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Measuring the Importance of Pollination Externalities in Agriculture

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Measuring the Importance of Pollination Externalities in Agriculture

The reciprocity of pollination in and outside pollination markets

Pollination economics

Background

A beehive contains thousands of bees, each of which can fly several miles for a pinch of pollen or a drop of nectar. Unless farms using pollinators were huge or isolated, it therefore seems unlikely that a beekeeper could ever get all the growers located in the foraging range of her hives to pay for the pollination services provided by her foraging bees. Conversely, it is unlikely that a grower could ever find a way to charge all the beekeepers for the pollen and nectar that their bees collect from her fields. With such a picture in mind, many economists would assume pollination in agriculture to be fertile ground for externalities. \cite{Meade1952} was maybe the first economist to use the canonical story of the beekeeper and the apple grower to illustrate how the existence of ``unpaid factors'' resulted in under-investment, here in apple trees and bees. His appealing illustration of positive externality remains to this day a staple of economics textbooks.

Two illustrative examples

First, imagine almond orchards owned by separate farmers who rent hives to pollinate their crops. As a simplifying approximation, the almond trees provide no resource for bees and the only revenue for the beekeeper in this contract comes from pollination fees. The fee per hive that a single grower pays is independent of the specifics of diffusion across her orchard and her neighbor's since the pollination fee is determined by the market rental rate for hives. A grower hires bees until the value of the marginal increase in her crop yield is equal to the market rental rate for hives. As a result, diffusion creates an externality among growers. A grower has clear incentives to free ride on bees renter by others. Underinvestment in bees could result from free riding among the growers, but the relationship between a grower and her beekeeper is not much different than the ones the grower maintains with her fertilizer or labor providers. The externality is among growers and not between growers and beekeepers.

In the second example, growers of citrus lease their orchards to beekeepers as a source of nectar. Assume that the varieties of citrus involved neither benefit nor are damaged by bee visits. In this situation, beekeepers pay a location fee for access to groves from which nectar can be collected and honey produced. The value of a location to beekeepers depends on how much nectar is accessible from it. If the market for locations is competitive, each grower will receive in the form of location fees the marginal value of the nectar accessible from placing bees at her location as an input to honey production. Externalities occur when a grower rents out a location from which bees can access to her neighbor's nectar. Underinvestment in citrus trees can occur when the value of the trees' nectar is captured from groves other than the ones operated by the growers that receives the fees.

A model of externalities among growers

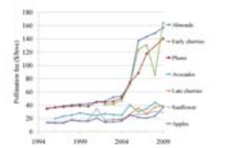
The problem of free riding among crop growers case is mentioned by Cheung who notes the existence of an informal custom among almond growers which discourages free riding for pollination services. According to Cheung's depiction of ``The Custom of the Orchards'', almond growers expect each other to stock their orchards with hives at a same density as their neighbors. Although we have not heard mention of this custom in conversations with current almond growers in California, known free-riders are still considered to be bad neighbors. The problem has not involved any formal institution, and free riding is not listed among major concerns by growers in the almond industry.

$$\begin{cases} \Pi_i(b_i,f_i) = p_a\, a_i + p_h\, h_i - (p_b\, b_i + p_f\, f_i) \\ a_i = a(v_{i,i} + v_{i,-i}) \\ h_i = h(v_{i,i} + v_{-i,i}) \end{cases}$$

$$t_i^b = p_a \frac{\partial a_{-i}}{\partial v}\left[\frac{\partial v_{-i,i}}{\partial b_i} + \frac{\partial v_{-i,-i}}{\partial b_i}\right] + p_h \frac{\partial h_{-i}}{\partial v}\left[\frac{\partial v_{i,-i}}{\partial b_i} + \frac{\partial v_{-i,-i}}{\partial b_i}\right]$$
$$t_i^f = p_a \frac{\partial a_{-i}}{\partial v}\left[\frac{\partial v_{-i,i}}{\partial f_i} + \frac{\partial v_{-i,-i}}{\partial f_i}\right] + p_h \frac{\partial h_{-i}}{\partial v}\left[\frac{\partial v_{i,-i}}{\partial f_i} + \frac{\partial v_{-i,-i}}{\partial f_i}\right]$$

Pollination Markets

Cheung noted the existence of pollination markets.



