THE FABLE OF THE BEES: AN ECONOMIC INVESTIGATION*

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> Economists possess their full share of the common ability to invent and commit errors. . . . Perhaps their most common error is to believe other economists.
>
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EVER since A. C. Pigou wrote his books on "welfare,"[1] a divergence between private and social costs has provided the main argument for instituting government action to correct allegedly inefficient market activities. The analysis in such cases has been designed less to aid our understanding of how the economic system operates than to find flaws in it to justify policy recommendations. Both to illustrate the argument and to demonstrate the nature of the actual situation, the quest has been for real-world examples of such defects.

Surprisingly enough, aside from Pigou's polluting factory and Sidgwick's lighthouse, convincing examples were hard to come by.[2] It was not until 1952, more than thirty years after Pigou's initial analysis, that J. E. Meade proposed further examples and revitalized the argument for corrective govern-

* Facts, like jade, are not only costly to obtain but also difficult to authenticate. I am therefore most grateful to the following beekeepers and farmers: Leonard Almquist, Nat Giacomini, Ancel Goolsbey, L. W. Groves, Rex Haueter, Harold Lange, Lavar Peterson, Elwood Sires, Clarence Smith, Ken Smith, John Steg, P. F. Thurber, and Mrs. Gerald Weddle. All of them provided me with valuable information; some of them made available to me their accounting records and contracts. R. H. Coase inspired the investigation, Yoram Barzel saw that it was conducted thoroughly, and Mrs. Lina Tong rendered her assistance. The investigation is part of a proposed research in the general area of contracts, financially supported by the National Science Foundation.

[1] A. C. Pigou, Wealth and Welfare (1912); and The Economics of Welfare (1920).

[2] Pigou had offered other examples. The example of two roads was deleted from later editions of The Economics of Welfare, presumably in an attempt to avoid the criticism by F. H. Knight in Some Fallacies in the Interpretation of Social Cost, 38 Q. J. Econ. 582 (1924). The railroad example has not enjoyed popularity. Most of Pigou's examples, however, were drawn from land tenure arrangements in agriculture, but an exhaustive check of his source references has revealed no hard evidence at all to support his claim of inefficient tenure arrangements.

ment actions.[3] Meade's prime example, which soon became classic, concerned the case of the apple farmer and the beekeeper. In his own words:

Suppose that in a given region there is a certain amount of apple-growing and a certain amount of bee-keeping and that the bees feed on the apple blossom. If the apple-farmers apply 10% more labour, land and capital to apple-farming they will increase the output of apples by 10%; but they will also provide more food for the bees. On the other hand, the bee-keepers will not increase the output of honey by 10% by increasing the amount of land, labour and capital to bee-keeping by 10% unless at the same time the apple-farmers also increase their output and so the food of the bees by 10%. . . . We call this a case of an unpaid factor, because the situation is due simply and solely to the fact that the apple-farmer cannot charge the beekeeper for the bees' food. . . .[4]

And Meade applied a similar argument to a reciprocal situation:

While the apples may provide the food of the bees, the bees may fertilize the apples. . . . By a process similar to that adopted in the previous case we can obtain formulae to show what subsidies and taxes must be imposed. . . .[5]

In another well-known work, Francis M. Bator used Meade's example to infer "market failure":

It is easy to show that if apple blossoms have a positive effect on honey production . . . any Pareto-efficient solution . . . will associate with apple blossoms a positive Lagrangean shadow-price. If, then, apple producers are unable to protect their equity in apple-nectar and markets do not impute to apple blossoms their correct shadow value, profit-maximizing decisions will fail correctly to allocate resources . . . at the margin. There will be failure "by enforcement." This is what I would call an *ownership* externality.[6]

It is easy to understand why the "apples and bees" example has enjoyed widespread popularity. It has freshness and charm: the pastoral scene, with its elfin image of bees collecting nectar from apple blossoms, has captured the imagination of economists and students alike. However, the universal credence given to the lighthearted fable is surprising; for in the United States, at least, contractual arrangements between farmers and beekeepers have long been routine. This paper investigates the pricing and contractual arrangements of the beekeeping industry in the state of Washington, the location having been

[3] See J. E. Meade, External Economies and Diseconomies in a Competitive Situation, 52 Econ. J. 54 (1952).

[4] *Id.* at 56-57.

[5] *Id.* at 58.

[6] Francis M. Bator, The Anatomy of Market Failure, 72 Q. J. Econ. 351, 364 (1958).

selected because the Pacific Northwest is one of the largest apple-growing areas in the world.

Contrary to what most of us have thought, apple blossoms yield little or no honey.[7] But it is true that bees provide valuable pollination services for apples and other plants, and that many other plants do yield lucrative honey crops. In any event, it will be shown that the observed pricing and contractual arrangements governing nectar and pollination services are consistent with efficient allocation of resources.

I. Some Relevant Facts of Beekeeping

Although various types of bees pollinate plants, beekeeping is confined almost exclusively to honeybees.[8] The hive used by beekeepers in the state of Washington is of the Langstroth design which consists of one or two brood chambers, a queen excluder, and from zero to six supers. A brood chamber is a wooden box large enough to contain eight or ten movable frames, each measuring 9-⅛ by 17-⅝ by 1-⅜ inches. Within each frame is a wax honeycomb built by the bees. In the hexagonal cells of this comb the queen lays her eggs and the young bees, or "brood," are raised. It is here also that the bees store the nectar and pollen which they use for food. Honey is not usually extracted from this chamber but from the frames of a shallower box, called a super, placed above the brood chamber. The queen excluder, placed between the super and the brood chamber, prevents the laying of eggs in the upper section.[9]

The bees, and consequently the beekeepers, work according to a yearly cycle. Around the beginning of March, a Washington beekeeper will decide whether he wants to prepare for the pollination season by ordering booster packages of bees from California to strengthen his colonies, depleted and

[7] The presence of apple honey in the market is therefore somewhat mysterious. While occasionally apple orchards in the Northwest do yield negligible amounts of nectar, beekeepers are frank to point out that the dandelion and other wild plants in the orchard are often the sources of "apple" honey, so called. Elsewhere, as in New York, it was reported that apple orchards yielded slightly more nectar. See, for example, A. I. & E. R. Root, The ABC and XYZ of Bee Culture 386 (1923). The explanation for this divergence of facts, to my mind, lies in the different lengths of time in which the hives are placed in the apple orchards: in Root's day the hives were probably left in the orchards for longer periods than today.

[8] See George E. Bohart, Management of Wild Bees, in U. S. Dep't of Agriculture, Beekeeping in the United States 109 (Ag. Handbook No. 335, 1971). [Hereinafter cited as Beekeeping. . .]. Leafcutters, for example, have recently been introduced for the pollination of alfalfa and clover seeds. But these bees yield no honey crop and are seldom kept.

