Honeybee Valuation 10 Years After Colony Collapse Disorder

Meghan Wirtz[a]

[a]*Hamilton College, 198 College Hill Road, Clinton, New York, 13323*

Abstract

Using the bioeconomic method to calculate honeybee value, I find that honeybees in the US in 2015 are worth $26.7 billion. This is greater than all past values done using the bioeconomic method, but this increase is due to the $5 billion increase in almond value as well as the 7 crops that this paper uses that the others did not. Excluding these, the 2015 value is $3.78 billion less than the 1996-98 value using the bioeconomic method. This decrease is not due to the dramatic loss of honeybees over the past 15 years as a result of Colony Collapse Disorder, but rather due to the substantial increase in fruit and vegetable imports over the last two decades. It is possible that outsourcing US pollination needs to foreign countries is accommodating for the effects honeybee loss would have on US agriculture.

JEL codes: Q10, Q17, Q19

Keywords: Honeybees, pollination, imports, Colony Collapse Disorder,

Introduction

Nearly a third of the food consumed in the US is pollinated by bees. Farmers are hugely dependent on honeybees for both quality and quantity of crop production. In recent years, this has been threatened by a decline in the honeybee population. Beekeepers have been facing problems with honeybee loss since the early 2000s. In 2002, the USDA Agricultural Research Service responded to reported bee colony loss in Alabama and then again in 2004 in Minnesota (USDA, 2016). In its early days, the losses were spread apart and there was no discernable common cause, so the cases seemed unrelated. By 2006, however, there were so many reports of loss that it was named Colony Collapse Disorder (CCD). CCD describes the phenomenon that occurs when the majority of worker bees disappear from their colony, leaving behind the queen bee and remaining immature bees (EPA, 2017). The issue is widespread and quickly increasing. In 2016, beekeepers reported a 44% loss of their colonies in the prior year. That is up 42.1% from 2015 and 39% in 2014. If beekeepers continue to lose colonies at this rate, commercial honeybees could disappear by 2035 (Johnson, 2016). While there has been much research on the issue, it is still unclear why the losses are occurring. Most researchers attribute it to some combination of climate change, loss of habitat, the stresses of beekeeping practices on colonies, and pesticide use. There is one pesticide in particular that is thought to cause CCD called neonicotinoids. Like the name suggests, it has similar qualities of nicotine and is thought to disorient the bees so that they cannot find their way back to their colony. In an attempt to alleviate the losses of CCD, the European Union temporarily banned the use of neonicotinoids, with undetermined results. While unwilling to ban neonicotinoids, the USDA offered a $3 million subsidy to research and protect the bees, fearing that their loss would severely hurt food prices (Hagopian, 2017).

Countless papers written between 2005 and the present warn of the drastic effect that the loss of bees will have on our population both physically and financially. They warn of the enormous cost that will come due to the increased prices of crops. This expected increase in cost would either be because farmers would need to find alternate ways to pollinate crops without bees, which would likely be expensive, or it would be because the loss of crops would affect the amount of crop produced, therefore causing the prices to go up due to the shortage

Email address: mwirtz@hamilton.edu (Meghan Wirtz)

of supply. The Guardian, the LA Times, the Balance, the Cornell Chronicle, and BBC News all warn of the impending price increases if CCD continues. There have been many efforts to attach an economic value to honeybees, but surprisingly there has only been one since 2006, when CCD was recognized as a global problem. This paper intends to do a current valuation of honeybees to find the effects that massive honeybee loss has had on the US economy in terms of agriculture.

Lit Review

The value of honeybees is something that economists have tried to calculate many times before. Between 1973 and 2012, there have been seven papers dedicated to determining their value in the US using three methods. The first of these methods is the crop value method and is utilized by Ware (1973) and Levin (1983), the oldest papers of the bunch. In these papers, they find the value of honeybees simply by summing the value of nearly 50 crops that are dependent on honeybee pollination. These values are clearly an overestimate since they do not take into account how dependent the crops are on honeybees or how much of the pollination of that crop is coming from other insects. Some crops would not exist without the pollination of bees, but others would just lack in quantity or quality. Ware acknowledges in his paper that only 28 of the crops he used are completely dependent on pollination, however he still includes the total value for the other 18 crops. Levin used the same formula only a decade later using one additional crop and also includes cattle and dairy production value. He reaches a larger value than Ware because of both the steep increase in production of many of these crops and well as the added value of cattle and dairy. He includes them because alfalfa hay is almost entirely dependent on honeybee pollination and cattle are fed alfalfa hay. Instead of using the entire value of cattle and dairy production, Levin added 10% of their value to his total valuation of the honeybees. His paper is the only one that includes cattle and dairy in its valuation.

