*US Pollination Markets: Recent Changes and Historical Perspective*

Randall Rucker, Walter Thurman, Michael Burgett, Stan Daberkow

**Goal of the Paper**: The paper focuses on the characteristics of honeybee markets, fees received by the bee keepers, size of the US colony rental market for these bees, and a comparison of pollination income and honey income in an effort to discuss trends in honey and pollination markets in the US.

**Methods:** The data was collected from Oregon State University and from surveys of farmers in the Pacific Northwest. These was no demand equation and instead this article focused on the pollination fee associated with certain crops as well as the total production which helped in finding the amount of income associated with pollination.

**Findings**: they discovered that the income of commercial bee keepers in the Pacific Northwest is 60% attributable from providing pollination services whereas the 60% of the income of non-commercial bee keeping is the result of from selling honey. The percentage of income from pollination has not displayed significant differences for commercial bee keepers in recent years but has actually decreased for the non-commercial keepers.

In regards to pollination sets, PNW bee-keepers are more efficient(they pollinate 5 more crops per year and in 7 different counties) since they don’t use as much of their colonies to pollinate almonds. The value of crops pollinated has increased by 1/3 during 2000-2007

Almond pollination is integral to California beekeepers and can be attributable to 90% of their pollination incomes whereas beekeepers in the Pacific Northwest is less significant for at least a third of their pollination income comes from non-almond crops.

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*Honey Bee Pollination Markets and the Internalization of Reciprocal Benefits*

Randall Rucker, Walter Thurman, Michael Burgett

**Goals of the Paper:** The Paper’s main focus is to re-examine the factors in pollinator fees by using more updated data from farmers in the Pacific Northwest as well as data from Oregon State University.

**Methods:** The research team is able to derive an equation (profit maximization) that can calculate the optimum amount of bees on land. The demand equation did not involve cross-price elasticities and instead was using an aggregate demand curve when trying to find the equilibrium price and quantity for the market of pollination services. This aggregate demand function is derived from adding up all of the optimal bee density functions (the summation of all the optimum amount of bees on the land). Thurman uses linear regressions with information that is obtained through surveying over 200 farmers, to help determine if there is a relationship between different variables.

**Findings:** There are relatively inexpensive substitutes for wild pollinators and that the effects of honey price on pollination fees is ambiguous. Thurman also derived 4 possible outcomes when equilibrium is obtained.   
1. Pollination fees will be lower for crops that yield more honey

2. If stocking densities, the amount of bees on the land, are fixed then pollination fees will vary over time with pollination costs

3. If stocking densities are fixed, then pollination fees will increase as the acreage of pollinated crops increases

4. If stocking densities are fixed then changes in crop prices will not affect pollination fees.

Thurman also finds that there is no relation between colony density and honey or crop prices. He believes that this is because the cost of pollination is small in the overall production of crops, and that the demand for pollination services is inelastic due to the information surrounding the benefits of pollination.

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*Valuing Insect Pollination Services with Cost of Replacement*

Mike Alsopp, Willem de Lange, Ruan Veldtman

**Goal:** The goal of this paper was find a more accurate method of determining the value of wild pollination services and that of managed pollinators. The team decided replacement costs, finding the costs associated with using appropriate substitutes, would be the best method. Ascribing a value to honeybee pollination is important for it creates a case to preserve natural biodiversity which is integral in maintaining food security.

**Methods and Findings:** To determine the value of pollination services, the team calculated the cost of replacing them with pollen dusting and hand pollination. Under the aforementioned substitutes, the team found that pollination services are **significantly** more valuable than the market price for commercial pollination although “lower than traditional proportional estimates”. The value of **managed** pollination was calculated by multiplying the insect dependent production value with the proportion of pollination attributable to managed pollinators. The value of **wild** pollinators is the difference between total insect dependent pollination and the value of managed pollination. This method is flawed however, as it exaggerates the value of pollination as it does not consider other input factors and assumes the market have an infinitely elastic demand. A South African fruit industry was used as a case study to determine the value of wild and managed pollination services.

**Findings:**  The contribution of **managed** pollination is found to be between 28-122.8 million dollars, whereas **wild** pollination is between 49.1-310.9 million dollars. These numbers were calculated with the usage of the appropriate substitutes: pollen dusting and hand pollination, and a key reason for the why they are so high is due to their inefficiencies.