[9] For further details see Spencer M. Riedel, Jr., Development of American Beehive, in Beekeeping. . . 8-9; A. I. & E. R. Root, *supra* note 7, at 440-58; Carl Johansen, Beekeeping (PNW Bulletin No. 79, rev. ed. March 1970).

weakened during the winter and early spring. Alternatively, he may decide to build up the colony by transporting the hives to farms or pastures in warmer areas, such as Oregon and California. The colony hatches continuously from spring to fall, and the growth rate is rapid. Reared on pollen, the infant bees remain in the brood stage for about three weeks before entering the productive life of the colony for five or six weeks. Active workers spend three weeks cleaning and repairing the brood cells and nursing the young, then live out the remainder of their short lives foraging for pollen and nectar.[10]

Because of the bees' quick growth, the working "strength" of a colony includes both brood and workers, and increases from about five frames in early spring to about twelve by late summer. Spring is the primary season for fruit pollination, and beekeepers usually market a standard colony strength of roughly four frames of bees and two to three frames of brood for pollination services. But since empty frames are needed to accommodate the expanding colony, two-story hives, with 16 or 20 frames, are used. The swarming period, beginning in mid-summer and lasting until early fall, is the peak honey season, and the yield per hive will vary positively with the colony strength. Because the maximization of honey yield requires that the colonies be of equal strength, they are usually reassorted in preparation for the major honey season, so that the number of colonies at the "peak" is generally larger than the number in spring.[11]

When pollen fails in late fall, the hives become broodless and the bee population begins to decline. During the idle winter months adult bees live considerably longer than in the active season, and they can survive the winter if about 60 pounds of nectar are left in the hive. But in the northern part of the state and in Canada, where cold weather makes the overwintering of bees more costly, the common practice is to eliminate the bees and extract the remaining honey. It should be noted here that bees can be captured, and that they can be easily eliminated by any of a large number of pesticide sprays.[12] The cost of enforcing property rights in nectar is therefore much lower than economists have been led to believe.

[10] For further details see Carl Johansen, *supra* note 9; F. E. Moeller, Managing Colonies for High Honey Yields, in Beekeeping. . . 23; E. Oertel, Nectar and Pollen Plants, in Beekeeping. . . 10.

[11] According to a survey conducted by Robert K. Lesser in 1968, based on a sample of 30 out of 60 commercial beekeepers in the state of Washington, the total number of peak colonies is 14.6% higher than that of spring colonies. See Robert K. Lesser, An Investigation of the Elements of Income from Beekeeping in the State of Washington 74 (unpublished thesis, Sch. of Bus. Admin., Gonzaga Univ., 1969).

[12] See, for example, A. I. & E. R. Root, *supra* note 9, at 97-103; Eugene Keyarts, Bee Hunting, Gleanings in Bee Culture 329-33 (June 1960); U.S. Dep't of Agriculture, Protecting Honey Bees from Pesticides (Leaflet 544, 1972); Carl A. Johansen, How to Reduce Poisoning of Bees from Pesticides (Pamphlet EM 3473, Wash. St. Univ., College of Ag., May 1971); Philip F. Torchio, Pesticides, in Beekeeping. . . 97.

Few agricultural crops, to my knowledge, exhibit a higher year-to-year variance of yield than does the honey crop. Several natural factors contribute. Cold weather and rain discourage the bees from working, and winds alter their direction of flight. Also, the nectar flows of plants are susceptible to shocks of heat and cold.[13] The plants yielding most honey are mint, fireweed, and the legumes, such as alfalfa and the clovers. Fruit trees usually have low nectar flows, although orange blossoms (in California) are excellent. Indeed, the pollination of fruits, especially the cherry in early spring, may actually detract from the yield of honey: less honey may be in the hive after pollination than was there initially, owing to the bees' own consumption. Another reason for the low honey yield from fruit trees is the relatively short time that the hives are left in the orchards.

Cross-pollination is accidentally effected as the bees forage for nectar and pollen. Pollination services were not marketed before World War I, primarily because small farms had enough flowering plants and trees to attract wild insects. It was not until 1910 and the advent of modern orcharding, with its large acreage and orderly planting, that markets for pollination services began to grow rapidly.[14] Today, the services are demanded not only for production of fruits but also for the setting (fertilizing) of seeds for legumes and vegetables. Evidence is incontrovertible that the setting of fruits and seeds increases with the number of hives per acre, that the pollination productivity of bees is subject to diminishing returns, and, despite some beekeepers' claims to the contrary, beyond some point the marginal productivity may even be negative.[15] There is also strong evidence that pollination yield will improve if the hives are placed strategically throughout the farm rather

[13] See E. Oertel, *supra* note 10; C. R. Ribbands, The Behaviour and Social Life of Honeybees 69-75 (1953); Roger A. Morse, Placing Bees in Apple Orchards, Gleanings in Bee Culture 230-33 (April 1960). Owing to its weather, Washington is not one of the better honey yielding states in the Union. Data made available to me by the U. S. Dep't of Agriculture indicates that over the years (1955-1971) Washington ranks 24th among 48 states in yield per colony and 20th in the total number of colonies. The U.S. Dep't of Agriculture data, like those obtained by Lesser, provide no information on the different honey yields and pollination requirements of various plants and are therefore of little use for our present purpose. It should be noted that the U.S. Dep't of Agriculture overall yield data are significantly lower than those obtained by Lesser and by me. See Robert K. Lesser, *supra* note 11.

[14] See M. D. Levin, Pollination, in Beekeeping. . . 77.

[15] *Id.*; 9th Pollination Conference, Report, The Indispensable Pollinators (Ag. Extension Serv., Hot Springs, Ark., October 12-15, 1970); G. E. Bohart, Insect Pollination of Forage Legumes, 41 Bee World 57-64, 85-97 (1960); J. B. Free, Pollination of Fruit Trees, 41 Bee World 141-51, 169-86 (1960); U.S. Dep't of Agriculture, Using Honey Bees to Pollinate Crops (Leaflet 549, 1968); Get More Fruit with Honey Bee Pollinators (Pamphlet EM 2922, Wash. St. Univ., March 1968); Protect Berry Pollinating Bees (Pamphlet EM 3341, Wash. St. Univ., February 1970); Increase Clover Seed Yields with Adequate Pollination (Pamphlet EM 3444, Wash. St. Univ., April 1971); Honey Bees Increase Cranberry Production (Pamphlet EM 3468, Wash. St. Univ., April 1971).

than set in one spot.[16] The closer a particular area is to a hive, the more effective will be the pollination within that area. Although each individual bee will forage only a few square yards, the bees from one hive will collectively pollinate a large circular area,[17] and this gives rise to a problem: given a high cost to control fully the foraging behavior of bees, if similar orchards are located close to one another, one who hires bees to pollinate his own orchard will in some degree benefit his neighbors. This complication will be further discussed in the next section.