The next method is the bioeconomic method. This is similar to the crop value method, but takes into account how dependent each crop is on honeybees. This method is used by Robinson, Nowogrodski, and Morse (1989); Calderone and Morse (2000); and again by Calderone (2012) who looked at the value of honeybees in 1996 and 2009 using the same method to measure the variation. Using the bioeconomic method, the author collects data on the value of all crops dependent on honeybees and multiplies each crop's value by a dependency coefficient as well as the proportion of insect pollinators that are honeybees. The dependency coefficient is based on how dependent the crop is on insect pollination. For these papers, the crops were separated into three groups: highly dependent (.9), somewhat dependent (.4), and slightly dependent (.1). Multiplying the crop value by the proportion of insect pollinators that are honeybees allowed the authors to hone in on the value of the crop that was dependent on solely honeybees rather than any other pollinator. For this proportion, they used a baseline number of .8, which came from Eckert and Shaw (1960) and adjusted the number when they had more evidence from outside papers of a differing proportion. The four papers use all the same 47 crops. The outcomes are fairly close and only show slight variation. Calderone (2012) looked at the variation between 1996 and 2009, which is of interest since it is looking at years before and after CCD. Interestingly, he found that the value of honeybees dropped between 1996 and 2009. He split up the crops he used into two categories: directly dependent and indirectly dependent crops. Directly dependent crops are those that need the pollination of honeybees to exist, while indirectly dependent crops benefit from pollination, but will still grow without it. He found that the value of directly dependent crops decreased from 1996 to 2001, but the increased between 2001 and 2009, confusing the value's relationship with CCD. Furthermore, he found that the value of indirectly dependent crops fell between 1996, 2001, and 2009. He does not explore the reason for these numbers in great detail, but warns of our extreme dependence on honeybees and the need to continue to study their value and work to protect them. From his numbers though, it is difficult to attribute the decrease in value between 1996 and 2009 to the loss of honeybees.

The last valuation method is the market value method, which simply looks at how much commercial beekeepers were making from honeybee rental fees. This method is important to note since the value more than doubled between 2005 and 2012. This is a direct effect of CCD, which caused beekeepers to have trouble keeping colonies alive leading to a smaller supply of bees and therefore increased prices. An increase in demand for commercial pollination is also likely to have had an effect on the price. The table below shows each of the papers and the value they came up with. The values have been adjusted for inflation using the Bureau of Labor Statistics CPI inflation calculator with 2015 as a base year.

Authors	Year	Method	Adjusted Value of Bees
Ware	1973	Crop Value	42.12Billion
Levin	1983	Crop Value	45.63Billion
Robinson et al	1989	Bioeconomic	18.3Billion
Calderone et al	2000	Bioeconomic	20.28Billion
Calderone	2012	Bioeconomic	20.7Billion (1996)
Calderone	2012	Bioeconomic	19.1Billion (2009)
Rucker et al	2005	Market Value	185.73Million
Rucket et al	2012	Market Value	433.36Million

Data

Using the same methodology as Robinson, Nowogrodski, Morse, and Calderone, I perform an updated version of the bioeconomic method. I obtained a list of 91 crops that are dependent on honeybees from the Mid-Atlantic Apiculture Research and Extension Consortium. Like all of the other papers before me, my valuation was constrained by the data available to me. I was able to find data on the total production of 52 of the 91 crops from the USDA National Agricultural Statistics Service. I was unable to obtain data on many of these crops because they are no longer produced in large enough quantities in the US to be recorded, so while my valuation may be an underestimate due to the lack of data on these crops, it is unlikely that it would have a substantial effect on the final value. For the 52 crops I did have data for, I took the 2013, 2014, and 2015 total production values of each crop and averaged them, using the averaged number for my valuation. This was to account for any crops that may have had a total production in one year that was an outlier due to factors such as bad weather. The list of 52 crops that I used included all but 6 crops that Calderone and Morse had used in 1989 and 2000. It included 7 additional crops that they did not use. I also included the production value of honey, which none of the other papers included.

The list of 91 crops from the Mid-Atlantic Apriculture Research and Extension Consortium also included the dependency of the crop on bees and ranked them between 1 and 4. This was slightly more specific than the earlier papers, which split the dependency coefficient into three groups. I was able to split them up into four groups: slightly dependent (.1), somewhat dependent (.4), greatly dependent (.7) and essential (.9). The Robinson et al (1989) paper cited many additional papers that looked at specific crops and their relationship with pollinators and I relied heavily on this information. If the 1989 paper had specific evidence for a different dependency coefficient, I would prioritize that number.

For the proportion of insect pollinators that are honeybees, I used a baseline of .8 based on the findings of Levin (1983) and Eckert and Shaw (1960). If commercial bees were used on the crop, I used a proportion of .9 since there was a greater concentration of honeybees. Additionally, if Robinson et al (1989) cited a source that provided evidence for a differing proportion, I would use that number. Since these numbers were found over twenty years ago, before the start of CCD, it is possible that they are an overestimate. However, there has not been a paper published since 1989 that offered any alternative estimate on the proportion of pollinators that are honeybees for each crop. Additionally, Calderone (2012) used the same numbers as the 1989 paper, assuming that they had not changed drastically even after CCD.

The table below shows the breakdown of each crop, their dependency coeffiencient, their proportion of insect pollinators that are honey bees, as well as the total amount that the crop is adding to the valuation. The values are in millions of dollars.

