



Dijlah Journal of Agricultural Sciences

Journal homepage: <https://djas.uowasit.edu.iq/index.php/djas/en>



Research article

Economic Profit Function of Honey Production in Wasit Governorate, Iraq: Evidence from 39 Apiaries, Including Large Commercial Units

Sara Ali Hussein

Department of Crop Sciences, College of Agriculture, Wasit University, Wasit, Iraq

ARTICLE INFO

Keywords:

honey production,
economic profit,
economies of scale,
apiary size,
robust regression,
Wasit, Iraq

Article history:

Received: 22 Jul
Accepted: 23 Sep
Online: 30 Sep

ABSTRACT

Nevertheless, beekeepers in Wasit Governorate, Iraq raise an inquiry that what are the variables that affect the profitability of honey production, and also whether the higher number of hives in the apiary would bring more economic returns. This paper develops an economic profit function per hive based on a questionnaire survey of 39 beekeepers for the 2025 season, without discarding any observation. Profit is the economic return to honey and secondary income (sales of colonies, packages, and other products) less variable inputs, labor, land rent, straight-line depreciation of all investments, and interest on capital. This recast-of-accounts raises the profit from IQD 162 thousand per hive to IQD 173 thousand, and the economic cost is composed of 51.7% depreciation and interest. Apiaries were classified as small (≤ 30 hives, $n = 13$), medium (31–100, $n = 19$), and large (> 100 , $n = 7$). Costs tend to increase sub-linearly with output (cost elasticity=0.67, 95% CI [0.48, 0.85]), but profit per hive does not significantly differ among classes (Kruskal-Wallis $p=0.33$) because large-scale apiaries experience lower yields (6.9 vs. 10.6 kg per hive). An OLS estimation with HC3 robust standard errors (R-squared=0.85) indicates that price (+IQD 9.8 thousand per 1,000 hive per IQD 1,000/kg) and yield (+IQD 32.7 thousand per kg per hive) have positive effects on profit, but labor intensity negatively affects it (−116.1 for each additional worker for 10 hives); number of hives, experience, and education level do not have statistically significant effects. Huber regression, leave-one-out estimates, bootstrap intervals, and seven other scenarios yield the same conclusions. We conclude with recommendations for marketing, cost accounting, yield improvement, shared labor-saving equipment, colony renewal, and diversification, and suggest that focusing on expansion alone is insufficient.

1. Introduction

Beekeeping is common worldwide, with major honey producer countries including China, the United States, Canada, Argentina, Nigeria, and Australia (Vural, 2010). Honey World production was 1.3 million tonnes from 72.5 million hives with beekeepers achieving an average yield of 18.2 kg per hive in 2007 (Cvitkovic et al., 2009); Australia led the world with 90 kg per hive in production (Jadran, 2011). In the Arab world, natural honey production was about 26.5 thousand tons, of which production in Iraq amounted to 100 tons (AOAD, 2011).

Beekeeping products - from food and medicine to employment — can help promote economic and social development. It needs minimal capital, offers rapid returns, and does not require sophisticated technology

✉ *Corresponding author:
sahussain@uowasit.edu.iq (Sarah Ali Hussein)

(Mbah, 2012). Bees also produce bee jelly, wax, propolis and venom (Abo El-Nag & Abdelghfar, 2011) and they rank as the chief pollinators of fruit trees, field crops and vegetables (Hasnawi, 2008).

However, the importance of honey as a commodity has not been reflected in the amount of honey supplied in Wasit Governorate (Beekeepers Association in the Central Province of Diyala, 2011), and beekeepers have limited knowledge about the factors influencing profit. Two questions are especially relevant for policy. First, how profitable is an apiary when all costs, including the depreciation of colonies and equipment and the opportunity cost of capital, are accounted for, and when revenue from selling colonies, packages, and other products is credited to the enterprise? Second, are larger commercial apiaries more profitable per hive than small and medium-sized ones, as the logic of economies of scale would suggest? Excluding costs and revenues other than operating costs and honey sales overstates profit, and the regression of profit on its own accounting components yields a near-perfect fit with no behavioral content. Some recent economic analysis on beekeeping in Türkiye, India, Hungary, and Iraq has highlighted profitability, break-even scale, and efficiency (Abd et al., 2020; Feketéné Ferenczi et al., 2023; Horo & Singh, 2024; Polat et al., 2023), however, for Iraqi apiaries of different sizes there is still a lack of information on the factors influencing profit per hive.

Thus, this paper (a) calculates economic profit per hive using full cost structure and all revenues, (b) estimates a profit function where the explanatory variables are not profit components of the dependent variable, keeping all observations and using robust inference, (c) tests for economies of scale and contrasts small, medium and large apiaries and (d) concludes with policy recommendations that flow directly from the estimates.

2. Theoretical Framework

2.1 Economic Profit and Accounting Profit

Profit is the difference between total revenue and total cost (Khan et al., 2008). In a beekeeping business, which sells its honey (in quantity Q at price P) and secondary products (revenue SR) the economic profit is:

$$\pi = P \cdot Q + SR - (VC + L + R + D + iK) \quad (1)$$

Here, VC represents variable expenses such as feed, medicines, containers, protective gear, and transport. R is land rent, L is labor, and D covers depreciation on colonies, frames, hives, extractors, and other equipment tools. i and K are the interest rate and average invested capital, respectively. EBIT does not take into account depreciation and the return on invested capital, despite the fact that these are real expenses - the equipment is wearing out and must be replaced, and the money that's invested could be used for other things.

When average cost is defined as $C = (VC + L + R + D + iK)/Q$, Equation 1 can be restated as the accounting identity $\pi - SR = (P - C) \cdot Q$. A regression of profit on P , C , and Q therefore does not reveal a behavioral relationship. Apart from SR , the outcome is determined exactly by the variables on the right-hand side.