In the state of Washington, about 60 beekeepers each own 100 colonies or more; at the peak season the state's grand total of colonies is about 90,000. My investigation, conducted in the spring of 1972, covered a sample of nine beekeepers and a total of approximately 10,000 spring colonies. (One of these beekeepers specialized in cut-comb honey and he will be treated separately in a footnote.) Table 1 lists the bee-related plants covered by my investigation. As seen from Columns (3) and (4), some plants (such as cherry trees) require pollination services for fruit setting but yield no honey; some (such as mint) yield honey while requiring no pollination service; and some (such as alfalfa) are of a reciprocal nature. Note that when alfalfa and the clovers are grown only for hay, pollination services are not required, although these plants yield honey.

The practice of relocating hives from farm to farm, by truck, enables the beekeeper to obtain multiple crops a year, either in rendering pollination service or in extracting honey. However, while the maximum observed number of crops per hive per year is four and the minimum is two, my estimate is that a hive averages only 2.2 crops a year. More frequent rotation not only involves greater costs of moving and of standardizing hives, but abbreviates the honey yield per crop. In the southern part of the state, where the relatively warm climate permits an early working season, beekeepers usually begin by pollinating either cherry or almond (in California) in early spring. The hives may or may not then be moved northward in late spring, when apple and soft fruits (and some late cherry) begin to bloom.[18]

The lease period for effective pollination during spring bloom is no more than a week. But then, for a month or two between the end of fruit pollina-

[16] See, for example, Douglas Oldershaw, The Pollination of High Bush Blueberries, in The Indispensable Pollinators, *supra* note 15, at 171-76; Roger A. Morse, *supra* note 13.

[17] There is, however, little agreement as to how far a bee could fly: estimated range is from one to three miles. For general foraging behavior, see M. D. Levin, *supra* note 14, at 79; O. W. Park, Activities of Honeybees, in The Hive and the Honeybee 125, 149-206 (Roy A. Grout ed., 1946); C. R. Ribbands, *supra* note 13.

[18] Following the practice of local beekeepers, we use the term "soft fruit" to refer to peaches, pears, and apricots, generally grown in the same area, and often in the same orchard, as apples. (By standard usage, the term refers only to the various berry plants.)

TABLE 1
BEE-RELATED PLANTS INVESTIGATED
(State of Washington, 1971)

(1) Plants	(2) Number of Beekeepers	(3) Pollination Services Rendered	(4) Surplus Honey Expected	(5) Approximate Season	(6) Number of Hives Per Acre (range)
Fruits & Nuts					
Apple & Soft Fruits[a]	7	Yes	No	Mid-April—Mid-May	0.4 to 2
Blueberry (with maple)	1	Yes	Yes	May	2
Cherry (early)	1	Yes	No	March—Early April	0.5 to 2
Cherry	2	Yes	No	April	0.5 to 2
Cranberry	2	Yes	Negligible	June	1.5
Almond (Calif.)	2	Yes	No	February—March	2
Legumes					
Alfalfa	5	Yes and No[c]	Yes	June—September	0.3 to 3
Red Clover	4	Yes and No	Yes	June—September	0.5 to 5
Sweet Clover	1	No[d]	Yes	June—September	0.5 to 1
Pasture[b]	4	No	Yes	Late May—September	0.3 to 1
Other Plants					
Cabbage	1	Yes	Yes	Early April—May	1
Fireweed	2	No	Yes	July—September	n.a.
Mint	3	No	Yes	July—September	0.4 to 1

[a] Soft fruits include pears, apricots, and peaches.

[b] Pasture includes a mixture of plants, notably the legumes and other wild flowers such as dandelions.

[c] Pollination services are rendered for alfalfa and the clovers if their seeds are intended to be harvested; when they are grown only for hay, hives will still be employed for nectar extraction.

[d] Sweet clover may also require pollination services, but such a case is not covered by this investigation.

tion and the beginning of summer nectar flow, the hives have little alternative usage. Since this period is substantially longer than the time needed for the beekeeper to check and standardize his hives for the honey crops, he will generally be in no hurry to move them and will prefer to leave them in the orchards with no extra charge, unless the farmer is planning to spray with insecticide. The appropriate seasons for the various plants listed in Column (5) of Table 1, may not, therefore, match the lengths of hive leases. Lease periods are generally longer for honey crops, for the collection of nectar takes more time.

The sixth column in Table 1 indicates the various hive-densities employed. The number of hives per acre depends upon the size of the area to be serviced, the density of planting, and, in the case of fruit pollination, the age of the orchards. For the pollination of fruits, the hives are scattered throughout the farm, usually with higher densities employed in older orchards because the trees are not strategically placed to facilitate the crossing of pollen. The most popular choices are one hive per acre and one hive per two acres. It is interesting, and easily understood, that farmers demand significantly fewer hives for pollination than the number recommended by entomologists:[19] both are interested in the maximization of yield, but for the farmer such maximization is subject to the constraint of hive rentals. When bees are employed to produce honey only, the hives are placed together in one location, called an apiary, for greater ease of handling.[20] The relatively large variation in hive densities required if legumes are, or are not, to be pollinated is discussed in the next section.

Before we turn to an analysis of the pricing and contractual behavior of beekeepers and farmers, I must point out that the two government programs which support the beekeeping industry did not constitute relevant constraints for the period under investigation. The honey price-support program, initiated in 1949, involves purchase of honey at supported prices by the Commodity Credit Corporation.[21] For the period under investigation, however, the supported price was about 20 per cent lower than the market price.[22] Section 804 of the Agricultural Act of 1970, effectuated in 1971 and designed to reimburse beekeepers for any loss due to pesticide sprays, has been largely ignored by

[19] See note 15 *supra*.

[20] See, for example, W. P. Nye, Beekeeping Regions in the United States, in Beekeeping . . . 17.

[21] See Harry A. Sullivan, Honey Price Support Program, in Beekeeping . . . 136.