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*Pollinators provide economic incentive to preserve natural land in agroecosystems*

Lora A. Morandin , Mark L. Winston

**Goal:** The goal of this work was to show that determining the economic value of ecosystem service could be used as an incentive to preserve natural land. In order to accomplish this, the team hypothesized that by preserving natural land, wild bee populations would be saved and therefore promoted and as a result there would be significant economic benefit for growers because these bees would enhance seed production and yield.

**Methods and Procedures:** To test the aforementioned hypothesis, the team determined and compared the effectiveness of pollination from an area that was being rapidly cleared for agriculture to a conventional and non-cleared area. To determine the effectiveness of pollination they compared the seed set of open pollinated and supplementally pollinated flowers.

**Findings:** Based on their research, the group discovered that there was a strong diminishing returns relationship between bee abundance estimates and seed sets. The fields that had moderate to high bee abundance had nearly maximum yields and this loss of seeds as a result of pee pollination was evident in the fields the team conducted. For example in a GHMT field that was in the area that was being cleared for agriculture, the standard error for the potential number of seeds per pod was 10.2 +/- 0.7 whereas for an un-cleared land this ratio was 23.3 +/- 0.6. This shows the discrepancy between the two areas and that cleared land resulted in less seed capacity. In addition, the team also reconfirmed, through aforesaid statistic, the previous belief that increases in weed cover increased bee abundance.

The group used a canola agroecosystem to determine the potential benefit of an uncultivated area. **With a mean of 18.1 seeds/pod in a cultivated land and an average of 91.1 seeds/pod from an uncultivated land the profit from an uncultivated land would be 38% greater ($8350 compared to a cultivated $6069)** assuming that the land was 800m x 800m canola field. Finally the team discovered that maximum landscape profit could be obtained when just over 30% of the land was uncultivated.

While this research did do justice to the value of honeybees and their pollination services, **it did not provide** a demand equation, but simply showed that clearing the land for agricultural purposes did not correspond to higher seed output from pollination.

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*How much does agriculture depend on pollinators? Lessons from long-term trends in crop production*

Marcelo A. Aizen, Lucas A. Garibaldi, Saul A. Cunningham and Alexandra M. Klein

**Goals:** This study aims estimate the value of crop pollination and pollinator dependency without introducing a complex demand equation and other economic factors. To accomplish this goal, the team focused on predicted changes in crop output and the required amount of land necessary to maintain the current level of production and used a model that highlighted the differences in pollination dependency and the subsequent effect on agricultural productivity.

**Methods and Procedures:** The team used long term data provided by the Food and Agriculture Organization of the United Nations and a 2007 study by Klein that detailed the pollinator dependence of certain crops to estimate the current dependency of crops. To evaluate the dependency of agriculture on pollination services the group incorporated a deficit and compensation method. The former was calculated by finding the percentage decrease in agricultural production “decline in the diversity

of agricultural production caused by complete loss of pollinators”. For the compensation method they “predicted the percentage increase in total cultivated area needed to mitigate the production deficit in

each affected crop”.

**Findings: The team found that the production deficit that would occur in the absence of pollinators in the developed world ranged from 3-5% whereas in the developing world this rate was 8%.** This estimated deficit has actually increased since the 1980s due to the 12% jump in pollination dependency (from 50% to 62%) during the years 1961-2006. The team also found that there was no significant difference in pollination dependency of similar crops between the developed and developing countries. In determining the required amount of land necessary to maintain the current level of production the researchers found that the amount of land needed to offset the absence of animal pollination was much higher in the developing countries as opposed to the developed ones. **In the developed world, a 15% increase in cultivated land would be required to compensate the production deficit compared to 42% in the undeveloped countries based on the observed years from 1961-2006.** This work provided useful information in regarding the output if pollination were lost but it did not economically/ financially evaluate the effects of pollination as our study will do. The study also clearly stated that they would and did not incorporate a demand equation as they wanted to simplify their findings and endeavors.

