

Socioeconomic Assessment of the Beekeeping Sector in the Region of Murcia (Spain)

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Abstract

Beekeeping plays a fundamental and irreplaceable role in the conservation of biodiversity and the sustainability of agricultural systems in the Mediterranean region. While in other climatic regions this activity shows a low degree of professionalization, in southeastern Spain, around 80% of beekeeping farms are managed by professional beekeepers. However, the economic viability of these farms is becoming increasingly threatened due to rising production costs, climate change, and growing market pressure. In this context, the present study aims to technically and economically characterize the three most representative beekeeping production systems in the Region of Murcia: non-transhumant systems, local transhumant systems, and long-distance transhumant systems. To this end, an economic and financial analysis was carried out using a cost accounting approach, establishing the production cost structure for a representative annual production cycle. The results show that transhumant systems require greater investment, mainly as a consequence of the operating expenses associated with hive mobility and supplementary feeding. Nevertheless, their higher productivity allows them to achieve lower unit production costs while generating higher employment levels and greater labor productivity. Overall, the results show that, in semi-arid Mediterranean regions, transhumance constitutes an essential adaptation strategy. This practice increases productivity, reduces dependence on supplementary feeding, lowers unit production costs and, ultimately, strengthens the economic viability and competitiveness of beekeeping farms.

Keywords

Costs, Transhumance, Apicultural Products, Economics

1. Introduction

The Spanish beekeeping sector accounts for approximately 0.44% of total national

livestock production and 0.17% of overall agricultural production, with an estimated annual output value—derived from honey, wax, and pollen—of approximately €62 million (Ministerio de Agricultura, Pesca y Alimentación, 2025). At the European Union level, Spain stands out not only for its large number of bee-hives, but also because nearly 80% are managed by professional beekeepers, defined as those operating more than 150 hives. However, the significance of this sector cannot be assessed solely in economic terms. The contribution of beekeepers extends far beyond the production of honey, pollen, and wax; most importantly, bees play an essential and irreplaceable role in the pollination of both wild flora and agricultural crops, thereby contributing to the preservation of biodiversity and the sustainability of agricultural production systems (Calderone, 2012; Feketéné Ferenczi et al., 2023; Gallai et al., 2009).

Beekeeping in southeastern Spain, particularly in the Region of Murcia, presents distinctive characteristics that clearly differentiate it from practices observed in other Spanish areas. One of its defining features is the semi-arid climate, characterized by prolonged periods of drought, which directly affects flowering cycles and hinders the permanent establishment of hives in the same location. As a result, seasonal hive transhumance to northern regions with more favorable environmental conditions is a widespread practice (Ferreira-Golpe et al., 2021). This includes both internal transhumance within the region itself—commonly referred to as local transhumance—and long-distance transhumance to other Spanish provinces such as Soria, Burgos, Palencia, and Albacete.

According to Ministerio de Agricultura, Pesca y Alimentación (MAPA) (2025), two main beekeeping systems can be identified in Spain. The first predominates in the north and northwest and is characterized by a high proportion of hobbyist and small-scale non-professional beekeepers, most of whom do not practice transhumance. The second, prevalent in the central and southern/southeastern regions of the Iberian Peninsula, is marked by a higher degree of professionalization and a predominantly transhumant production model. Indeed, Extremadura, Andalusia, and the Region of Murcia exhibit the highest relative proportion of professional beekeeping operations within their respective territories.

The sector currently faces a range of structural weaknesses and external threats. These include adverse climatic conditions—such as extreme temperatures, prolonged droughts, or excessive rainfall—which directly affect floral availability; rising production costs combined with low market prices received for honey and pollen; and substantial imports of honey and other apicultural products from third countries at prices significantly below domestic production costs (Aydin et al., 2019). In addition, sanitary challenges, including *Varroa destructor* infestation (varroosis) and other biological threats such as *Vespa velutina*, continue to undermine colony health and reduce bee populations (Feketéné Ferenczi et al., 2023; Gregorc & Sampson, 2019).