[22] From 1970 to 1972 the supported prices were near 11.5 cents per pound, whereas the market wholesale price was above 14 cents per pound. Between 1950 and 1965 were seven years in which the CCC purchased no honey, and two years of negligible amounts. See Harry A. Sullivan, *supra* note 21, at 137.

beekeepers because of the difficulty of filing effective claims with the federal government.[23]

II. The Observed Pricing and Contractual Behavior

It is easy to find conclusive evidence showing that both nectar and pollination services are transacted in the marketplace: in some cities one need look no further than the yellow pages of the Telephone Directory. But the existence of prices does not in itself imply an efficient allocation of resources. It is, therefore, necessary to demonstrate the effectiveness of the market in dictating the use even of those resources—bees, nectar, and pollen—which, admittedly, are elusive in character and relatively insignificant in value. In doing so, I shall not attempt to estimate the standard sets of marginal values which an efficient market is said to equate: the burden of such a task must rest upon those who believe the government can costlessly and accurately make these estimates for the imposition of the "ideal" tax-subsidy schemes. Rather, I offer below an analysis based on the equimarginal principle. To the extent that the observed pricing and contractual behavior fails to falsify the implications derived from this analysis we conclude that (1) the observed behavior is explained, and (2) the observations are consistent with efficient allocation of resources.

A. *The Analysis*

The reciprocal situation in which a beekeeper is able to extract honey from the same farm to which he renders pollination services poses an interesting theoretic riddle. The traditional analysis of such a condition relies on some interdependent production functions, and is, I think, unnecessarily complex.[24] The method employed here simply treats pollination services and honey yield as components of a joint product generated by the hive. That is, the rental price per hive received by a beekeeper for placing his hives on a farm may be paid in terms of honey, of a money fee, or of a combination of both. The money fee or the honey yield may be either positive or negative, but their total measures the rental value of the hive.

[23] See 7 U.S.C. § 135 b, note (1970); Pub. L. No. 91-524 § 804. My judgment is based both on the behavior of beekeepers (see next section) after the initiation of the Act and on the complexity of relevant claim forms which I have at hand. In April 1972 beekeepers associations were still lobbying for easier claiming conditions.

[24] In J. E. Meade, *supra* note 3, at 58, this problem is set up in terms of the interdependent functions $x_1 = H_1 (l_1, c_1, x_2)$ and $x_2 = H_2 (l_2, c_2, x_1)$. I find Meade's analysis difficult to follow. Elsewhere, Otto A. Davis and Andrew Whinston employ the functions $C_1 = C_1 (q_1, q_2)$ and $C_2 = C_2 (q_1, q_2)$ in their treatment of certain "externalities." It is not clear, however, that the authors had the bee example in mind. See Otto A. Davis & Andrew Whinston, Externalities, Welfare, and the Theory of Games, 70 J. Pol. Econ. 241 (1962).

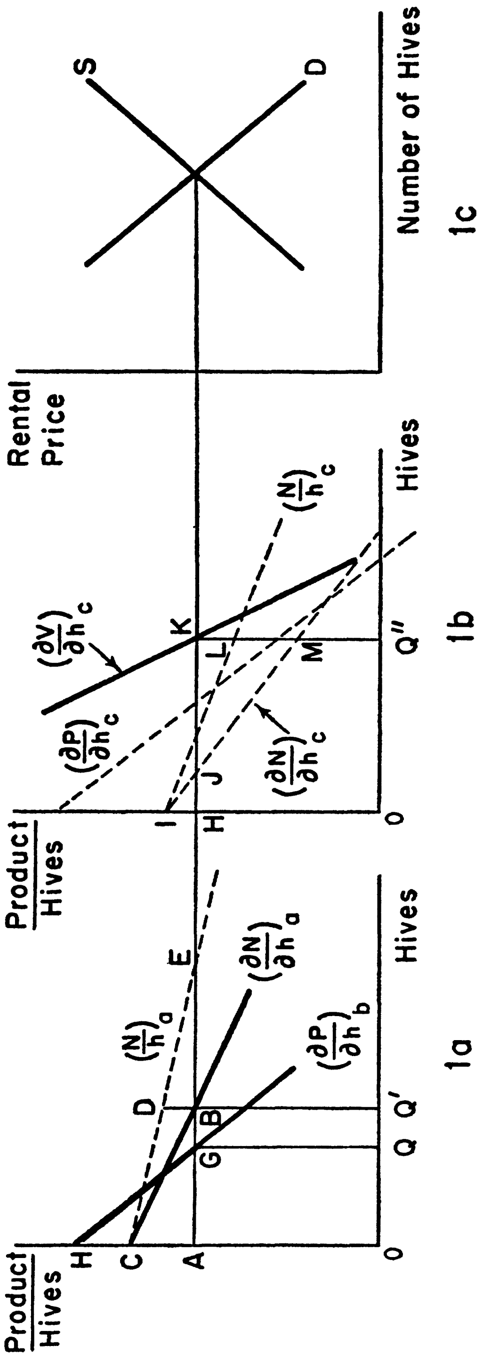
Product/Hives
Hives
1a
Product/Hives
Hives
1b
Rental Price
Number of Hives
1c

Figure I

The solution is illustrated in Figure I. We assume that the hives are always strategically placed. In Figure Ia the curve $(\partial N/\partial h)_a$ depicts the value of the marginal nectar product of a farm in which beehives are used *only* for the extraction of nectar (as with fireweed, mint, or alfalfa grown only for hay), with the farming assets held constant. Given the market-determined rental price of OA per hive, constrained wealth maximization implies that OQ′ of hives will be employed. In this case, the beekeeper will be remunerated only in honey, and will pay an *apiary rent* equal to area ABC (or DB per hive) to the farmer. The curve $(\partial P/\partial h)_b$, on the other hand, depicts the value of the marginal pollination product for a farm which employs hives for pollination *only* (as with cherry or apple orchards). Here the number of hives employed will be OQ, which again is the result of wealth maximization. With zero honey yield, the money pollination fee per hive is again OA, and the *orchard rent* is represented by the area AGH.

We now turn to the joint product case in Figure Ib, where hives are used both for pollination and for the extraction of nectar (as in the setting of alfalfa and clover seeds). The curves $(\partial P/\partial h)_c$ and $(\partial N/\partial h)_c$ respectively are the values of marginal pollination and of marginal nectar products. Their *vertical* summation, the solid line $(\partial V/\partial h)_c$, is the total marginal value. Wealth maximization implies the employment of OQ″ of hives, the point where the rental price per hive equals the aggregate marginal value. As drawn, area HIJ is smaller than area JKM. This implies that the value of the *average* nectar product, $(N/h)_c$, must pass below point K, as it does here at L. In this case the rental price per hive, KQ″, will consist of LQ″ in honey yield and KL in pollination fee. For this joint product situation, of course, it is possible to construct a case in which $(N/h)_c$ passes above point K, thus yielding an apiary rent. It is also possible to construct cases where the number of hives employed yields zero or negative marginal productivity, in either nectar or pollination. In other words, *zero or negative marginal productivity in one component of the joint product is consistent with efficient allocation of resources.*

Under open competition, there are large numbers of potential participants in each of the cases above. The aggregate total marginal value curve for the market, or the market demand for hives, is therefore the horizontal summation of a large number of the *solid* curves in Figures Ia and Ib. Similarly, the market supply of hives is the horizontal summation of the marginal costs of producing and keeping hives of all actual and potential beekeepers. Both market curves are shown in Figure Ic.[25] Assuming no costs for collating bids

[25] More variables are usually used in the derivation of these curves, but for our present purpose little is gained by incorporating them.

and asks or for forming rental contracts among all actual and potential participants, the price per hive, OA, is determined in the market. The Pareto condition is satisfied: the value of the marginal product of a hive is the same on every farm, and in turn equals the rental price and the marginal opportunity cost of producing the hive.