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*Economic valuation of the vulnerability of world agriculture confronted with pollinator decline*

Nicola Gallai, Jean-Michel Salles, Josef Settele, Bernard E. Vaissière

**Goals:** The goal of this paper was the measure the consequence of diminishing pollination services throughout the world. To accomplish this endeavor the team not only measured the contribution of insect pollination to the economic value of world agricultural output but also the vulnerability of agricultural output when faced with a decline in pollinators.

**Methods:** In order to determine the consequence of diminishing pollination returns the team first quantified the economic loss that would be incurred if insect pollinators were completely removed. The team relied on dependence ratios from a 2007 study by Klein. The total economic value of insect pollination (IPEV) was the summation of the price \* dependency ratio \* quantity consumed of a particular crop in various world regions. To find the vulnerability ratio of a crop the team let the vulnerability ratio be defined as the ratio between the economic value of pollination and the current total crop value. In other words the vulnerability words was IPEV/ EV, where EV is defined as the summation of the price \* quantity of a particular crop at various world regions. The world regions consisted of Africa, Asia and Oceania, Europe, North America and Caribbean, South and Central America.

**Findings:** The team found that 46 of their 89 direct crops were dependent on insect pollination for their production and pollination was essential for 6 of them. The total value of these 46 insect dependent crops totaled 625 billion euros, which represent 39% of the world production value for crops used for human food. The team also found that the economic value of insect pollination totaled 153 billion euros. The most pollinator-dependent crop categories ranked by decreasing economic value of insect

pollination were vegetables, fruits, and edible oil crops

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*Valuing pollination services to agriculture*

Rachael Winfree , Brian J. Gross , Claire Kremen

**Goals:** The objective of this paper was to use a newfound approach, **attributable net income approach,** to evaluate insect pollination on crops. The second objective is to show that the older methods of evaluating insect pollination, replacement (estimating the value of pollinators by using an alternative source) and production (the estimation of the value of crop production attributable to pollination) are actually each special cases that are derived from the same general equation.

**Methods:** To illustrate the improvements highlighted by the attributable net income approach the group used data on native (unmanaged) bees and honey bees pollinating watermelons. The team’s newfound approach differed from the standard versions in the sense that the method values only the amount of pollen needed for fruit production. The second difference is that the new approach accounts for the possibility of other pollinators. However, despite these improvements the study does not focus on the demand for these services and fails to account for cross price elasticities- so while it represents a better method than the previous one it still contains some flaws.

**Findings:** Based on using their new methods, the team found that the value of renting enough hives to replace existing ones, based on the replacement method, was .21 million dollars per year, and for the replacement of honey bee pollination this amount totaled .18 million dollars annually. The team discovered that using the production method yielded significantly higher results. The annual value of pollination services provided by native bees totaled 4.74 +/- .38 million dollars per year and the value of pollination services provided by honey bees totaled 2.9 +/- .38 million per year. When the team evaluated the impact of insect pollination using their attributable net income approach they discovered that when native bees were the main pollinators their value totaled 3.4 +/- .16 million per year. When the bees were not the primary pollinators (residual) this value decreased to .56 +/- .25 million per year. As aforementioned this study did not provide an updated demand equation but rather focused on an alternative method of evaluating the impact of honey bees.

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*Bee-conomics and the Leap in Pollination Fees*

Daniel A. Sumner and Hayley Boriss

**Goal:** The purpose of this paper is to examine why Californian pollinators have decreased, the causes of an increase in demand for their services, as well as the consequences these two factors have on the Californian agriculture.

**Methods:** The team was able to gather much of their data from the USDA National Agricultural Statistics Service. The team did not formulate a demand equation but rather used the numbers available to them by the USDA.

**Findings:** The average fee for pollination services on valuable honey crops is about 50% less than for crops that do not provide nectar. The 3.4 million decrease in honey producing colonies from 1989 to 2004 can be attributable to an increase in the price of honey in 2002 and the Varroa mite has been killing many of these colonies. The main reason behind the large increase in demand for these pollination services is due to the increase in the land for almonds which are heavily dependent on honeybee pollination. This demand has in turn also increased the need for pollination services during the Californian winters as well. Based on their data, the team projected that the almond acreage would continue to increase, which would further increase the demand for pollinators as well. They also found that the price of pollination would also increase. In general the greater the demand for the pollinators has resulted in a higher pollination price and this represents normal market behavior and government intervention is not required.