2.2 Restricted Profit Function and the Per-Hive Model

The profit function is derived by duality theory over output and input prices and fixed factors (Varian, 1992). When input prices are unobserved for all inputs, the variable profit function with fixed factors such as number of hives is a conditional one (Lau & Yotopoulos, 1971). Two specifications are estimated here, there is no output quantity or average cost on the right hand side in either of the two. Neither of them contains output quantity or average cost on the right-hand side of the equation. A linear expression of economic profit per hive is the first:

$$\pi/H = \beta_0 + \beta_1 P + \beta_2 Y + \beta_3 \ln H + \beta_4 W + \beta_5 \text{Exp} + \beta_6 \text{Edu} + u \quad (2)$$

where H is the number of hives, y is yield (kg per hive), W is labor intensity (workers per 10 hives), Exp is years of experience, and Edu is a dummy for diploma or higher education. Expected signs are $\beta_1 > 0$ and $\beta_2 > 0$; β_3 indicates whether larger apiaries have higher income per hive, β_4 is expected to be negative if labor represents a cost, β_5 and β_6 are nonnegative. Since price and yield enter revenue multiplicatively ($P \cdot y$), their coefficients are partly arithmetic reflections of revenue; the behaviorally interesting coefficients are those on W , $\ln H$, Exp , and Edu . The second model is a log-linear restricted profit function, $\ln \pi_v = \alpha_0 + \alpha_1 \ln P + \alpha_2 \ln H + \alpha_3 \ln W_{tot} + \alpha_4 Exp + \alpha_5 Edu + u$, where π_v represents profit before depreciation and interest and W_{tot} denotes number of workers. Coefficient α_2 is the elasticity of restricted profit with respect to hives; $\alpha_2 = 1$ implies that profit is linear in the size of an apiary.

2.3 Economies of Scale

Cost economies of scale are measured by the output elasticity of total cost, b in $\ln EC = a + b \ln Q$ (where EC is economic cost; $b < 1$ shows falling average cost and the hypothesis $b = 1$ is tested (Chambers, 1988)). Since lower cost per kg does not necessarily mean higher profit per hive (due to differences in yield or price), scale is also determined by comparing profit per hive between size classes and by the coefficient β_3 .

3. Materials and Methods

3.1 Data and Sample

A questionnaire was distributed in 2025 to a random sample of beekeepers in Wasit Governorate including; Kut, Aziziyah, Suwaira, Sheikh Saad, Numaniyah and Hai districts. A total of 39 questionnaires were returned, or approximately 8% of the beekeepers of the survey area. The questionnaire measured production and prices, cost components, the amount and price of each input, labor, household secondary income, and individual attributes. Every one of the 39 questionnaires is used in each estimate; no indium has been omitted.

3.2 Measurement of Revenues and Costs

Honey production is $P \times Q$, where P is price and Q is production (= hives $\times$ yield per hive). Secondary income results from the sales declared of hives or colonies, packages, and other products. In the list of inputs are included various types of feeds like sugar and protein, medicines, honey cans, plastic containers, winter covers, bee hives transportation, wire and nails, and the gas-stove set. Cost of labor is derived from the information given in the original data, where it can be found in 21 out 39 questionnaires. In case the land is paid for, it has to be added to the previous accounts. A "packages" column in the expense report could not match up with the information on investment, therefore it had to be excluded in order not to be counted twice; accounts for package boxes are included in investments. Investment was calculated as quantity $\times$ price for colonies, hives, extra boxes, frames, package boxes, extractors, and ten hand tools or pieces of protective gear. Straight line depreciation with zero residual value and assumed useful life of 5 years for colonies, frames and package boxes; 10 years for hives, extra boxes and extractors; 3 years for protective suits, masks and gloves; and 5 years for other instruments. The interest on capital is 5% of average capital ($\frac{1}{2}$ of the purchase value).

3.3 Data Harmonization

Revenues from secondary products were reported in nonuniform units. The units for small numbers less than 1,000 hives or packages for sale are notional at best and to the extent that these entries would correspond to zero; one entry for a sale of hives for IQD 100 million is larger than the stock of hives of the whole apiary and was also set to zero; text entries such as “_” were considered equivalent to zero. Seven questionnaires (1, 3, 5, 6, 14, 15, and 28) were flagged: five for such secondary-revenue entries and two for an assumed unit price. Because all doubtful entries have been made zero, the secondary revenue is understated. The unit prices of

hives or packages not known were replaced with the sample median and one amount of family labor was missing. Labor hours and labor cost in the data are the same in 21 of 39 forms, suggesting these are standardized rather than recorded values; as an upper-bound sensitivity scenario, a worker-day valuation (number of workers $\times$ 180 days $\times$ IQD 10,000) is adopted.

3.4 Size Classes

Apiaries were categorized as small (30 hives or less), medium (31–100 hives), or large (> 100 hives). Class means were compared with the Kruskal–Wallis test (Kruskal & Wallis, 1952), and large apiaries were compared to the remaining apiaries using Welch's *t* test (Welch, 1947). Model 2 of Equation 2 was also re-estimated excluding the large apiaries.

3.5 Estimation, Robustness, and Diagnostics

The models were estimated by ordinary least squares (OLS; Gujarati, 2004; Koutsoyiannis, 1977). Given the small size of the sample and that the size of apiary differs dramatically, we employ HC3 heteroskedasticity-robust standard errors which are reported in parentheses and which are known to yield the best finite sample properties (MacKinnon & White, 1985; Long & Ervin, 2000) to draw inference. Robustness was examined by Huber–M-estimation (Huber, 1981), a pairs bootstrap with 5,000 replications (Efron, 1979), Cook's (1977) distance (diagnosis—only), leave-one out re-estimation of all coefficients... the once troubled Belsley et al., (1980), re-estimation upon dropping groups of observations, and seven alternative cost and data scenarios. For each of the considered problems, one diagnostic test was chosen: the variance inflation factors (VIF,...values lower than 10 are good enough, Gujarati, 2004) for multicollinearity; the White (1980) test for heteroskedasticity; the Breusch–Godfrey test (Breusch, 1978; Godfrey, 1978) for higher-order autocorrelation; the Jarque–Bera test (Jarque & Bera, 1987) for distributional normality of the error terms; and the Ramsey's (1969) RESET for functional form. The computations were performed using Python and the statsmodels module (Seabold & Perktold, 2010).

4. Results and Discussion

4.1 Sample and Cost Structure

Most apiaries were small. They contained an average of 95.7 hives, with a median of 40 and a range of 9 to 800; nearly three-quarters (74.4%) had no more than 60 hives. Honey yield is 9.5 kg/hive on average. The average beekeeper experience was 10.6 years and the average price of honey sold was 26,026 IQD per kg. Among the beekeepers interviewed, 7 were with their education finished at the primary level or below, 11 had intermediate education, 11 had secondary education, and 10 had obtained a diploma or higher level of education. Each apiary had an average of IQD 19.0 million in invested capital, with colonies making up 71.6% of that amount.