B. *Tests of Implications*

Before we derive and test some implications of the above analysis, it is necessary to point out the limitations of the information at hand. Since no attempt is made to estimate the marginal values or the elasticities of the marginal products, we will seek to confirm the marginal equalities with some observed average values. These include apiary rent, pollination fees, honey yields per hive, and the wholesale price of honey. We also have information on the number of hives employed on different farms, and some other numerical data. My choice of data for the honey yield per hive, however, must be qualified. The large fluctuations in yield from year to year and even from farm to farm caused by uncontrollable natural phenomena makes the use of the actual observed yields of a particular year, or even of a few years, irrelevant for our purposes. Take, for example, the exceptionally poor year of 1971 when, in many cases, the yield per hive was just one-third of that in a normal year. This windfall loss is irrelevant for decision-making (although the expected variance is relevant), and it cannot be attributed to market "failure." Lacking sufficient data to compute the honey yield per hive extracted from various plants over time, I resort to the expected yields as reported by beekeepers. Fortunately, their estimates for yields under comparable conditions exhibit remarkable consistency.

An overall view of the pricing structure is shown in Table 2. Since a hive has different rental values for different seasons, we divide the time period into three productive seasons: early spring, late spring, and the honey season (summer to fall). Surplus honey is not expected in the early spring season, although nectar may accumulate in the brood chamber and there may be a gain in brood strength. Most beekeepers in the state are idle during this season, and pollination is confined to almond in California or cherry in the southern part of Washington. The rental value of hives is the highest in the major pollination season of late spring (April to June), second highest in the major honey season, and lowest in the early spring (March).

The pollination fees listed in Table 2 are based on 1971 data, but they have remained roughly constant from 1970 to 1972. The wholesale honey prices, however, are based on 1970 and early 1971 data, as the unexpectedly low honey yield throughout the country in 1971 generated a a sharp rise in prices (from 14 cents a pound in April 1971 to 32 cents a pound in March

TABLE 2
PRICING SCHEMES AND EXPECTED HONEY YIELDS OF BEE-RELATED PLANTS
(State of Washington, 1970-1971)

Seasons	Plants	Surplus Honey Expected (pounds per hive)	Honey Prices Per Pound (wholesale, 1970)	Pollination Fees (range, 1971)	Approximate Apiary Rent Per Hive (range, 1970-1)
Early Spring	Almond (Calif.)	0	—	\$5–\$8	0
	Cherry	0	—	\$6–\$8	0
Late Spring (major pollination season)	Apple & Soft Fruits	0	—	\$9–10	0
	Blueberry (with maple)	40	14¢	\$5	0
	Cabbage	15	13¢	\$8	0
	Cherry	0	—	\$9–\$10	0
	Cranberry	5	13¢	\$9	0
Summer and Early Fall (major honey season)	Alfalfa	60	14.5¢	0	13¢–60¢
	Alfalfa (with pollination)	25–35	14.5¢	\$3–\$5	0
	Fireweed	60	14.5¢	0	25¢–63¢
	Mint	70–75	11¢	0	15¢–65¢
	Pasture	60	14¢	0	15¢–65¢
	Red Clover	60	14¢	0	65¢
	Red Clover (with pollination)	0–35	14¢	\$3–\$6	0
	Sweet Clover	60	14¢	0	20¢–25¢

1972). The apiary rents are paid mostly in refined and bottled honey, and are therefore converted into money values according to 1970 retail honey prices. To maintain consistency with pollination fees, the apiary rents are computed per hive, although in the latter contracts the number of hives is not stipulated.

The following test implications are derived from our analysis:

(1) Our first implication is that, at the same season and with colonies of the same strength, the rental price per hive obtained from different farms or by different beekeepers will be roughly the same whether the hive is employed for pollination, for honey production, or for a combination of both. By "roughly the same" I do not mean that hive rentals are invariable among different beekeepers. Rather, I mean that (a) any differences which do occur are statistically no more significant than those for most other commodities in the market, and that (b) there is a strong *negative* correlation between the pollination fee (hive rental in money) and the expected honey yield (hive rental in kind).

Data from the early spring season are not suitable to test this implication because during this period there are great variations in colony strength, in the gains in brood and unextracted nectar, and in distances travelled by beekeepers to deliver the hives.[26] Lacking sufficient information to make appropriate adjustments for these variations in calculating the rental price per hive, we concentrate on data from the late spring and summer seasons.

In contracting for pollination services, beekeepers offer discounts for larger numbers of hives and for less elaborate hive dispersals. Of the four beekeepers from whom detailed records are available, for example, each served from 10 to 14 farms of apples and soft fruits; their mean hive rentals in the major pollination season ranged from $9.20 to $9.68 and their coefficients of variation from 0.025 to 0.053.[27] To reduce the effects on price generated by discounts, we use the mean rentals for the above four beekeepers and the reported means from beekeepers who did not maintain records. Our data thus comprise separate observations of the mean hive rental of each beekeeper, of each different plant, and (for the summer season) of each different

[26] In the pollination of almond, for example, $5.00 is charged for a one-story hive and $6.00 to $8.00 for a two-story hive. On the one hand, Washington beekeepers have to travel to California to obtain this amount when they could have earned the same fee locally in the pollination of early cherry. On the other hand, however, the brood gain is greater with almond than with cherry; also, unextracted nectar in the brood chamber gains significantly in the case of almond but is likely to suffer a net loss with early cherry.

[27] An analysis of variance performed for these four beekeepers shows no significant difference in their mean rentals in the pollination of apple and soft fruits. However, the coefficient of variation of their means, 0.018, is lower than those computed from a larger body of data. This simply indicates a very low variation among the four who provided detailed records.

expected honey yield for the same plant. The latter separation is requisite because the expectation of honey yield varies greatly depending on whether pollination is, or is not, required in the case of such plants as alfalfa.

The coefficient of variation of the mean hive rentals among beekeepers who engaged in the pollination of apples (including soft fruits) and cherries (9 observations in total) is 0.035. The expected honey yield for these observations is zero. When we extend the computation to include cranberry, blueberry and cabbage pollination (13 observations in total), with expected honey yields converted into monetary terms and added to the pollination fees, the coefficient of variation is 0.042. We may meaningfully compare our coefficients of variations with those cited by George Stigler:[28] automobile prices (0.017) and anthracite coal prices (0.068).