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*The Plight of the Bees*

Marla Spivak, Eric Mader, Mace Vaughan, Ned Euliss Jr.

**Goal:** The goal of this publication is to inform people about the decline of the honeybees and the importance of the other bees (non honey ones). By showing their significances, the paper hopes to convey the role of pollination in food security.

**Methods:** The team’s format of this report was to present the threats of the bees and their benefits and follow it up by proposing suggestions or highlighting the actions government groups have took. For example the team mentions that the Farm Bill has promoted research on bees and finding ways to eliminate their predators in an eco-system friendly manner. Unlike the other reports, it appeared that much of the goals had been resolved not through extensive research but through proposals or current legislation.

**Findings:** The team concluded that one of the chief reasons for the decline in honeybees has been diseases as well as the modernization of agriculture. While more advanced fertilizers have helped the farmer’s crops, they have had detrimental impacts on the bees by reducing their numbers, and have also eliminated animals that prey on crop damaging pests. Aside from human induced causes, the team notes that the Varroa mite has been ravaging pollinating colonies by infecting them with pathogens. Without treatment 80-90 percent of the colonies would die within 2-3 years. Bumblebees are significantly more efficient at pollinating than honeybees due to their ability to buzz-pollinate. This paper cites 3 chief reasons for the bee decline. The first, as mentioned above, is due to parasites. The second is due to many nesting areas being contaminated with human fertilizers and pesticides. Finally, the team sites that there are an insufficient about of blooming flowers during the length of a growing season to support the bees. The team believes that the best way to combat the effects of pesticides and fertilization is to have farmers not use them entirely.

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*The Fable of Bees: An Economic Investigation*

Steven Chueng

**Goals:** This paper aimed to examine the pricing and contractual agreements of the beekeeping industry in Washington.

**Methods:** The researcher’s data was from a 1972 examination of 9 beekeepers with a combined total of 10,000 colonies. He also employs the equimarginal principle in trying to determine how efficient/productive the allocation of resources is. As mentioned above, much of the data was created by the expected yields reported by beekeepers. The researcher’s efforts do not consist of a demand equation but rather the main source of data comes from the reports from farmer’s and their expected yields. With these numbers, the research team is able to generate an appropriate supply and demand function and from there state the associated implications.

**Findings:** Honey crop products often exhibit the greatest annual variance for production and this can be largely attributed to the cold weather and rain which discourages the honeybees from pollinating. This inconsistency in the weather also impacts on flowers and their ability to generate nectar. The team also stated that there is undeniable evidence that the setting of seeds and fruits increases with the number of hives in the area and that there is diminishing returns for the pollination productivity of bees. The author also estimates the average amount a hive can pollinate is 2.2 different crops per year. In terms of the pattern and spacing of the crops and hives, the report found that the most common placement either 1 hive per acre, or 1 hive per 2 acres. It also noted that many of the farmers employ less than the optimal amount of hives necessary for optimal production, and the author believes that this is due to the financial constraint of purchasing hives. In regards to the efficiency of allocating resources, it was found that zero or negative marginal productivity in one component of the joint product was consistent with an efficient allocation of resources. It was also found that the value of the marginal product of a hive is the same on every farm and that this value is equivalent to rental price and marginal opportunity cost of producing the hive. Regardless of its use, the rental hive price per colony is roughly the same from farm to farm. To test this finding, the team used **the equation rent paid in money + rent paid in nectar = total rent per hive**

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*Economic and environmental threats of alien plant, animal, and microbe invasions*

David Pimental, 2001

**Goal:** The paper aims to examine alien plants, animal, and microbe evasions and their economic and environmental impacts on the following nations: US, UK, Australia, South Africa, India, and Brazil.

**Method:** The report gathered its data from using all of the available data on invasive species in the nations mentioned above. The reports they obtained contained the economic impacts of invasive species on crops, pastures, forests, livestock and public health. In the cases where the information was unavailable, the team calculated the control cost associated with the environmental impact. While the team used data globally and domestically, the findings I have listed pertain specifically to the US environmental market.