As shown in Table 1, the average economic cost per apiary was IQD 7.79 million. Depreciation formed the largest proportion of overall expenses, being 45.6%, followed by labor costs which amounted to 33.0%. The two together accounted for 51.7% of total expenses. Depreciation consisted largely of the colonies making up 76.4% of it, while hives and boxes represented 6.4% only. For the remaining part of depreciation, the shares of frames and package boxes and the costs of the hand tools and protective equipment had the values of 8.5% and 7.9% respectively.

Table 1: Economic Cost Structure per Apiary (n = 39)

Cost item	Mean (IQD)	Mean per hive (IQD)	Share of economic cost (%)
Labor	2,567,308	63,198	33.0
Sugar and protein feed	133,718	2,025	1.7
Honey containers	389,872	3,756	5.0
Medicines (pest control)	67,276	1,428	0.9
Plastic vessels	16,692	330	0.2
Winter covers	190,833	4,722	2.4
Transport of hives	120,641	2,648	1.5
Wire and nails	51,115	1,491	0.7
Gas stove set	69,487	1,656	0.9
Land rent	155,128	3,112	2.0
Depreciation	3,554,188	40,265	45.6
Interest on capital	474,581	5,355	6.1
Total economic cost	7,790,839	129,986	100.0

Note. Source: author's survey and calculations. Per-hive values are means of apiary-level ratios, so they do not equal the ratio of the means.

Table 2: Descriptive Statistics of the Model Variables (n = 39)

Variable	Mean	SD	Min	Median	Max
Economic profit per hive (IQD thousand)	161.6	130.4	-42.4	132.1	557.8
Honey price (IQD per kg)	26,026	6,302	15,000	25,000	40,000
Yield (kg per hive)	9.49	2.75	4.00	10.00	15.00
Number of hives	96	156	9	40	800
Workers per 10 hives	0.74	0.46	0.06	0.75	2.22
Experience (years)	10.64	8.63	2.00	7.00	35.00

Note. Source: author's survey and calculations.

4.2 Alternative Definitions of Profit

Table 3 presents three profit measures. When profit is calculated as honey income and nothing else apart from inputs and labor, it amounts to IQD 173 thousand on average per hive. If it is further adjusted for secondary income and land rent, it brings the number up to IQD 207 thousand. After deducting depreciation and interest costs from the calculations, the average economic profit is IQD 162 thousand with IQD 132 thousand being the median. In the sample of the 39 hives, the estimate of economic profit based on operating cost measure is overvalued by 18.7%. Finally, secondary sources account for 9.8% of total income and brought revenue in 35 out of 39 hives. Sample-wide, they brought in IQD 42.9 million from hives and colonies, IQD 20.3 million from packages, and IQD 12.3 million from other products. Two apiaries—questionnaires 1 and 12—recorded negative economic profit. Stationary beekeeping in India has been reported to have benefit-cost ratios of 2.1–2.5 (Horo & Singh, 2024), but these figures are not directly comparable, as they do not account for depreciation and interest, and the source does not specify whether they are gross or net.

Table 3: Profit under Alternative Definitions

Definition	Revenue	Costs deducted	Mean total (IQD million)	Median total (IQD million)	Mean per hive (IQD thousand)
A. Operating, of honey	Honey	Inputs, labor	14.30	6.68	173.0
B. Operating, total revenue	Honey + secondary	Inputs, labor, land rent	16.08	7.21	207.2
C. Economic profit	Honey + secondary	B + depreciation + interest	12.05	5.84	161.6

Note. Source: author's calculations. Definition C is used as the dependent variable in all subsequent models.

4.3 Apiary Size and Economies of Scale

Table 4 and Figure 1 are for the three size groups. Larger apiaries are more seasoned (23.4 years in the large class compared to 5.6 in the small class) and require far fewer workers per hive (0.14 workers per 10 hives versus 1.08). Their economic cost per hive is much less (IQD 67 thousand versus 176 thousand), and their cost per kilo is less (IQD 10,818 versus 17,501); the cost elasticity of output is 0.67 (HC3 SE = 0.09; 95% CI [0.48, 0.85]), which is significantly less than 1 ($p < .001$), and 0.59 if Labor is valued at worker-days. There are thus economies of scale in costs.

These cost advantages are, nevertheless, balanced by the revenue-side. Large apiaries had lower yields (6.9 kg per hive versus 10.6 for small apiaries; Kruskal–Wallis $p = .014$; Welch test of large against the rest $p = .013$), they received lower prices (IQD 22,857 per kg against 28,077; $p = .059$ for large against the rest), and secondary revenue per hive was also lower, so that revenue per hive in large apiaries is about one half of that in small apiaries. Hence, the average economic profit per hive amounts to IQD 179 thousand for small, 170 thousand for medium, and 106 thousand for large apiaries, a difference that is not statistically significant (Kruskal–Wallis $p = .33$). It should be mentioned, that the total profit per apiary is much larger in large units (mean IQD 36.5 million versus 4.7 million in small and 8.1 million in medium apiaries), and no large apiarist has negative profits. Figure 2 reveals no systematic relationship between profit per hive and $\ln(\text{hives})$ (slope = -19.5, $p = .38$). This is also in line with Polat et al. (2023) who reported significant differences in unit costs and profit per hive between scales of enterprise in Türkiye's Black Sea region, with small enterprises enjoying the lowest unit costs and highest profit per hive compared to medium and large ones. It follows a break-even logic as well: Feketéné Ferenczi et al. (2023) also showed that a modeled migratory apiary becomes profitable at 71 colonies, so scale and yield together determine profitability.

Table 4: Characteristics by Apiary Size Class (Class Means)

Variable	Small (≤ 30 ; $n = 13$)	Medium (31–100; $n = 19$)	Large (> 100 ; $n = 7$)	Kruskal–Wallis p
Hives	23.8	47.3	360.7	$< .001$
Yield (kg per hive)	10.6	9.7	6.9	.014
Honey price (IQD per kg)	28,077	25,789	22,857	.219
Experience (years)	5.6	9.4	23.4	$< .001$

Variable	Small (≤ 30 ; n = 13)	Medium (31–100; n = 19)	Large (> 100 ; n = 7)	Kruskal-Wallis p
Workers per 10 hives	1.08	0.72	0.14	—
Honey revenue per hive (IQD thousand)	305.8	253.2	161.4	.020
Secondary revenue per hive (IQD thousand)	49.8	38.3	11.3	.006
Total revenue per hive (IQD thousand)	355.6	291.5	172.8	.004
Variable inputs per hive (IQD thousand)	22.8	18.8	7.4	< .001
Labor per hive (IQD thousand)	108.2	50.9	13.1	< .001
Depreciation per hive (IQD thousand)	40.1	40.1	40.9	.947
Interest per hive (IQD thousand)	5.3	5.4	5.4	.943
Economic cost per hive (IQD thousand)	176.4	121.5	66.9	< .001
Economic cost per kg (IQD)	17,501	13,308	10,818	.055
Economic profit per hive (IQD thousand)	179.2	170.0	105.9	.327

Note. Source: author's calculations. Workers per 10 hives are workers per apiary divided by hives $\times 10$ (Kruskal-Wallis p for the number of workers per apiary = .007).