Another, and more illuminating, way of testing our implication is through the relationship

$$x_0 = x_1 + x_2, \qquad (1)$$

where x_0 is the total rent per hive, x_1 is the rent paid in money, and x_2 is the expected rent paid in nectar. During the major pollination season, x_1 is positive for all our observations, but during the summer honey season negative values for x_1 (that is, payments in apiary rents) are common. As noted earlier, x_2 may also be positive or negative, but it is generally either zero or positive for the late spring and summer seasons. In the major pollination season, the mean values of equation (1) are \$9.65 = \$9.02 + \$0.64.

The variance of x_0 can be broken down to

$$\sigma^2_{x_0} = \sigma^2_{x_1} + \sigma^2_{x_2} + 2\,\mathrm{Cov}\,(x_1, x_2). \qquad (2)$$

With a total of 13 observations in late spring, the corresponding values are

$$0.166 = 1.620 + 2.317 - 3.771.$$

The variability in x_1 is almost entirely accounted for by the variability in x_2, as reflected by the large negative covariance term. The coefficient of correlation between x_1 and x_2 is −0.973.

Turning to the summer honey season, we have a total of 23 observations, covering mint (3), fireweed (2), pasture (4), sweet clover (1), red clover (6), and alfalfa (7). The mean values of equation (1) are \$8.07 = \$1.30 + \$6.77. The values corresponding to equation (2) are

$$0.806 = 5.414 + 6.182 - 10.791.$$

Again, most of the variability in x_1 is strongly and negatively correlated with that of x_2. The remaining variance for x_0 (with a coefficient of variation of

[28] George J. Stigler, The Economics of Information, 69 J. Pol. Econ. 213 (1961).

0.111) is larger here than in the major pollination season. This can be explained as follows. First, high risks are associated with the expected honey yields, and beekeepers seem willing to settle for lower, but more certain, incomes. Since x_1 is more certain than x_2, beekeepers seem willing to accept a lower x_0 with a higher ratio of x_1 to x_2,[29] and the variability in this ratio is larger in summer than in spring. Similarly, they will accept a lower expected mean of x_2 for mint than for other honey crops, since mint is generally known to have the smallest variance in expected honey yield of any crop in the state.[30] A second, and more important, factor contributing to the larger variance of x_0 is the premium paid to beekeepers to assume the risk of pollinating crops (notably red clover) where the use of pesticide sprays on neighboring farms poses the danger of loss of bees. Since our information is inadequate to support adjustments for these factors, the resultant distortions must remain. Even so, the coefficient of correlation between x_1 and x_2 computed from the data is —0.933.

(2) The preceding evidence confirms that the rental prices of hives employed in different uses by different beekeepers lie on a roughly horizontal line. However, it does not confirm that these prices are equated to the marginal productivities. Refer to Figure I, for example: the employment of hives might be at a point such as E rather than at G, B, or K. We now turn to some testable implications regarding the tendency toward the equalization of price and marginal productivity.

One obvious implication is that, if the employment of hives renders no valuable pollination services, then an apiary rent will always be observed. In the entire body of evidence available to me, there is not a single observation to the contrary,[31] and this means, referring to Figure Ia, that the employment

29 This statement is drawn only from casual conversations with beekeepers; no attempt was made to seek refuting evidence.

30 Inconclusive evidence indicates that hive rentals (paid in honey) obtained from mint is about 40 cents less than those obtained from other honey-yielding plants. Although available information is insufficient for us to compute the year-to-year variances of the honey yields of different plants, ranges of yields as recalled by beekeepers are larger than most agricultural crops.

Because honey from mint has an undesirably strong flavor that excludes it from the retail market, it is either sold to bakeries or used to feed bees during the winter. Quite understandably, onion honey shares the distinction of being much cheaper than any other. Generally rated as the best is orange honey, which commands a wholesale premium of about 1 to 2 cents a pound. Between the extremes, different varieties of honey have roughly the same value and are graded more by clarity than by taste.

31 One beekeeper specializing in cut-comb honey reported that he pays apiary rents even though no surplus honey is expected, provided that gains in brood strength and in unextracted nectar are expected to be substantial, as when the hives are placed in a farm with maples. This beekeeper is excluded from our first test of implication because he did not engage in pollination and his colonies were of greater strengths.

of hives is to the left of point E. It should be noted here that even in the absence of demand for pollination some is effected when bees forage for nectar from alfalfa and the clovers, but this is not to be treated as a service unless the seeds are harvested.

Less obvious implications can be obtained from the case of a farm where hives may be employed for nectar extraction only *or* jointly with pollination services. When we discussed the reciprocal case, as depicted in Figure Ib, it was noted that either an apiary rent or a pollination fee may be paid. With simple manipulation, the following implications are evident:

(a) If an apiary rent is paid in the case of a joint product, and if the marginal pollination product is positive, the number of hives employed per acre is necessarily greater than where bees are used only for nectar extraction on the same or a similar farm.

(b) If a pollination fee is paid in the case of a joint product, the number of hives employed per acre is necessarily greater than where bees are used only for nectar extraction on the same or a similar farm.

While both implications indicate a tendency toward point K (in Figure Ib), we lack sufficient information regarding the marginal pollination product to test (a) above. But since in every available observation involving pollination and nectar extraction a pollination fee is paid, only implication (b) is relevant for our purposes.

The evidence, obtained from red clover and alfalfa farms, strongly confirms the implication. The density of hives employed is at least twice as great when the bees are used for both pollination service and nectar extraction as when used for nectar extraction only. As a rule, this increase in hive density leads to a sharp decrease in the expected honey yield per hive. In the typical case, the density of hives in alfalfa and clover farms for pollination services is about 2.5 times what would be employed for nectar extraction only, and the expected honey yield per hive is reduced by 50 per cent. This indicates the marginal nectar product of a hive is close to zero and possibly negative. In

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Cut-comb honey is more expensive than ordinary honey because the comb wax, which goes with the honey, is about three times the price of honey per pound. Only honey of top grades (very clear) will be extracted. This observation is implied by the law of demand, since with the comb top-grade honey becomes relatively cheap. Implied by the same law also is that this beekeeper chooses to forgo pollination contracts so that a higher honey yield can be obtained (see evidence in implication test 2). Even during the major pollination season, when little honey can be expected, he prefers to place his hives in farms where the colonies will gain greater strength than would occur if they were used for pollination. For a related discussion on similar implications of the law of demand, see Armen A. Alchian & William R. Allen, Exchange and Production: Theory in Use 78–79 (1969). These implications are accepted here in spite of the criticisms in John P. Gould & Joel Segall, The Substitution Effects of Transportation Costs, 77 J. Pol. Econ. 130 (1969).

one extreme case, in a red clover farm the hive density with pollination services is reported at about seven or eight times that for nectar extraction only; since the expected honey yield is then reduced to zero, the marginal nectar product of the hive is clearly negative! But, as noted earlier, zero or negative marginal product in one component of a joint product is consistent with efficient allocation of resources.