Crops	Crop Value(V)	Dependency Coefficient(D)	Proportion of Pollinators(P)	V x D x P
Fruits and Nuts				
Almond	6365.9	1.0	1.0	6365.9
Apple	3132.6	1.0	0.9	2819.4
Apricot	46.6	0.7	0.8	26.1
Avocado	327.9	1.0	0.9	295.1
Blackberry	43.5	0.7	0.8	24.3
Blueberry (tame)	790.4	1.0	0.9	711.3
Blueberry (wild)	58.9	1.0 0.9	52.9	
Cantaloupe	294.6	0.8	0.9	212.1
Cherry (sour)	99.4	0.9	0.9	80.5
Cherry (sweet)	765.4	0.9	0.9	619.9
Cranberry	266.1	1.0	0.9	239.5
Grapefruit	59.9	0.8	0.9	43.1
Honeydew	83.1	0.8	0.9	59.9
Kiwifruit	31.4	0.9	0.9	25.4
Lemon	579.5	0.2	1.0	115.9
Macadamia	40.4	0.9	0.9	32.7
Nectarine	151.3	0.6	0.8	72.6
Olive	122.8	0.1	0.1	1.2
Orange	2097.1	0.3	0.9	566.2
Papaya	10.1	0.1	0.8	0.8
Peach	594.4	0.6	0.8	285.3
Peanut	1124.6	0.1	0.2	22.5
Pear	466.1	0.7	0.9	293.6
Plum	89.9	0.7	0.9	56.7
Prune	219.3	0.7	0.9	138.2
Raspberry	483.9	0.7	0.8	271.0
Strawberry	2556.7	0.4	0.9	920.4
Watermelon	484.2	0.7	0.9	305.1
Vegetables				
Asparagus	80.6	1.0	0.9	72.6
Bell Pepper	653.9	0.1	0.8	52.3
Broccoli	885.8	0.1	0.9	79.7
Cabbage	411.7	0.1	0.8	32.9
Carrots	721.9	1.0	0.9	649.7
Cauliflower	327.7	1.0	0.9	294.9
Celery	398.9	1.0	0.8	319.1
Chili Pepper	173.3	0.1	0.8	13.9
Cucumber	182.6	0.9	0.9	147.9
Onion	962.6	1.0	0.9	866.3
Potato	4010.3	0.1	0.8	320.8
Pumpkin	127.3	0.9	0.8	91.6
Squash	197.0	0.9	0.9	159.6
Fieldcrops				
Alflafa Hay	9905.7	1.0	0.6	5943.4
Cotton Seed	1000.8	0.2	0.8	160.1
Flax	70.7	0.1	0.9	6.4
Mustard	10.8	0.4	0.8	3.4
Rapeseed	0.7	1.0	0.9	0.6
Safflower	54.8	0.1	0.9	4.9
Soybeans	39322.3	0.1	0.5	1966.1
Sugarbeet	1544.9	0.1	0.2	30.9
Sunflower	505.1	1.0	0.9	454.6
Other		4		
Coffee	56.3	0.4	0.8	18.0
Honey	344.9	1.0	1.0	344.9
Total				**26692.7**

Estimates of Valuation

I multiplied each crop's averaged total production value by the dependency coefficient and the proportion of insect pollinators that are honeybees. I summed all of those values and found that the value of honeybees in the US is $26.7 billion. This was expectedly much lower than Levin's 1983 value, but was surprisingly close to Calderone and Morse's 2000 value. It is especially significant since I included 7 crops that Calderone and Morse did not use along with honey. The value of these crops as well as honey resulted in a $6.7 billion increase in the value of honeybees. On top of this, almond production in the US has grown tremendously in the last decade and almonds alone added $5 billion dollars to the valuation since 1996-98. Calderone used 10 crops that I did not have data for, which altogether added $1.5 billion to his 2000 valuation. Looking at just the crops that both Calderone and I used and excluding almonds, Calderone's value is $3.78 billion greater than my own. This is the largest drop in value between any of the prior valuation papers. To visualize potential trends to explain this change in value, I created graphs to show the price of crops from three other papers: Levin (1983), Robinson, Nowogrodski, Morse (1989), and Calderone and Morse (2000) and compared them to the crop value data I had collected. The Levin paper used crop values for the year 1981 and Calderone and Morse used values from an average of the years 1996-98. I took this into consideration and accounted for inflation using the Bureau of Labor Statistics CPI inflation calculator again with 2015 as a base year. For simplicity's sake, I labeled the Calderone variable Calderone_1998 even though he used an average of the 1996-1998 values. Similarly, my own valuation is an average of 2013-2015 values, but is labeled My_Valuation_2015. It should also be noted that the value of Soybeans in 1981 has been multiplied by 10. This is because Levin recognized that soybeans are only partially dependent on honeybees, so he used 10% of the crop value in his valuation. To find the full original value, I multiplied his value by 10.