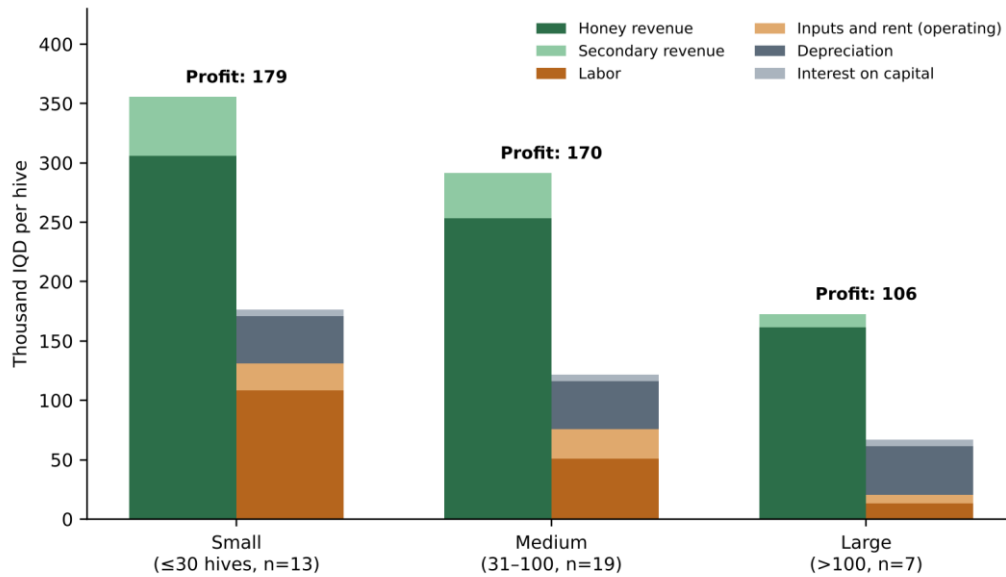


Figure 1. Revenue and economic cost per hive by size class (thousand IQD); profit per hive is the difference.

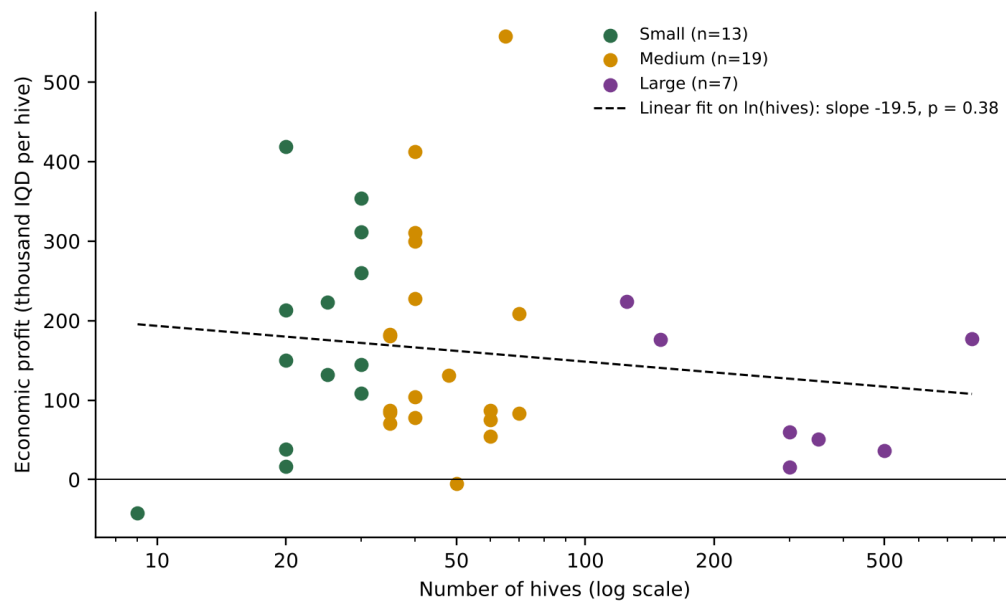


Figure 2. Economic profit per hive by the number of hives (log scale), according to size class.

4.4 The Profit Function

Table 5 reports the results of the per-hive profit function for the whole dataset of 39 observations ($R^2 = 0.855$, adjusted $R^2 = 0.828$; $F(6, 32) = 31.4$, $p < .001$). The estimated function is:

$$\hat{\pi}/H = -345.9 + 9.77P + 32.7y + 4.6\ln H - 116.1W + 0.03\text{Exp} + 40.8\text{Edu} \quad (3)$$

Price and yield both have the expected positive relationship with profit, and each is statistically significant at the 1% level. The selling price being IQD 1,000 more apparently brings IQD 9,800 more in profit per each hive, whereas additional kilogram of yield per hive is equal to IQD 32,700. These values correspond with expectations arising from average yield of 9.5 kg and average price of IQD 26,026 per kilogram. This shows that the values are compatible with revenue data, not indicating emergence of a new behavior.

Labor intensity is associated with less profit and has statistical significance (HC3 $p = .016$). Each additional worker per 10 hives means IQD 116,100 loss in profit per hive. Its standardized coefficient (-0.41) is in the third place assigned to yield (0.69) and price (0.47). Thus, when taking labor intensity into consideration, the amount of hives ($\ln H$) is not significant ($p = .76$). Moreover, experience ($p = .99$) and higher education ($p = .10$) is not significant also. However, the estimated influence of higher education is equal to IQD 40,800. When the coefficient of $\ln H$ becomes positive, ignoring labor intensity, and statistically significant ($b = 52.1$; HC3 $p = .020$; $R^2 = 0.794$). However, $\ln H$ is strongly negatively correlated with labor intensity ($r = -0.78$), suggesting that the apparent scale advantage mainly reflects lower labor use per hive in larger apiaries. Once labor intensity is accounted for, apiary size has no additional effect. Huber estimates closely match the OLS results: 9.7 for price, 32.4 for yield, and -114.3 for labor intensity, with five observations down-weighted. The bootstrap 95% intervals exclude zero for all three variables. In an analogous result, Tubene et al. (2023) found that improved management increased labor and materials costs, but also increased honey and nucleus-colony production and, therefore, profitability was improved by means of colony health and survival.