(3) It remains for us to show that the rental price of a hive is roughly equal to the marginal cost of keeping it. Lacking data on marginal cost, we will show that the price approximates the average cost, as implied by competition. We will make the comparison in terms of some general considerations. The expected annual income of a spring colony under a normal rate of utilization, as of 1970-1971, is about $19.00. This includes rentals from a pollination crop, a honey crop, an occasional extra crop (for some hives), and a small amount from the sale of beeswax.[32] The costs of delivering or moving a hive and of finding and contracting the farmers for its use are estimated to total about $9.00 per year.[33] This figure is obtained as follows. Some beekeepers lease some of their hives to other beekeepers on a share contract basis; the lessor receives 50 to 55 per cent of whatever income in money and in kind the lessee obtains from the farmers. Since the lessor could have contracted to serve the farmers himself and obtained the entire income of the $19.00, the fact that he has chosen to take 45 to 50 per cent less indicates that $9.00 must approximate such costs. The interest forgone in keeping a hive is about $3.00 per year.[34] The cost of renewing the colony strength in early spring is about $4.50, the price of a standard booster package of bees.[35] This leaves about $2.50 to cover the costs of depreciation of the hive value, the labor involved in checking and standardizing hives, space for keeping hives in the winter, and the equipment used for honey extraction.

[32] In Lesser's investigation (*supra* note 11) the actual mean annual income of a spring colony for the year 1967 was estimated to be $14.71, and the actual honey yields of that year were slightly larger than our expected honey yields. But in 1967 the price of honey was about 16% lower than that in 1970; and Lesser's estimate of pollination income per hive is about 37% lower than mine, owing both to a rise in pollination fees in recent years and to different samplings of beekeepers. According to Lesser's estimate, beeswax constitutes 4.4% of the beekeeper's total income.

[33] The moving costs cover labor, truck, and other hive-handling equipment. Depending on the time of the year, a complete hive (with supers) weighs somewhere between 80 and 250 pounds.

[34] A complete hive, used but in good condition, sells for about $35.00. The borrowing rate of interest for the beekeepers is around 8%.

[35] The nectar left unextracted in the brood chamber, which constitutes the major cost of overwintering, is not counted as part of income and therefore is not counted as part of the cost.

C. *Characteristics of the Contractual Arrangements*

Contracts between beekeepers and farmers may be oral or written. I have at hand two types of written contracts. One is formally printed by an association of beekeepers; another is designed for specific beekeepers, with a few printed headings and space for stipulations to be filled in by hand.[36] Aside from situations where a third party demands documented proof of the contract (as when a beekeeper seeks a business loan), written contracts are used primarily for the initial arrangement between parties; otherwise oral agreements are made. Although a written contract is more easily enforceable in a court of law, extra-legal constraints are present: information travels quickly through the closely knit society of beekeepers and farmers,[37] and the market will penalize any party who does not honor his contracts. Oral contracts are rarely broken.

Pollination contracts usually include stipulations regarding the number and strength of the colonies, the rental fee per hive, the time of delivery and removal of hives, the protection of bees from pesticide sprays, and the strategic placing of hives. Apiary lease contracts differ from pollination contracts in two essential aspects. One is, predictably, that the amount of apiary rent seldom depends on the number of colonies, since the farmer is interested only in obtaining the rent per apiary offered by the highest bidder. Second, the amount of apiary rent is not necessarily fixed. Paid mostly in honey, it may vary according to either the current honey yield or the honey yield of the preceding year.[38]

In general, contractual arrangements between beekeepers and farmers do not materially differ from other lease contracts. However, some peculiar arrangements resulting from certain complications are worth noting. First, because of the foraging behavior of the bees a farmer who hires bees may benefit his neighbors. Second, the use of pesticide sprays by one farmer may cause

36 Some beekeepers use just postal cards. The general contractual details reported below are similar to those briefly mentioned in Grant D. Morse, How About Pollination, Gleanings in Bee Culture 73–78 (February 1970).

37 During my conversations with beekeepers, I was impressed by their personal knowledge of one another, including details such as the number of hives owned, the kinds of farms served, and the rents received.

38 While we may attribute this behavior to the aversion of risks, the apiary contracts are not the same as share contracts. Rather, they resemble fixed-rent contracts with what I have called "escape clauses." For discussion of the "escape clause" and the stipulations of the share contract, see Steven N. S. Cheung, The Theory of Share Tenancy, ch. 2 & 4 (1969). One impression I obtain is that apiary rents generally involve such low values in Washington that elaborate formations and enforcements of apiary contracts are not worthwhile. In further investigations of these contracts, states with higher honey yields are recommended.

damage to the bees on an adjacent farm. And third, fireweed, which yields good honey, grows wild in forests. Let us discuss each in turn.

The Custom of the Orchards. As noted earlier, if a number of similar orchards are located close to one another, one who hires bees to pollinate his own orchard will in some degree benefit his neighbors. Of course, the strategic placing of the hives will reduce the spillover of bees. But in the absence of any social constraint on behavior, each farmer will tend to take advantage of what spillover does occur and to employ fewer hives himself. Of course, contractual arrangements could be made among all farmers in an area to determine collectively the number of hives to be employed by each, but no such effort is observed.

Acknowledging the complication, beekeepers and farmers are quick to point out that a social rule, or custom of the orchards, takes the place of explicit contracting: during the pollination period the owner of an orchard either keeps bees himself or hires as many hives per area as are employed in neighboring orchards of the same type. One failing to comply would be rated as a "bad neighbor," it is said, and could expect a number of inconveniences imposed on him by other orchard owners.[39] This customary matching of hive densities involves the exchange of gifts of the same kind, which apparently entails lower transaction costs than would be incurred under explicit contracting, where farmers would have to negotiate and make money payments to one another for the bee spillover.[40]

The Case of Pesticide Sprays. At the outset, we must remember that to minimize the loss of bees from insecticide usage is not necessarily consistent with efficient allocation of resources. The relevant consideration is whether the gain from using the pesticide is greater than the associated loss of bees, in total and at the margin. Provided that the costs of forming con-

[39] The distinction between an oral or an implicit contract and a custom is not always clear. A common practice in some areas is that each farmer lets his neighbors know how many hives he employs. Perhaps the absence of a court of law to enforce what could in fact be a highly informal agreement is the reason why farmers deny the existence of any contract among them governing the employment of hives.