Figure 1: Values for Fruit and Nut Crops

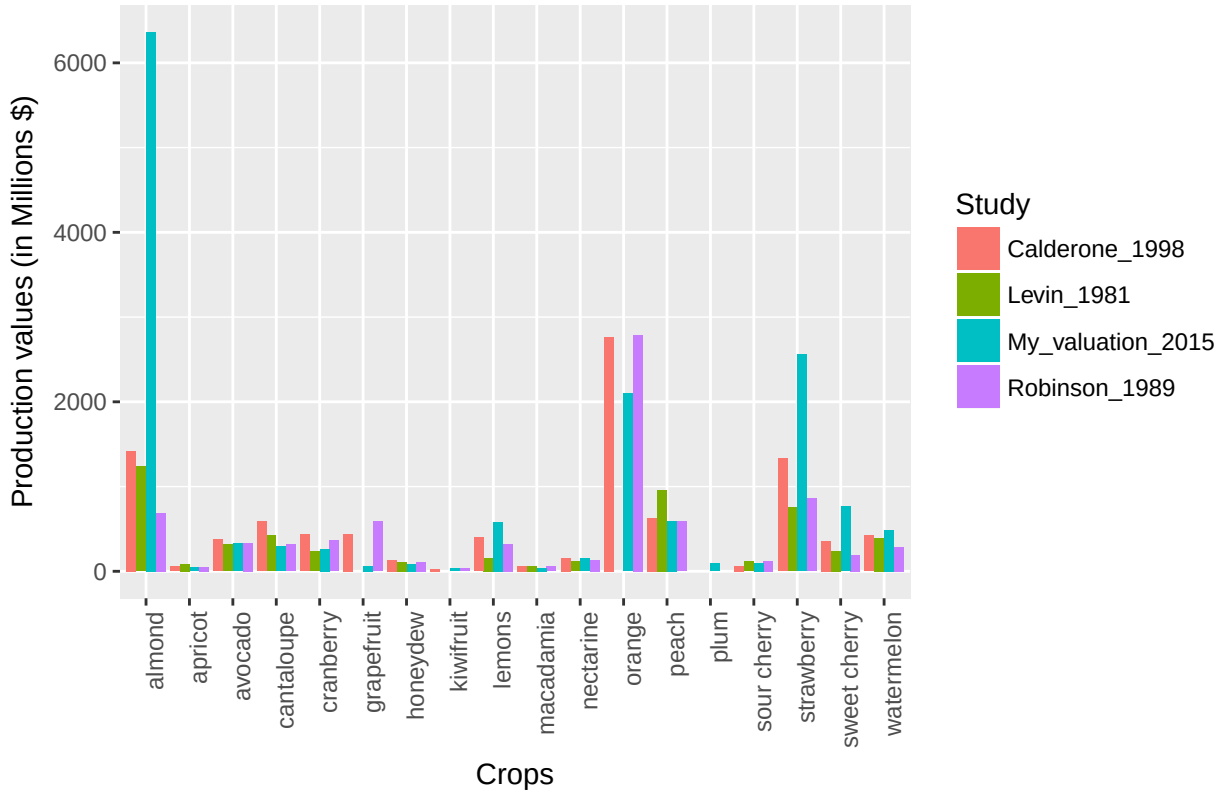


Figure 2: Values for Fieldcrops

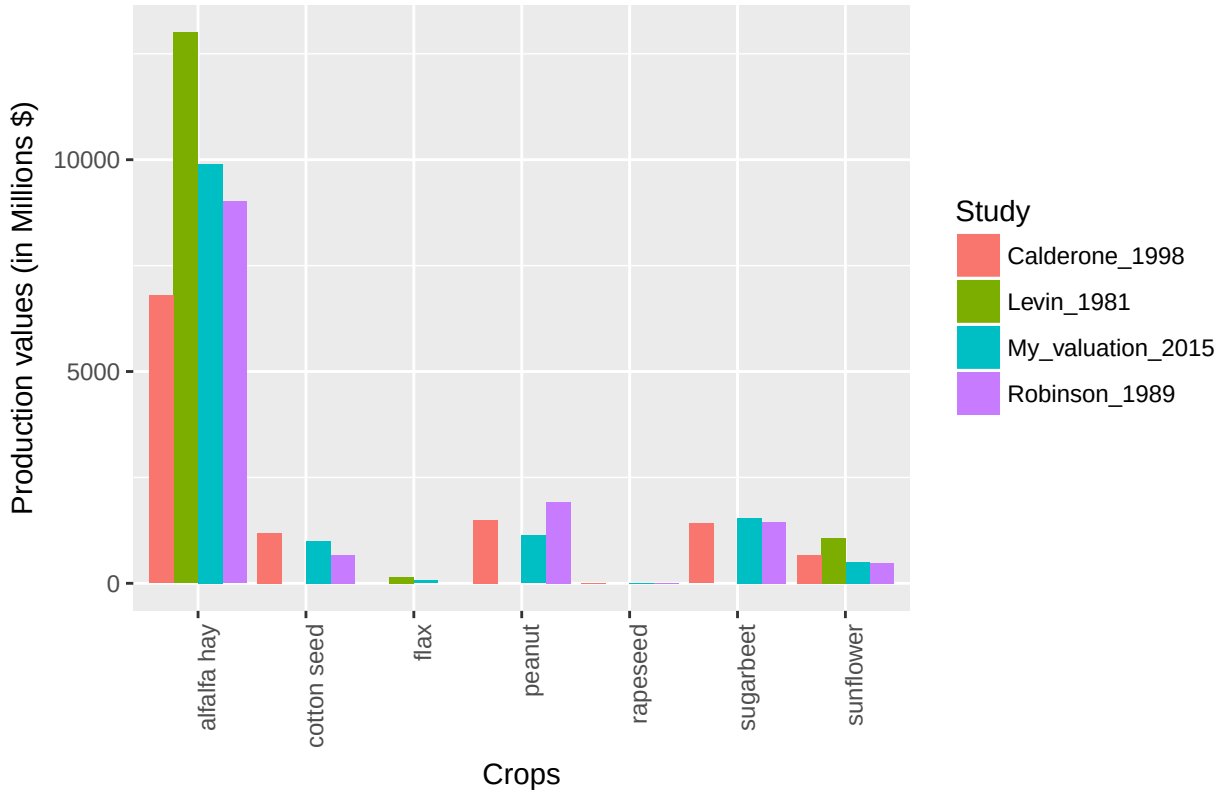
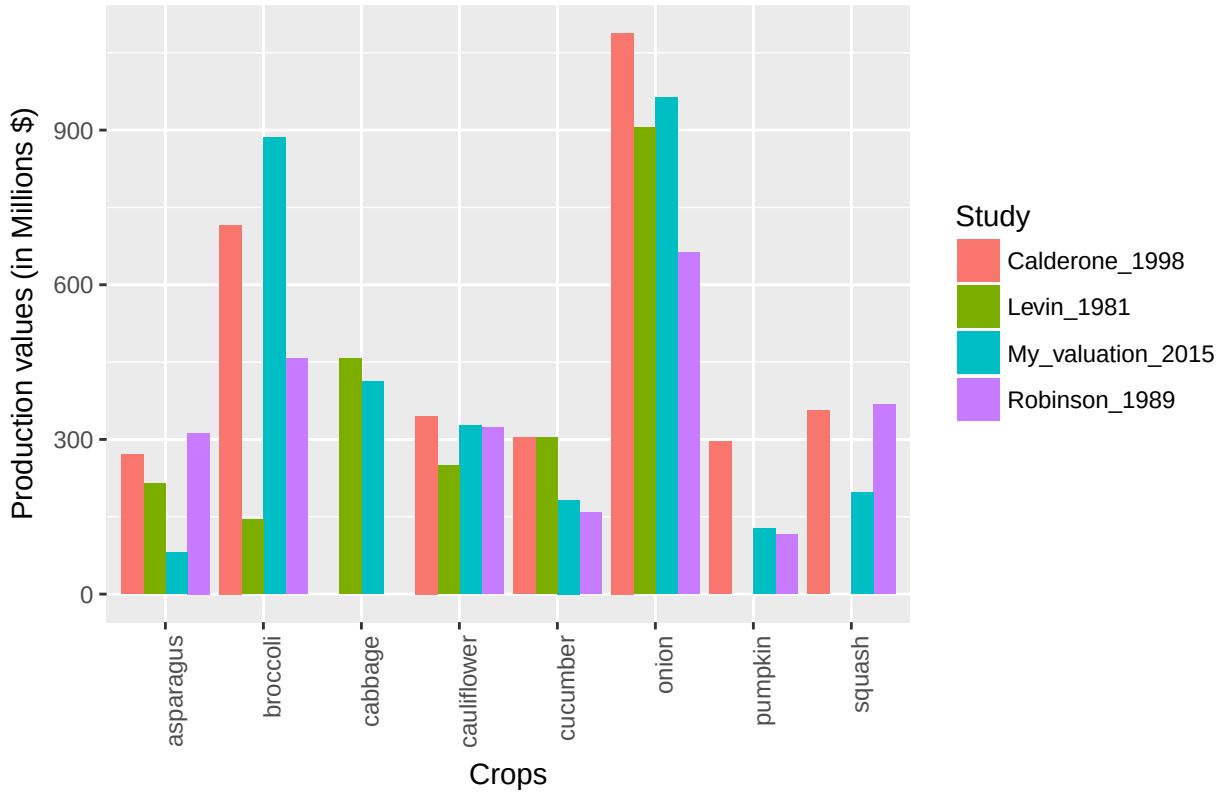


Figure 3: Values for Vegetables



There is no clear trend between the years and production values shown in these graphs. The years that have the lowest and greatest value varies greatly for each crop. There were 12 crops that had a higher value in 1996-98 than in 2013-15. These are: avocados, cantaloupes, cranberries, honeydew, melons, oranges, cottonseed, peanuts, asparagus, cucumber, onions, and squash. With the exception of cranberries, the reason that all of these production values have gone down since 1996-98 is because they are being imported at a much larger rate than they ever were before. In 2001, only 21% of the avocados consumed in the US were imported. Today, that number is nearly 85% (HASS Avocado Board). Only 1% of oranges were imported in 1975, but in 2015, 12.5% of oranges are imported (Perez, 2017). Peanut imports have increased dramatically due to a policy change under the 2002 farm act, which allowed greater quantities of imports (Ash, 2017). The other crops follow similar trends. Cranberries, however, are not imported. 100% of the cranberries consumed in the US are grown in the US. The reason the valuation was higher in 1996-98 than in 2013-15 is because farmers incorrectly predicted an increase in demand and they were left with a surplus of cranberries. This caused cranberry prices to fall in some cases to prices even below the cost of production. However, it is likely that cranberries will not be produced in the US alone for much longer since Chile was just approved to import cranberries (Karst, 2016). In fact, all vegetable and fruit imports have increased greatly in the past two decades. The graphs below show how the quantity of imports of fruits and vegetables into the US has changed between 1999 and 2014. The data for these graphs is from the USDA.