Table 5: Estimates of the Per-Hive Economic Profit Function ($n = 39$)

Variable	OLS coefficient	HC3 SE	HC3 p	Huber coefficient	Bootstrap 95% CI
Intercept	-345.93***	103.93	.002	-346.87	[-545.4, -143.2]
Price (IQD 1,000 per kg)	9.77***	1.83	< .001	9.71	[5.8, 13.1]
Yield (kg per hive)	32.68***	4.75	< .001	32.35	[23.1, 41.5]
$\ln(\text{hives})$	4.64	15.31	.764	6.13	[-29.7, 37.8]
Workers per 10 hives	-116.12**	45.76	.016	-114.27	[-181.2, -34.6]
Experience (years)	0.03	1.43	.985	-0.19	[-2.6, 2.9]
Diploma or higher (0/1)	40.85	24.38	.104	36.84	[-5.7, 92.4]

Note. Dependent variable: economic profit per hive (IQD thousand). *** $p < .01$, ** $p < .05$, * $p < .10$ (HC3). $R^2 = 0.855$; adjusted $R^2 = 0.828$; $F(6, 32) = 31.4$; standard error of the regression = IQD 54 thousand.

4.5 Diagnostic Tests

Table 6 shows one test per problem. (Multicollinearity is not an issue (largest VIF = 4.26, for $\ln H$, which is correlated with labor intensity as the source). The White test does not reject homoskedasticity ($p = .67$), the Breusch–Godfrey test does not find evidence of autocorrelation ($p = .56$), and the Jarque–Bera test does not reject normality of residuals ($p = .43$). The RESET test provides $p = .079$, so linearity is not rejected at 5%, but the evidence is weaker than for the other tests. Although the White test does not reject, HC3 standard errors are used throughout as a safeguard, because of the large range in apiary size, and the large apiaries are retained. Residuals and their normal probability plot are shown in Figure 3.

Table 6: Diagnostic Tests (One Test per Problem)

Problem	Test	H_0	Per-hive model Statistic / p	Decision	Log model Statistic / p
Multicollinearity	VIF (maximum)	VIF < 10	4.26	Acceptable	2.27
Heteroskedasticity	White (χ^2)	Homoskedasticity	22.34 / .670	Not rejected	23.15 / .231
Autocorrelation	Breusch–Godfrey (1 lag)	No autocorrelation	0.35 / .556	Not rejected	3.25 / .071
Non-normality	Jarque–Bera	Normal residuals	1.66 / .435	Not rejected	42.23 / < .001

Problem	Test	H ₀	Per-hive model Statistic / p	Decision	Log model Statistic / p
Functional form	Ramsey RESET (F)	Correct form	3.31 / .079	Not rejected	5.12 / .031

Note. Source: author's calculations.

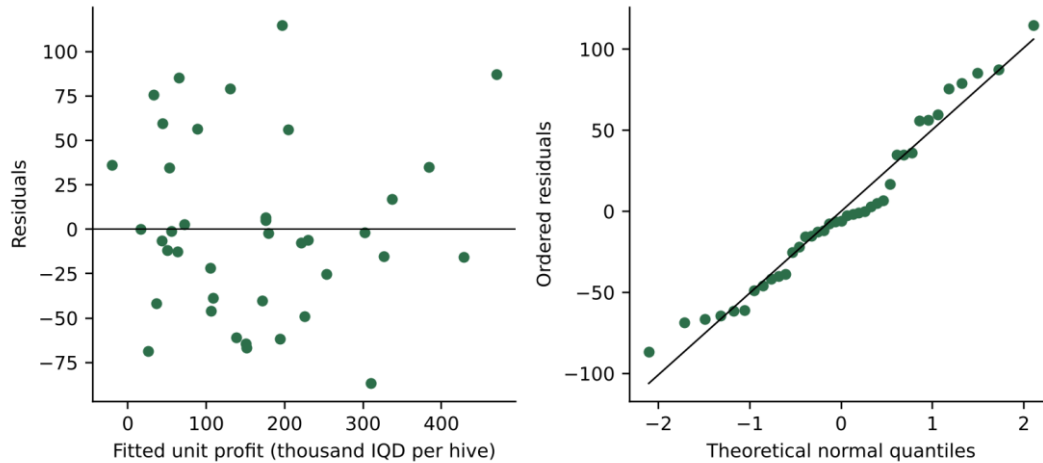


Figure 3. Residuals against fitted values (left) and normal probability plot of residuals (right), per-hive model.

4.6 Stability of the Results

The dependence of results on the selected observations was tested in the following four ways. First, Table 7 re-estimates the model excluding the largest apiary (questionnaire 20; 800 hives), all the seven large apiaries, and the four observations a routine screening exercise using Cook's distance and studentized residuals would identify as outliers (questionnaires 4, 5, 20, and 36). R^2 fluctuates between 0.82 and 0.86, the price and yield coefficients lie between 9.3 and 10.4 and 29.8 and 32.8, and labor intensity is negative and significant at five percent in all specifications. The number of hives never achieves significance. Second, leave-one-out estimation (Figure 4) gives ranges of 9.0 to 10.4 for price, 30.0 to 34.6 for yield, and -133.6 to -84.8 for labor intensity; no single observation alters the significance of any of these three coefficients. The largest Cook's distance is 0.27 (questionnaire 36, 65 hives), and the 800-hive apiary is not influential. Three, bootstrap intervals (Table 5) are consistent with HC3 intervals. Fourth, Table 8 consider an alternative set of assumptions on which the cost structure is based.

Table 7: Per-Hive Profit Function after Dropping Groups of Observations

Sample	n	R ²	Price	Yield	ln(hives)	Labor intensity
all 39	39	0.855	9.8***	32.7***	4.6	-116.1**
excl. #20 (largest)	38	0.855	9.8***	32.8***	5.4	-115.5**
excl. 7 large (>100 hives)	32	0.858	10.4***	32.4***	39.5	-97.5**
excl. 4 high-influence (4,5,20,36)	35	0.825	9.3***	29.8***	18.6	-98.5**

Note. Coefficients with HC3 significance: *** $p < .01$, ** $p < .05$, * $p < .10$. The first row replicates Table 5.