[40] Since with a sufficiently high reward the notoriety of being a "bad neighbor" will be tolerated, the likelihood of explicit contracting rises with increasing rental values of hives. Alternatively and concurrently, with a high enough rental price of hives the average size of orchards may increase through outright purchases, or the shapes of the orchards may be so tailored as to match the foraging behavior of the bees. By definition, given the gains the least costly arrangement will be chosen.

Some beekeepers reported that there are peculiar situations where the foraging behavior of the bees forces a one-way gift, but these situations are not covered by the present investigation. Even under these rare situations, the absence of both contractual and customary restraints may not result in a different allocation of resources. See Steven N. S. Cheung, The Theory of Inter-individual Effects and The Demand for Contracts (Univ. of Washington, Inst. of Econ. Res.).

tracts permits, beekeepers and farmers will seek cooperative arrangements such that the expected marginal gain from using the pesticide is equal to the value of the expected marginal bee loss. In the absence of the arrangements, however, the total gain from using the pesticide may still be greater than the associated loss; the greater the expected damage done to bees, the greater will be the gain from the cooperative arrangements.[41]

When a pollination contract is formed, the farmer usually agrees to inform the beekeeper before spraying his crop, but this assurance will not protect the bees from pesticide used on neighboring farms. In areas dominated by orchards which require pollination at roughly the same time, such as the apple-growing districts, this agreement will suffice, for no farmer will apply the spray during the pollination period. But in regions where adjacent farms require bee pollination at different times, or do not require it at all, a farmer with no present obligation to any beekeeper may spray his fields and inflict damages to the bees rented by other farms. In this situation, only cooperation over a large geographic area can avoid bee loss, and we find just such arrangements in the pollination of cranberries but not of red clover.

Cranberry farms near Seattle are usually found in clusters, and spraying is conducted shortly after the bloom, which may vary by as much as a week or two among neighboring farms. Although each cranberry grower agrees not to spray until the contracted beekeeper removes the bees from his farm, this does not protect bees which may still remain on adjacent farms. Therefore the beekeepers make a further arrangement among themselves to remove all hives on the same date, thus insuring that all the bees are protected.

Red clover presents a different situation. Since the plant is often grown in areas where neighboring farms require no bee pollination, the pesticide danger is reportedly high and beekeepers demand an additional $1.00 to $2.00 per hive to assume the risk. But just as the beekeepers cooperate with one another during cranberry pollination, a clover farmer could make arrangements with his neighbors. Given that neighboring farmers have the legal right to use pesticide, the clover farmer would be willing to pay them an amount not exceeding the beekeeper's risk premium if they would refrain from spraying during the pollination period. Although no such arrangements are observed, it would seem that the costs of reaching an agreement would be no higher than those encountered in the case of the cranberries, and we must infer, pending empirical confirmation, that the gain from using the sprays is greater than the associated loss. This would particularly apply when a single farm requiring pollination is located amidst a large number of farms which require spraying during that same period.

[41] For a fuller discussion, see Steven N. S. Cheung, *supra* note 40.

The Case of Fireweed. I have at hand two types of apiary contract pertaining to fireweed, a honey plant which grows wild in the forest. The first is between a beekeeper and the Weyerhaeuser Company, owner of private timber land; the second is between a beekeeper and the Water Department of the City of Seattle. Two distinctions between them are worth noting. First, while both contracts stipulate 25 cents per hive, Weyerhaeuser asks a minimum charge of $100, and the Water Department a minimum of $25. In the apiary for fireweed honey, the number of hives used by a beekeeper is more than 100 but less than 400. Thus it happens that in the case of Weyerhauser, the apiary rent is independent of the number of hives, whereas with the Water Department it is dependent. The "underpriced" rent levied by the Water Department would have implied some sort of queuing except that a second unique feature is incorporated in its apiary contracts: no beekeeper is granted the exclusive right to the fireweed nectar in a particular area. The implication is that competition among beekeepers will reduce the honey yield per hive until its apiary rent is no more than 25 cents; while no beekeeper attempts to exclude entrants, the parties do seek a mutual division of the total area to avoid chaotic hive placement. Finally, fireweed also grows wild in the national forests and for this case I have no contract at hand. My information is that apiary rent is measured by the hive, is subject to competitive bidding among beekeepers, and has a reported range of 25 to 63 cents with the winner being granted exclusive right to a particular area.

III. Conclusions

Whether or not Keynes was correct in his claim that policy makers are "distilling their frenzy" from economists, it appears evident that some economists have been distilling their policy implications from fables. In a desire to promote government intervention, they have been prone to advance, without the support of careful investigation, the notion of "market failure." Some have dismissed in cavalier fashion the possibility of market operations in matters of environmental degradation, as witnesses the assertion of E. J. Mishan:

> With respect to bodies of land and water, extension of property rights may effectively internalize what would otherwise remain externalities. But the possibilities of protecting the citizen against such common environmental blights as filth, fume, stench, noise, visual distractions, etc. by a market in property rights are too remote to be taken seriously.[42]

[42] E. J. Mishan: A Reply to Professor Worcester, 10 J. Econ. Lit. 59, 62 (1972). As immediate refutation of Professor Mishan's claim, I refer the reader to a factual example: Professor John McGee has just purchased a house, separated from that of

Similarly, it has been assumed that private property rights cannot be enforced in the case of fisheries, wildlife, and whatever other resources economists have chosen to call "natural." Land tenure contracts are routinely taken as inefficient, and to some the market will fail in the areas of education, medical care, and the like.

Then, of course, there is the fable of the bees.

In each case, it is true that costs involved in enforcement of property rights and in the formation of contracts will cause the market to function differently than it would without such costs. And few will deny that government does afford economic advantages. But it is equally true that any government action can be justified on efficiency grounds by the simple expedient of hypothesizing high enough transaction costs in the marketplace and low enough costs for government control. Thus to assume the state of the world to be as one sees fit is not even to compare the ideal with the actual but, rather, to compare the ideal with a fable.

I have no grounds for criticizing Meade and other economists who follow the Pigovian tradition for their use of the bee example to illustrate a theoretical point: certainly, resource allocation would in general differ from what is observed if the factors were "unpaid." My main criticism, rather, concerns their approach to economic inquiry in failing to investigate the real-world situation and in arriving at policy implications out of sheer imagination. As a result, their work contributes little to our understanding of the actual economic system.

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his neighbor by a vacant lot. That the space would remain vacant had been assured by the previous owner who (upon learning that a third party was planning to buy the lot and construct a house there) had negotiated with the neighbor to make a joint purchase of the ground, thus protecting their two households from the "filth, fumes, stench, noise, visual distractions, etc." which would be generated by a new neighbor.