Figure 4: US Import Trends for Vegetables

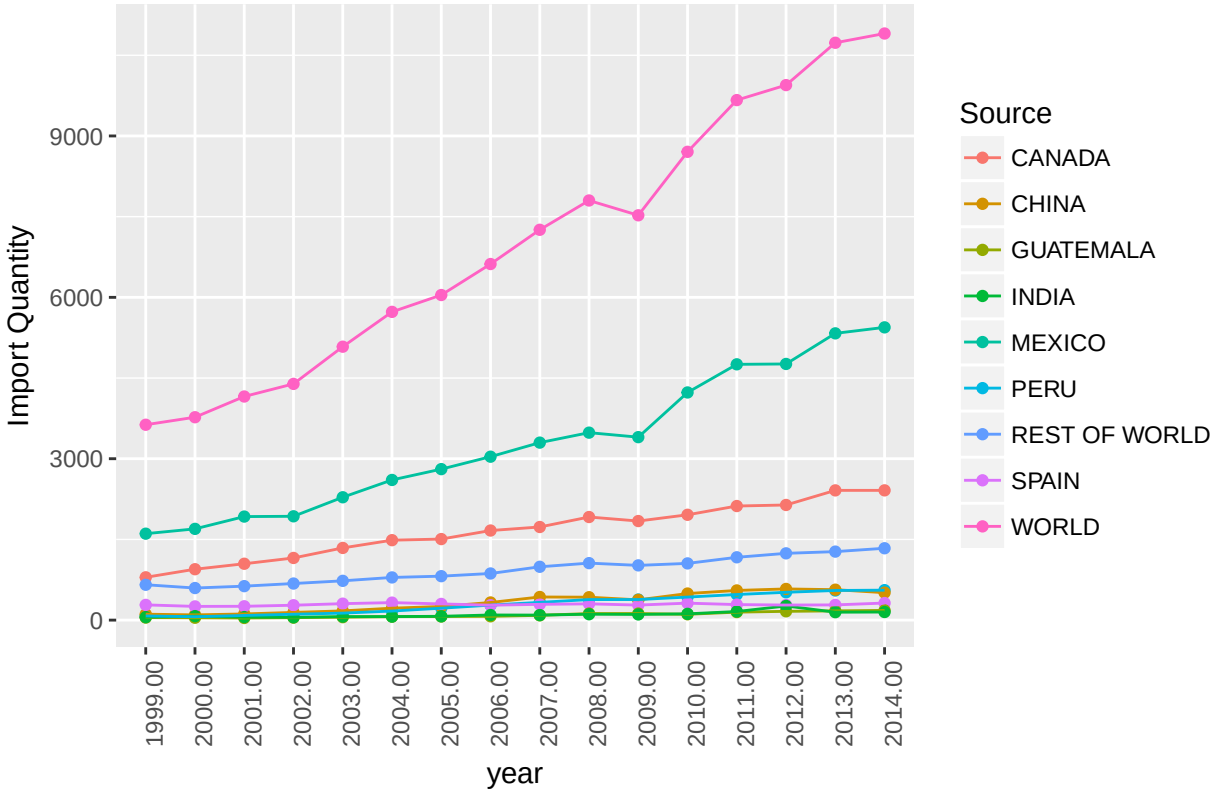
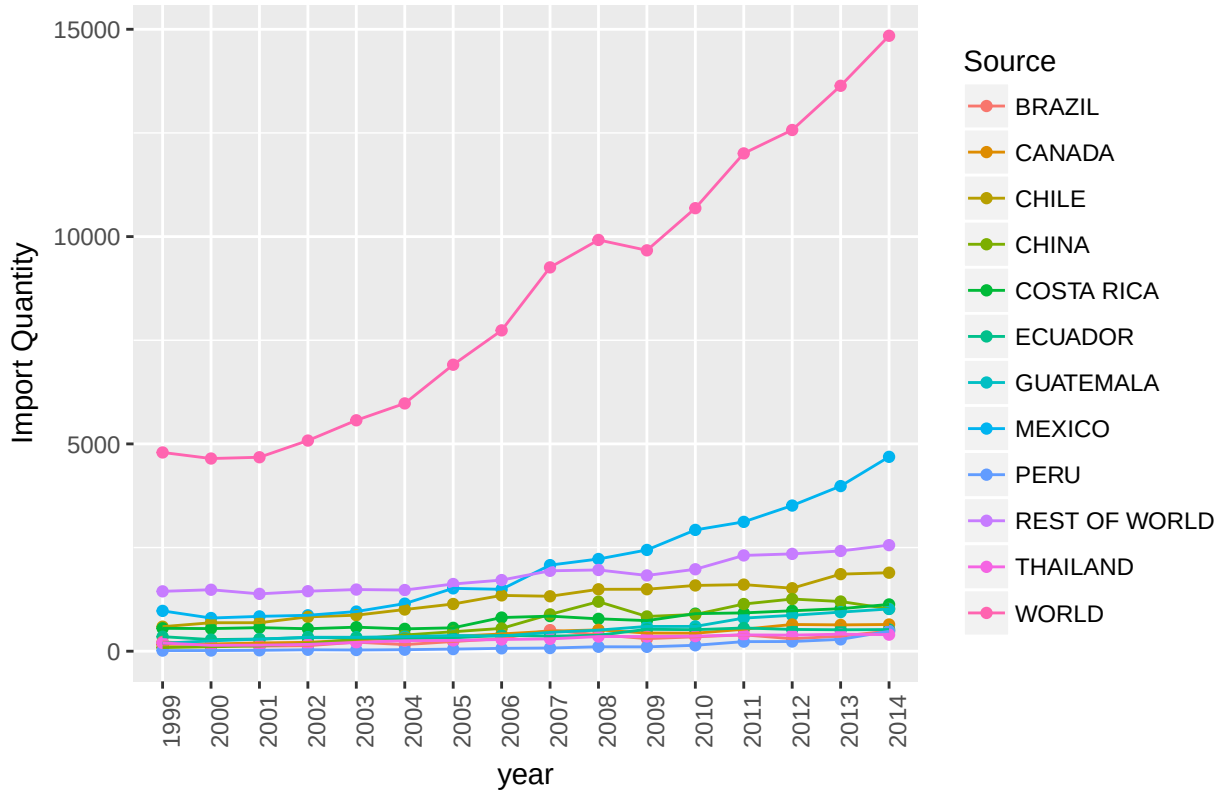