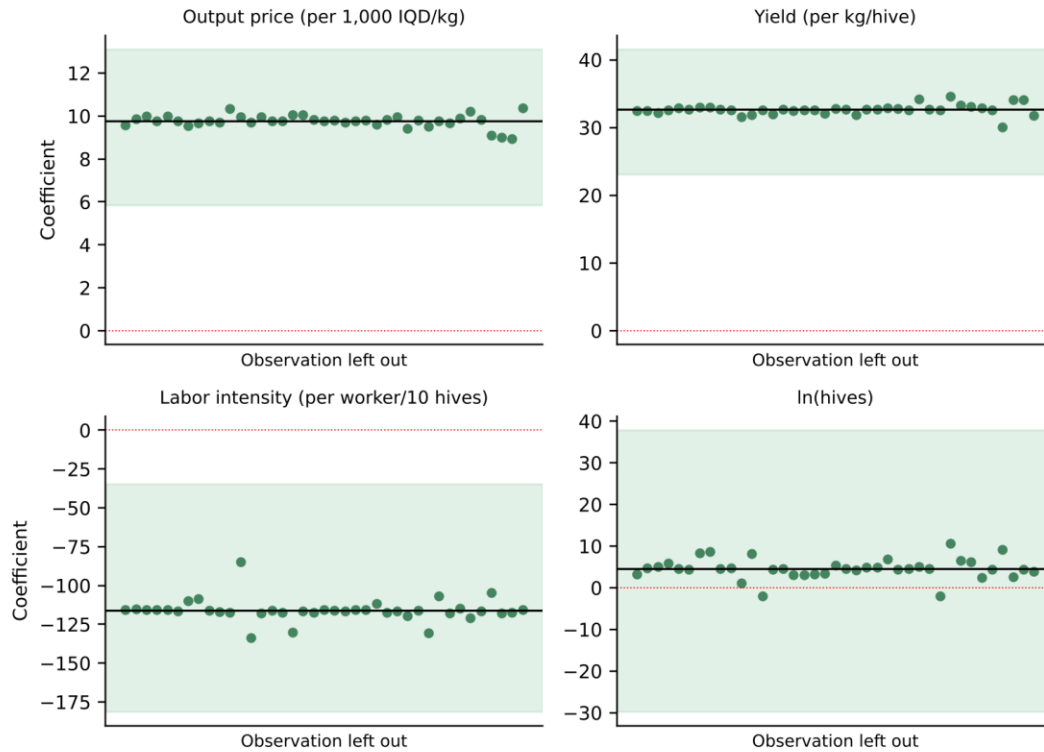


Figure 4. Leave-one-out coefficient estimates (dots) against the full-sample estimate (line) and its HC3 95% interval (shaded).

Table 8 shows that the conclusions regarding price and yield are robust to the choice of assumptions: the price coefficient ranges from 9.6 to 10.1 and the yield coefficient from 30.7 to 33.0. The mean profit per hive is more sensitive, varying from IQD 92 thousand (when labor is valued at worker-days) to IQD 181 thousand (without the flagged forms), and the number of apiaries with negative profit ranges from one to four (and 11 under worker-day valuation). Labor intensity retains its negative sign in all cases and is 5% significant in all cases except the no secondary revenue case ($p = .08$) and, marginally, the exclusion of flagged forms ($p = .050$), and $\ln H$ is only significant in the former case. The order of size classes is also consistent: large apiaries have the lowest profit per hive in all cases except the worker-day valuation, where the three classes are almost identical (IQD 92, 91, and 94 thousand). The main caveat in the results is the sensitivity of the labor-intensity coefficient and of class profits to the valuation of labor.

Table 8: Sensitivity of the Per-Hive Model to Data and Cost Assumptions

Scenario	R ²	Price	Yield	ln H	Labor int.	Profit per hive: small / medium / large	Mean profit per hive	Neg.
Base	0.85	9.8	32.7	4.6	-116.1**	179 / 170 / 106	162	2
No secondary revenue	0.92	9.6	31.2	35.3**	-67.9*	129 / 132 / 95	124	4
Excl. 7 forms with flagged secondary-revenue entries	0.85	9.8	33.0	3.5	-119.9*	193 / 191 / 110	181	1
Asset lives $\times 0.7$ (shorter)	0.85	9.7	33.0	6.4	-122.5**	162 / 153 / 88	144	3

Scenario	R ²	Price	Yield	ln H	Labor int.	Profit per hive: small / medium / large	Mean profit per hive	Neg.
Asset lives ×1.5 (longer)	0.85	9.8	32.4	3.3	-111.1**	193 / 183 / 120	175	1
Interest rate 0%	0.85	9.8	32.6	4.1	-114.3**	184 / 175 / 111	167	1
Interest rate 10%	0.85	9.7	32.8	5.2	-117.9**	174 / 165 / 100	156	2
Labor valued at worker-days (upper bound)	0.90	10.1	30.7	-16.6	-245.5***	92 / 91 / 94	92	11

Note. n = 39 in all scenarios except the exclusion of flagged forms (n = 32). Coefficients with HC3 significance as in Table 7. Profit per hive in IQD thousand.

4.7 Why a High R² Was Not Evidence of a Good Model

A profit function where profit is simply regressed on price, average cost, and quantity is an accounting identity hidden in algebraic form. In these data, $\pi - SR$ is $(P - C) \cdot Q$ to within a maximum error of $3.0e-8$ IQD and a regression of π on $(P - C) \cdot Q$ has $R^2 = 0.990$, where the residual 1.0% represents secondary revenue. Estimating $\pi = f(P, C, Q)$ using all 39 apiaries results in $R^2 = 0.923$ with a quantity coefficient equal to IQD 20.0 per kg, but the estimates are rejected by the diagnostics (White $p < 0.001$, Breusch-Godfrey $p = 0.001$, RESET $p < 0.001$) and the fit and coefficients are unstable: Removing the 800-hive apiary lowers R^2 from 0.923 to 0.74 and the quantity coefficient from 20.0 to 10.8, and dropping all the seven large apiaries makes $R^2 = 0.84$ and the quantity coefficient equal to 30.2. Neither the fit nor its sensitivity to the deletions tells anything about behaviour: each arises because the dependent variable is constructed from the regressors and because the product $P \cdot Q$ is represented by a linear approximation. Similarly, a large R^2 when excluding the investment costs, depreciation, and secondary revenue is due to the narrower concept of profit and not the goodness of the model. The per-hive specification in Equation 2 does not suffer from this problem, as average cost and total output are not regressors, and its $R^2 = 0.85$ is not close to 1. The link through $P \cdot y$ continues to hold, and so this is why the price and yield coefficients serve as consistency checks.

