	*Residual*	*Standard Residuals*
1	0.1908	0.0547	1.3154
2	0.2244	0.0297	0.713
3	0.3017	-0.0322	-0.7729
4	0.2864	-0.0039	-0.094
5	0.3236	-0.0403	-0.9679
6	0.4437	-0.0656	-1.5767
7	0.6224	0.0504	1.2113
8	0.6729	0.0183	0.4398
9	0.7009	-0.0112	-0.2682

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