Figure 5: US Import trends for Fruits

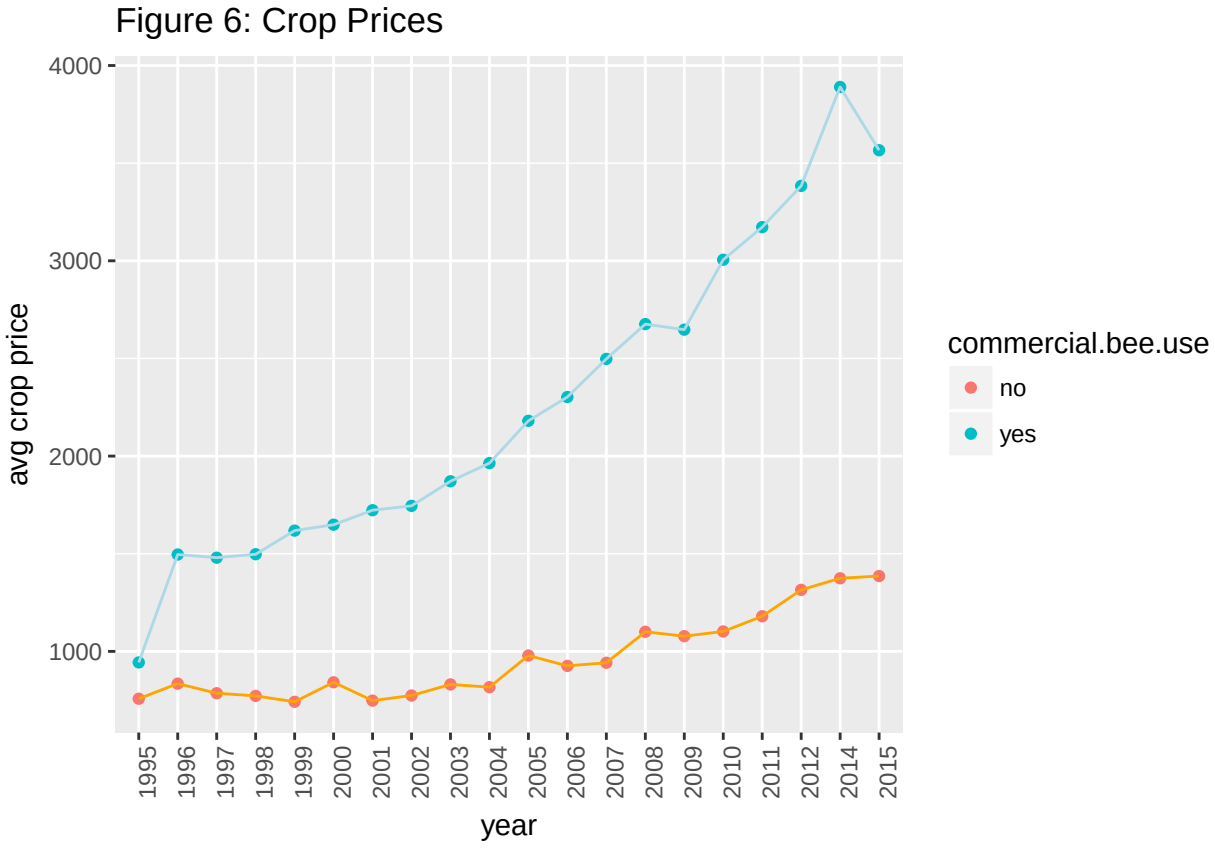


These graphs show clearly how quickly imports of fruits and vegetables have grown over a 15 year time period. Between the 1998-2000 period and the 2010-2012 period, the amount of fresh fruit consumed by Americans increased by 10.5%. During this time, however, the amount of fresh fruit being produced in the United States grew by only 1.4%. Similarly, the amount of fresh vegetables consumed by Americans grew by 9.1% over that same period, but the amount of fresh vegetables grown in the US decreased by 3.5% (Bronars, 2014). The reason for the increased demand in fresh produce is a combination of increased income, an aging population, market promotion, and a general awareness of the importance of eating healthy (Pollack, 2001). The new demand was accommodated outside of the US and the amount of imports increased dramatically. In the mid 1990's, the US had a net trade balance for fruits and vegetables (Johnson, 2016). In 2015, the US exported $6.3 billion in fruits and vegetables and imported $17.6 billion, resulting in a trade deficit of $11.4 billion. This has a big effect on the American economy, but the increase in imports is not a direct result of the declining bee population. One possible reason for the increase is labor shortages in the US (Bronars, 2014).

The U.S. is hugely dependent on Mexico for its fresh produce imports. Figures 4 and 5 show that the amount of imports from Mexico has increased more and at a faster rate than any other country importing fruits and vegetables. Mexico accounts for 69% of US fresh vegetable import value and 37% of fresh fruit import value. Import value of fresh fruit from Mexico has increased an average of 20% each year from 1999 to 2012. Import value of fresh vegetables has increased an average of 15% each year during this same period. This is largely due to NAFTA, which gives Mexico a competitive edge over other importers. Imports from other countries South of the Boarder have also increased, but not nearly as much. Chilean fruit import value has increased by an average of 10% between 1999 and 2012. Peruvian import value of fresh vegetables has increased by an average of 31% annually, even though Peru only accounts for 5% of US fresh vegetable import value. Many of the crops that are increasing in imports are ones that have a high dependency on honeybee pollination, such as avocados, kiwi, cherries, raspberries, and blueberries. Because most of our pollinator dependent crops are coming from South of the boarder, it is important to understand what the status of their bee health. South America has 6.8 million colonies of managed honeybees (Maggi et al., 2016). However, because of the lack of connection between institutions and network organizations in many South American countries, it is difficult to work out bee health at national levels and the information does not yet exist. A national study on Argentinian bee health was just

launched, but the data is not yet available.