Free riding among crop growers

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$$t^b_{i,almonds} = p_a \frac{\partial a_{-i}}{\partial v}\left[\frac{\partial v_{-i,i}}{\partial b_i} + \frac{\partial v_{-i,-i}}{\partial b_i}\right]$$
$$t^f_{i,almonds} = p_a \frac{\partial a_{-i}}{\partial v}\left[\frac{\partial v_{-i,i}}{\partial f_i} + \frac{\partial v_{-i,-i}}{\partial f_i}\right]$$

The pollination services provided by wild pollinators

Consider the diffusion of pollinators between wild habitat and farms. In this case, the diffusion is not limited to a single species but involves a number of wild insects in addition to managed bees. For simplicity, we consider wild pollinators as one group of pollinators and therefore only make a distinction between wild and managed pollinators. Under this assumption, the general model of pollinator diffusion above can be adapted to this special case by changing one of the farmers into the owner of wild habitat.

$$t_w^b = p_a \frac{\partial a}{\partial v}\left[\frac{\partial v_{i,w}}{\partial b_w} + \frac{\partial v_{i,i}}{\partial b_w}\right] + p_h \frac{\partial h}{\partial v}\left[\frac{\partial v_{w,i}}{\partial b_w} + \frac{\partial v_{i,i}}{\partial b_w}\right]$$
$$t_w^f = p_a \frac{\partial a}{\partial v}\left[\frac{\partial v_{i,w}}{\partial f_w} + \frac{\partial v_{i,i}}{\partial f_w}\right] + p_h \frac{\partial h}{\partial v}\left[\frac{\partial v_{w,i}}{\partial f_w} + \frac{\partial v_{i,i}}{\partial f_w}\right]$$

$$t_i^b = V_{wes} \frac{\partial wes}{\partial v}\left[\frac{\partial v_{w,i}}{\partial b_i} + \frac{\partial v_{w,w}}{\partial b_i}\right] + V_{b_w} \frac{\partial b_w}{\partial v}\left[\frac{\partial v_{i,w}}{\partial b_i} + \frac{\partial v_{w,w}}{\partial b_i}\right]$$
$$t_i^f = V_{wes} \frac{\partial wes}{\partial v}\left[\frac{\partial v_{w,i}}{\partial f_i} + \frac{\partial v_{w,w}}{\partial f_i}\right] + V_{b_w} \frac{\partial b_w}{\partial v}\left[\frac{\partial v_{i,w}}{\partial f_i} + \frac{\partial v_{w,w}}{\partial f_i}\right]$$

Pesticide damage to honey bees

The third third case of externality caused by pollinator diffusion is that of pesticide damages to domestic honey bees which have long been a concern for beekeepers. In general, beekeepers and the growers they contract with coordinate the placement of hives and the timing of pesticide application to limit damage to bees. However, it is difficult for individual beekeepers to ensure that pesticides are applied nowhere in the entire foraging range of their hives. But here again, the externality caused by diffusion is one occurring among growers as long as the market for pollination services or honey locations is competitive. Indeed, a farmer surrounded by neighbors who apply pesticides during the bloom of his crop will have to compensate for bee losses or pay a risk premium to his beekeeper which will result in either higher pollination fees, or smaller location fees.

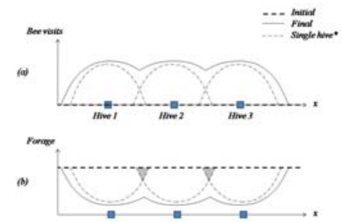
Crop damage from honey bee pollination

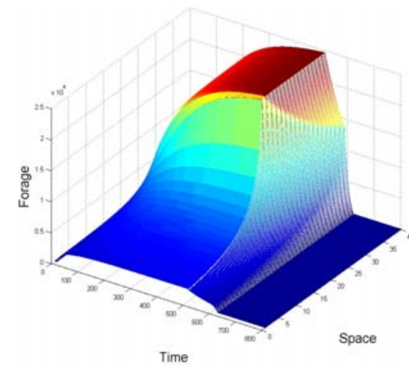
Cases where pollination visits by insects damage crops have been very rarely documented. \cite{Olmstead1987} reports that bees where thought once to be pests for alfalfa seed production but they turned out to be the opposite. A handful of authors argue that bees in large numbers may decrease crop yield, for instance by extracting large amounts of nectar and thus reducing the resources available to the plant for fruit production.

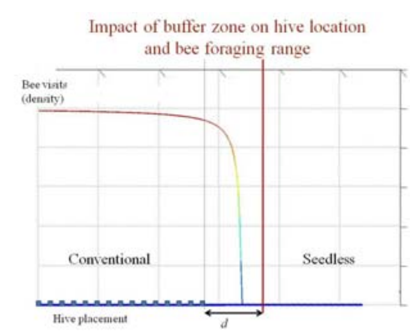
The difference in the political economy of beekeeping in the two regions provides reasonable candidate hypothesis to explain the difference in the resolutions of this negative pollination externality. In California, beekeepers have the support of a large almond industry to which they provide valuable pollination services. In the region of Valencia, citrus production is the single largest agricultural industry and beekeepers do not provide pollination services to any valuable crop.

Modeling foraging behavior and spatial diffusion of bees

$$C_i(i,t) = \frac{2d_i}{v} + \frac{LoadSize}{CollectionRateP_{i,t}/F_i} VisitDuration + UnloadDuration$$







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