4.8 Restricted Profit Function in Logarithms

The log-linear restricted profit function is given in Table 9. The profit elasticity with respect to price is 1.78 (HC3 $p < .001$), and the elasticity with respect to hive number is 1.07 ($p = .001$), and the test for this elasticity being equal to 1 cannot be rejected ($p = .83$), implying that restricted profits is a linear function of the number of hives and that there is no evidence of increasing or decreasing returns to apiary size in restricted profit. Neither the number of workers, experience, nor education matter. The Huber estimates are comparable (price 1.86, hives 0.98). This model is less statistically adequate ($R^2 = 0.78$): Jarque-Bera normality is rejected ($p < .001$) and RESET rejects correct form at 5% ($p = .031$).

Table 9: Log-Linear Restricted Profit Function (n = 39)

Variable	OLS coefficient	HC3 SE	HC3 p	95% CI (HC3)
Intercept	-6.26*	3.65	.095	[-13.68, 1.16]
ln(price)	1.78***	0.35	< .001	[1.07, 2.50]

Variable	OLS coefficient	HC3 SE	HC3 p	95% CI (HC3)
ln(hives)	1.07***	0.30	.001	[0.46, 1.67]
ln(workers)	-0.16	0.31	.609	[-0.79, 0.47]
Experience (years)	0.00	0.02	.814	[-0.04, 0.05]
Diploma or higher (0/1)	0.34	0.28	.233	[-0.23, 0.91]

Note. Dependent variable: ln of profit before depreciation and interest (secondary revenue included). $R^2 = 0.782$; adjusted $R^2 = 0.749$. Significance as in Table 5.

4.9 Limitations

The results work has following limitations in mind. (a) The sample is small (39 apiaries, only 7 of which are large), so the class comparisons have low power; the lack of a significant difference in profit per hive is not proof of equality. (b) Revenue and cost data are self-reported for one season. (c) The secondary-revenue units were not clear in seven questionnaires and were set to zero, which underestimates secondary revenue; the sensitivity analysis shows that the conclusions are robust without these products and without any secondary revenue. (d) In 21 of the 39 surveys, the labor cost is the identical normalized metric, thus, the estimated labor cost for one hive and the labor intensity factor is reliant in part on normalized numbers and the assessment of family labor. (e) Useful lives and interest are estimates; they impact profit levels but do not alter coefficient signs. (f) In 7 questionnaires, yield values are different between the pages of the dataset; the figures on the summary page were used. (g) Input prices were not observed, so all-inclusive (non-restricted) profit function and input demand equations could not be derived. (h) Price and yield coefficients are determined in part by revenue mathematics; the log model does not pass the normality test. Therefore, the outcomes should be regarded carefully and more data (in an ideal case, around many seasons and with actual labor measures) is required.

5. Conclusions and Recommendations

5.1 Conclusions

1. The profitability of apiaries is overstated by considering only operating costs and honey sales. The account for the depreciation of colonies and equipment, interest on capital, land rent, and secondary revenue, economic profit is IQD 162 thousand per hive; depreciation and interest account for 51.7% of economic cost, and the operating-cost definition overstates total profit by 18.7%.

2. For all 39 apiaries and using robust inference, price and yield increase profit per hive, while labor-intensive operation reduces it. Hive size, age, and education are not significant. The results are robust to dropping the largest (or all) of the large apiaries, to estimation by leaving-one-out, and to different assumptions.

3. Output 0.67. The apiary grows at less than proportional to output, and big apiaries do not earn more per hive, as they face lower yields and prices. Profit is roughly proportional to the number of hives (1.07 elasticity in the log model), so size per se does not enhance profitability, although larger apiaries do earn more income.

4. A profit function written in terms of price, average cost and output is an accounting identity and tells us nothing about the economic behavior of the firm; the per-hive model specification gets around this problem.

5.2 Recommendations

These are the recommendations that follow from the results, and the reasoning for each is found in the text. First of all, the yields need to be increased by extension and management support, focusing initially on large and medium apiaries: each extra kilogram per hive increases profit per hive by about IQD 32,700, large apiaries

have an average of 6.9 kg per hive compared to 10.6 kg in small apiaries, and a reduction of the 2.8 kg difference between medium and large apiaries would generate IQD 92,400 in additional revenue per hive, or 87% of the average profit per hive of large apiaries (IQD 106 thousand). "Second, marketing should be improved through cooperative selling, quality grading, and improved market access, since an increase of IQD 1,000 per kg in price yields an additional IQD 9,800 per hive, large apiaries were offered lower prices (IQD 22,857 compared to 28,077 per kg); reducing this gap by half would yield an additional IQD 25,500 per hive." Third, the costs of colony replacement and capital should be minimized through disease control, the local production of nucleus colonies, and credit for colony purchase at the low-interest rates, as depreciation accounts for 45.6% of the economic cost, colonies represent 76.4% of depreciation and 71.6% of invested capital, and interest is 6.1% of cost.

Fourth, shared labor-saving tools (e.g., collective extraction equipment) and training need to be promoted in the small and medium-scale apiaries given that an additional worker per 10 hives reduces profit by approximately IQD 116,100 per hive, small-scale producers employ 1.08 workers per 10 hives compared to 0.14 in large ones and labor accounts for 33.0% of cost; also, higher education leads to a positive though not significant impact (+IQD 40,800; $p = .10$), therefore training should be piloted and assessed.

Fifth, and related to the fifth issue mentioned above, there is a need to promote diversification into the sale of nuc colonies, packages and other bee products, especially in large scale apiculture, secondary income is 9.8% of total income (15.1% from small and 5.1% from large apiaries) and was positive in 35 of 39 apiaries. Sixth, policy should not be based simply on the promotion of expansion, but should initially focus on enhancing productivity and management and be oriented to medium size units: $\ln(\text{hives})$ is not significant ($p=0.76$), profit per hive is not higher in large apiaries ($p=0.33$), profit scales proportionally to hives (elasticity 1.07) and while lower cost per kg in large apiaries (IQD 10,818 versus 17,501) can be a source of advantage, it is only so if output levels are kept constant.