In response to these challenges, European Union Member States, within the framework of the Common Agricultural Policy (CAP), are redefining interven-

tion strategies and allocating financial support aimed at improving the production and marketing conditions of apicultural products. This renewed CAP vision seeks to strengthen food security, enhance environmental sustainability, and promote the socioeconomic development of rural areas by equipping Member States with the flexibility to design sector-specific interventions tailored to identified needs and priorities, while maintaining the economic viability of agricultural activity as a central principle (Feketéné Ferenczi et al., 2023).

Within this framework, particular emphasis is placed on improving commercialization through producer associations (Aydin et al., 2019) and encouraging generational renewal, given that the aging farming population remains one of the major structural challenges facing European agriculture (Makri et al., 2015).

Economic and production cost analyses constitute essential tools for agricultural decision-making, investment planning, and the establishment of prices that adequately reflect real production costs. In Spain, Law 16/2021 on the Food Chain reinforces this principle by requiring that contractual prices cover, at a minimum, the effective costs incurred at each stage of the food supply chain, thereby fostering more balanced and transparent commercial relationships (Egea Clemente et al., 2025). Despite this regulatory framework, there remains a notable scarcity of both official technical reports and peer-reviewed scientific studies addressing production costs in the agricultural sector in general, and more specifically in the beekeeping sector (Sturiale et al., 2024), which limits evidence-based policymaking and strategic planning. In this context, studies assessing production costs and economic viability are essential for guiding decision-making processes, enhancing the competitiveness and resilience of the agri-food chain, and providing reliable reference data for both policymakers and private stakeholders. The present study stems from a technical-economic assessment commissioned by the Regional Government of Murcia to support the justification of eligible beekeeping-related expenditures under tab-funded support schemes.

The socioeconomic relevance of the beekeeping sector in southeastern Spain, together with the urgent need for rigorous cost analyses within the framework of agricultural policy design and the limited availability of detailed scientific evidence, provides the rationale for this study. Consequently, the objective of this research is to provide a technical characterization and analysis of representative beekeeping production systems in southeastern Spain.

2. Materials and Methodology

2.1. Description of the Study Area and Production Systems

The study area considered in this research is southeastern Spain, specifically the Region of Murcia. According to livestock registry data published by Ministerio de Agricultura, Pesca y Alimentación (MAPA) (2025), the Region of Murcia has 508 registered transhumant beekeeping farms, representing slightly more than 88% of the total number of operations in the region. These farms account for 98.4% of

the total number of beehives and reflect a highly professionalized sector characterized predominantly by transhumant production systems.

The appropriate adaptation of economic and financial analysis methodologies to local production systems requires a prior understanding of the structural characteristics of production and marketing within the sector under study (García García, 2023; García García & García Brunton, 2013). The estimation of production costs depends not only on the productive orientation of the activity, but also on the specific characteristics of the farming system, including farm size, production practices, technological level, and the origin and composition of production inputs, particularly feed-related resources. Likewise, farm income is strongly influenced by commercialization channels, which are often specific to each geographical area. Consequently, it is essential to define production systems that are representative of the study area in order to ensure the validity and applicability of the economic analysis.

For this purpose, a farm size considered sufficient to ensure both technical and economic viability was established, corresponding to an operation of 750 Layens-type hives. Based on this representative scale, three production systems were defined: local transhumance, long-distance transhumance, and the minority fixed-location system without transhumance. By standardizing production capacity across all systems (750 hives), the study ensures that comparisons between alternative production models can be performed under equivalent technical conditions.

Table 1. Technical and economic data from the baseline information.

Description	Data (unit)
Layens-type hive	€38.50/unit
Initial swarm establishment	€72/unit
Storage and honey-processing facility	€215/m ²
Average gross honey production without transhumance	16 kg/hive
Average gross honey production with local transhumance	20 kg/hive
Average gross honey production with long-distance transhumance	25 kg/hive
Average annual gross wax production	800 g/hive
Annual wax reuse rate	75%
Unit revenue from surplus wax	€5.00/kg
Hives allocated to pollination services	75 hives
Revenue per hive from pollination services	€40.00/hive
Annual supplemental feeding without transhumance	18 kg/hive
Annual supplemental feeding with local transhumance	12 kg/hive
Annual supplemental feeding with long-distance transhumance	8 kg/hive
Average price of supplemental feed	€1.35/kg
Fixed land lease cost	€254.00