**Findings:** In regards to the United States, it was found that 400 of the 958 species on the Endangered Species List were threatened due to non-indigenous species. It was also found that introducing non-native plant, animals, and microbe species caused the US to lose 55 billion dollars in agriculture. This number was 248 billion for the global loss in agriculture. The team also found that he percentage of

the total invading species for each nation is: UK 53%, India 19%, South Africa 7%, US 6%, Australia 3%,

and Brazil 1%. In terms of the impact of weeds on agriculture, it was found that they cause about a 33 billion dollar loss in crop production annually and it is likely from that 33 billion, 27.9 billion can be attributable to introduced weeds. For US pastures, non-native weeds lead to nearly a 1 billion dollar in losses. Finally in terms of the impact non-native weeds have on potential crops, the study found that these weeds led to a 1.4 billion dollar loss. In terms of vertebrate pests it was found that the English sparrow and European starling cost the US 1 billion dollars in crop damage. For pest insects and mites the cost of destruction of US crops totaled 33 billion dollars and non-native pests and insects contribute 15.9 billion. The net cost of destruction, caused by alien insects and pests, for forest products was 2.1 billion dollars. In regards to plant pathogens, these diseases cost the US 33 billion dollars in production annually and 23.5 billion is the result of alien pathogens. These pathogens led to a 7 billion dollar loss in forest production and 2.1 billion of this loss was the result of non-indigenous plant pathogens. Aside from pathogens and plants, mammals have also caused massive damage economically to crop output. Feral pigs, which cause soil erosion and pose other threats to livestock, contribute to 800.5 million dollars worth of damage economically. Snakes and other reptiles also pose a threat to agriculture and the US invests about 5.6 million dollars annually to find ways to ameliorate their damage. Alien fish are detrimental economically in the sense that they threaten the fishing sport and these non-native fish account for 1 billion dollars annually in economic losses. Aside from fish, mollusks (predominately the Asian clam and Zebra mussel) pose threats to society. The Asian clam is responsible for about 1 billion dollars in damage to the aquatic ecosystems and the zebra mussel accounts for 5 billion dollars annually in terms of damage. Ants and termites also pose a threat to the agriculture economy and it was found that both insects contribute to a one billion dollar loss in economic production. **In total it was found that the damage caused by alien species globally totaled 336 billion dollars annually, and that the control costs totaled 30 billion. It was also estimated that between 20-30% of introduced species posed threats to the environment.**

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*Environmental and Economic Costs of Nonindigenous Species in the United States*

David Pimental, 2000

**Goals:** This paper is an older study of the previous article and it also aims to determine the economic and environmental costs associated with foreign species within the United States.

**Methods**

**Findings:** The team found that the total economic damage associated with invasive species and the cost to control them totaled 137 billion dollars annually. The team broke down the total cost by various plants, mammals, and pathogens. For the aquatic life, the team found that the US invests about 100 million in controlling aquatic see weeds. On land one of the biggest threats to agriculture and plants is the purple loosestrife and this invasive plant costs the US about 45 million dollars annually in control costs and production losses. Weeds are also a major factor in economic loss and it is estimated that alien weeds account for a 23.4 billion dollar loss in crop production. In terms of combating these weeds, it is estimated that about 1.3 billion dollars is spent on weed control. Aside from plants, non-native mammals also pose a threat to agriculture. One of the more significant ones is the rat which destroys stored grains and the total damage these alien rats cause total 19 billion dollars annually. Feral cats also pose an economic threat to society as they kill birds which are a staple of the livelihood in the states bordering Canada. The estimated damage these cats caused is around 17 billion dollars annually. Though it is often ignored, pigeons also pose a threat to the economy as they lay their waste on human property without regard, and even feed on grain. The estimated economic damage these creatures cause is about 1.1 billion dollars annually. In the sea fish, in particular, the alien grass carp, is an economic threat as it eliminates many of the fish caught for sport. The estimated damage these carp cause is about 1 billion dollars. Zebra mussels are also one greatest threats aquatically as they invade and clog water pipes. These mussels account for 100 million dollars annually in damage. While it is not as common as the zebra mussel, the Asian clam also causes threatening damage to aquatic species and it is estimated that the amount of damage they cause is 1 billion dollars a year. Insects and other pests also contribute to the economic loss in crops as they often destroy potential crop production. It is estimated that they contribute to a13.9 billion dollar loss annually.