Seventh, beekeepers should be educated in cost accounting including depreciation, interest, and alternative source of revenue, and urged to standardized record keeping since the definition of operating cost overestimates total profit by 18.7%, seven questionnaires had non-usable secondary-revenues data, and labor cost was a single standardized figure in 21. Lastly, in light of this study's limitations ($n = 39$ comprising only 7 large-scale commercial beekeeping operations, with no observed input prices), future research should consider larger and multi-season samples as well as recorded labor hours and input prices. The above projections are simple linear extrapolations from the estimated coefficients and class means and should be considered as illustrative.

References

- Abd, S. S., Ahmad, M. A., & Abd, Z. F. (2020).** Measuring the economic efficiency of honey production in Nineveh Governorate for the season 2018–2019. *Al-Qadisiyah Journal for Agriculture Sciences*, 10(2), 335–342. <https://doi.org/10.33794/qjas.2020.167477>
- Feketéné Ferenczi, A., Szűcs, I., & Bauerné Gáthy, A. (2023).** Economic sustainability assessment of a beekeeping farm in Hungary. *Agriculture*, 13(6), Article 1262. <https://doi.org/10.3390/agriculture13061262>
- Horo, A., & Singh, J. M. (2024).** An economic analysis of stationary beekeeping in the northern states of India. *Indian Journal of Entomology*, 86(4), 1176–1180. <https://doi.org/10.55446/IJE.2023.1136>

- Polat, M., Çevrimli, M. B., Mat, B., Akın, A. C., Arıkan, M. S., & Tekindal, M. A. (2023).** Economic analysis of beekeeping enterprises producing chestnut honey Black Sea region in Türkiye. *Cogent Food & Agriculture*, 9(1). <https://doi.org/10.1080/23311932.2023.2237279>
- Tubene, S., Kulhanek, K., Rennich, K., & vanEngelsdorp, D. (2023).** Best management practices increase profitability of small-scale US beekeeping operations. *Journal of Economic Entomology*, 116(1), 47–55. <https://doi.org/10.1093/jee/toac174>
- Abo El-Nag, M. A. A., & Abdelghfar, M. S. (2011).** An economic study of honey bee production and its economic feasibility in North Sinai governorate. *Journal of Agricultural Economics and Social Sciences, Mansoura University*, 2(10), 1367–1377.
- Arab Organization for Agricultural Development. (2011).** *Statistical yearbook* (Vol. 31).
- Beekeepers Association in the Central Province of Diyala. (2011, March 4).** Decrease production of honey bees in the province of Diyala [Newspaper article]. *Al Shaab*(137).
- Belsley, D. A., Kuh, E., & Welsch, R. E. (1980).** *Regression diagnostics: Identifying influential data and sources of collinearity*. Wiley.
- Breusch, T. S. (1978).** Testing for autocorrelation in dynamic linear models. *Australian Economic Papers*, 17(31), 334–355.
- Chambers, R. G. (1988).** *Applied production analysis: A dual approach*. Cambridge University Press.
- Cook, R. D. (1977).** Detection of influential observation in linear regression. *Technometrics*, 19(1), 15–18.
- Cvitkovic, D., Grgic, Z., Zoran, M., & Pavlak, M. (2009).** Economic aspects of beekeeping production in Croatia. *Veterinarski Arhiv*, 79(4), 397–408.
- Efron, B. (1979).** Bootstrap methods: Another look at the jackknife. *The Annals of Statistics*, 7(1), 1–26.
- Godfrey, L. G. (1978).** Testing against general autoregressive and moving average error models when the regressors include lagged dependent variables. *Econometrica*, 46(6), 1293–1301.
- Gujarati, D. N. (2004).** *Basic econometrics* (4th ed.). McGraw-Hill.
- Hasnawi, M. S. (2008).** Beekeeping in the nature of Iraq's wealth is on its way to collapse [Newspaper article]. *The New Environment*(708), 4.
- Huber, P. J. (1981).** *Robust statistics*. Wiley.
- Jadran, K. K. (2011).** Measurement of economic efficiency for the projects of bee raising inside and outside towns in Wasit governorate [in Arabic]. *Al-Anbar Journal of Agricultural Sciences*, 9(3), 1–13.
- Jarque, C. M., & Bera, A. K. (1987).** A test for normality of observations and regression residuals. *International Statistical Review*, 55(2), 163–172.
- Khan, M. J., Sarfraz, A., & Khurram, S. (2008).** Economic analysis of wheat profitability in Peshawar. *Pakistan Journal of Life and Social Sciences*, 6(2), 112–117.
- Koutsoyiannis, A. (1977).** *Theory of econometrics* (2nd ed.). Macmillan Press.

- Kruskal, W. H., & Wallis, W. A. (1952).** Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association*, 47(260), 583–621.
- Lau, L. J., & Yotopoulos, P. A. (1971).** A test for relative efficiency and application to Indian agriculture. *The American Economic Review*, 61(1), 94–109.
- Long, J. S., & Ervin, L. H. (2000).** Using heteroscedasticity consistent standard errors in the linear regression model. *The American Statistician*, 54(3), 217–224.
- MacKinnon, J. G., & White, H. (1985).** Some heteroskedasticity-consistent covariance matrix estimators with improved finite sample properties. *Journal of Econometrics*, 29(3), 305–325.
- Mbah, S. O. (2012).** Profitability of honey production enterprise in Umuahia agricultural zone of Abia State, Nigeria. *International Journal of Agriculture and Rural Development*, 15(3), 1268–1274.
- Ramsey, J. B. (1969).** Tests for specification errors in classical linear least-squares regression analysis. *Journal of the Royal Statistical Society: Series B (Methodological)*, 31(2), 350–371.
- Seabold, S., & Perktold, J. (2010).** Statsmodels: Econometric and statistical modeling with Python. *Proceedings of the 9th Python in Science Conference* (pp. 57–61).
- Varian, H. R. (1992).** *Microeconomic analysis* (3rd ed.). W. W. Norton.
- Vural, H. (2010).** Socio-economic analysis of beekeeping and the effects of beehive types on honey production. *African Journal of Agricultural Research*, 5(22), 3003–3008.
- Welch, B. L. (1947).** The generalization of “Student’s” problem when several different population variances are involved. *Biometrika*, 34(1–2), 28–35.
- White, H. (1980).** A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica*, 48(4), 817–838.