Continued

Land lease cost for local transhumance	€386.00
Land lease cost for long-distance transhumance	€548.00
Unit cost of sanitary treatment	€2.50/hive
Unit cost of disinfection	€2.50/hive
Annual LHPA veterinary service fee	€365.00
Average duration of local transhumance (2 workers)	2 days
Average duration of long-distance transhumance (2 workers)	3.5 days
Liability, theft, and vandalism insurance	€1.05/hive
Passenger car/van insurance	€400
Open-bed truck insurance (3500 kg)	€550
Truck insurance (8000 kg)	€750
Truck insurance with crane (16,000 kg; 1500 kg crane capacity)	€1050
Adjusted interest rate (opportunity cost)	1.50%

2.2. Data Collection

Data on production processes used to define the representative production models and their corresponding cost structures were collected in 2025 through field surveys conducted with beekeepers, sector technicians, and representatives of public institutions responsible for agricultural production in the Region of Murcia. Specifically, 12 on-site surveys were conducted with professional beekeepers selected by the Animal Production Service of the Directorate-General for Livestock, Fisheries and Aquaculture of the Autonomous Community of the Region of Murcia. The surveys were distributed across the three farm typologies, with four beekeepers surveyed for each type.

The survey covered all technical and economic variables required to define the production cost structure, including production characteristics (productivity, management practices, supplemental feeding, etc.), infrastructure (hive type, vehicle characteristics, auxiliary buildings, etc.), production inputs, and labor and equipment performance across the different production stages.

Data collection was carried out in three sequential phases. The first phase consisted of open-ended interviews with respondents to identify the main technical and management characteristics of the production systems. In the second phase, a structured questionnaire specifically designed by the research team at the Murcian Institute for Agricultural and Environmental Research and Development (IMIDA) was administered. This instrument collected detailed information on production systems, associated investments, production performance indicators, labor requirements, and other relevant operating costs. Finally, once the representative production models had been defined, the collected information was validated through targeted follow-up interviews with respondents (García Castellanos et al., 2025).

Price data were updated using the internal database of IMIDA's Bioeconomy Research Team, which contains unit prices for production inputs, yields, technical coefficients, and cost structures across a wide range of agricultural and livestock sectors, and has served as the basis for several official technical publications (García García, 2024; García García & García Brunton, 2013).

2.3. Socioeconomic Analysis

To evaluate the production systems described above, an economic and financial analysis was conducted using a cost-accounting approach, establishing the production cost structure for a representative annual production cycle (García García, 2023, 2024). The prices of inputs and productive resources used in the calculations were obtained from the database described above.

Costs were classified into fixed and variable components, and opportunity costs were incorporated into the analysis (Egea Clemente et al., 2025; García Castellanos et al., 2024, 2025). Opportunity cost was estimated based on the return obtainable from alternative low-risk financial investments, represented in this study by a 1.5% annual interest rate (García García, 2023).

This study has limitations as is based on a representative one-year production cycle and average production yields, which may not capture interannual and farm-level variability. Moreover, the analysis is specific to beekeeping systems in the Region of Murcia and socioeconomic studies are subject to market variability. Therefore, although the methodological approach is transferable, the quantitative results should be generalized to other regions with caution.

1) *Fixed costs*

Fixed costs comprise expenditures associated with capital depreciation. Depreciation was calculated using the straight-line method.

The initial investment considered for each production system included infrastructure related to beekeeping operations (hives and initial swarms), vehicles adapted to each production model, storage and honey-processing facilities, extraction equipment, protective clothing, auxiliary materials, and legal registration and administrative costs.

In all scenarios, the initial investment corresponding to 750 hives was considered. This size was established as the representative average of regional beekeeping operations and was provided by the Animal Production Service of the Directorate-General for Livestock, Fisheries and Aquaculture of the Autonomous Community of the Region of Murcia. Additionally, an investment equivalent to 80% of the total required swarms was included, reflecting the common practice of gradually expanding the number of colonies over time in order to improve sanitary conditions and facilitate the progressive establishment of bee populations.