I still wanted to see if the honeybee loss affected prices in any significant way like so many had warned. To do this, I looked at how the price of 19 crops from, whose dependency coefficient was over .4, varied between 1995-2015. This data came from the USDA. This shows ten years before and ten years after CCD. Inflation was accounted for with 1990-1992 as base years. Nine crops are pollinated by commercial bees and eleven are not. The graph below is looking at the average prices of these crops separated by use of commercial bees. Data about which crops use commercial bees also came from the Mid-Atlantic Apicultural Research & Extension Consortium. The year 2013 did not have data on all of the crops that every other year did, so was out of place when the prices were averaged. To avoid confusion, I removed the year 2013 from the graph. It should also be noted that a portion of the prices were recorded as parity prices by the USDA. This should not affect the results in any significant way.



This graph shows that there is a clear increase in prices of crops using commercial bees. This is likely because the cost of commercial bees more than doubled between 2005 and 2009. For almond farmers specifically, this price has tripled. In 2003, beekeepers charged almond growers $51.99 per hive . By 2009, that number had reached $157.03 per hive (Carman, 2011). These increased costs have affected prices in a way other crops have not been affected. There are 23 crops in the US that use commercial pollination, so while this is significant, it is not affected all food prices. The prices for crops not using commercial pollination also increased slightly more than they had in the decade before CCD, but not nearly as much as the crops using managed honeybees. It is possible that the reason for this increase is due to smaller outputs and higher costs due to the lack of bees as some articles have suggested may happen, but there is little evidence to suggest that this is the case.

Conclusion

It is possible that we have enough bees to support food production currently and that the loss of bees has not been severe enough to have any effect on production or prices (other than crops using commercial bees). There is little evidence that farmers are making any concerted effort to accommodate for the loss of bees and it seems that

the same if not sufficient amounts of crops can be produced despite the loss of bees. Regardless of the reason our food production is going overseas, a large portion of our pollination dependent crops are being grown elsewhere. In a sense, we are outsourcing our pollination needs. Even if there were to be effects on US agriculture due to a loss of honeybees, it is hard to determine what it is since we are accommodating for the loss by importing more of our produce.

In coming years, it will be useful to look at the results of national bee health studies in South America. It will also be interesting to see what happens with NAFTA with the current administration and how this will change US imports.

As for now, we can see that the loss of honeybees is affecting our food prices, specifically by increasing prices of crops that are dependent on commercial honeybees. The loss is also increasing our trade deficit, although this is only an indirect link.

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