Fixed-location operations and farms practicing local transhumance generally require storage facilities of approximately 40 m². By contrast, long-distance transhumant operations typically involve higher production volumes and larger infrastructures, with an estimated storage requirement of approximately 50 m², accord-

ing to survey results.

Vehicle requirements also vary according to the production system, ranging from smaller transport vehicles for fixed and local systems to larger-capacity trucks for long-distance transhumance operations.

2) *Variable Costs*

Variable costs include all expenditures that may vary during the annual production cycle and are associated with inputs, services, and operational activities carried out throughout the fiscal year.

- **Supplemental feeding:** Beekeepers commonly provide supplemental feed during periods of limited floral availability, particularly in unfavorable seasons. Feed requirements depend on the production system: non-transhumant systems show the highest consumption levels, which progressively decrease in local and long-distance transhumant systems. Average annual feed consumption values are presented in **Table 1**. Supplemental feeding generally consists of sugar-based syrups or commercial feeding pastes, occasionally enriched with vitamin supplements. Water consumption associated with feeding was considered negligible.
- **Land lease:** This cost corresponds to the lease of the fixed land base used by the operation and was estimated according to prevailing dryland rental values.
- **Administrative transhumance permits:** Transhumant systems incur additional costs associated with temporary settlement in destination areas, generally in the form of land rental payments or municipal concession fees. These costs are higher in long-distance transhumance systems due to longer average stays.
- **Animal health treatments:** At least one acaricide-insecticide treatment is legally required each year; however, two treatments are common practice. Common active substances include amitraz, tau-fluvalinate, and oxalic acid. In addition, routine hive disinfection is performed using diluted caustic soda.
- **Livestock Health Protection Association (LHPA) veterinary services:** Professional beekeeping operations commonly belong to an LHPA associated with their home territory. Membership involves an annual fixed fee covering veterinary supervision and advisory services, generally determined according to farm size.
- **Hive transportation for transhumance:** This cost includes transporting hives to and from seasonal destinations and comprises fuel, lubricants, and driver-related expenses. It varies according to both transport distance and vehicle type. Vehicle depreciation is accounted for under fixed costs.
- **Travel and accommodation during transhumance:** These costs correspond to travel and accommodation expenses incurred by beekeeping workers during transhumance operations. The analysis assumes two workers per transfer, with average stays of 2 days for local transhumance and 3.5 days for long-distance transhumance.
- **Maintenance:** Annual maintenance costs for infrastructure—including vehi-

cles and storage facilities—were estimated as 1.0% of the initial investment value.

- **Insurance:** Each hive is assumed to be covered by liability, theft, and vandalism insurance. In addition, annual insurance premiums were included for the different vehicle types used in each production system (**Table 1**).
- **Labor:** Labor costs include the value of the time devoted by the owner or farm manager to production-related tasks, including hive management, loading and unloading during transhumance, sanitary treatments, supplemental feeding, resource management, and general administrative duties.

3) *Unit cost and productivity*

- Interviews conducted with beekeepers and sector specialists revealed that, in addition to income generated from the sale of the main product—honey—beekeeping operations typically obtain revenue from complementary products and services.
- In all production systems, beeswax is generated as a secondary product. Most of this wax is reused internally in the form of foundation sheets for hive maintenance and renewal; however, approximately 25% of total annual wax production constitutes surplus output and can be marketed as a by-product (**Table 1**).
- An additional source of income derives from pollination services provided to nearby agricultural holdings. These services are particularly relevant for crops with high pollination requirements, including fruit trees (such as peach, apricot, and almond) and horticultural crops (such as watermelon, melon, and zucchini). In practice, this activity is usually carried out locally using a limited proportion of the available hives; in the present study, this proportion was established at 10% of the total number of hives (**Table 1**).
- Based on the estimated cost structures and production levels of each system, a comparative analysis of unit production costs was subsequently performed.

The results are expressed in terms of unit production cost considering two scenarios: 1) accounting only for revenues generated from honey sales, and 2) accounting for revenues from both honey sales and by-products (wax and pollination services). In the second scenario, revenues from wax sales and pollination services were treated as offsets to total production costs and were therefore deducted from total costs before calculating the unit production cost. The unit costs were calculated using the following equations:

Unit cost without by products:

$$TC/HP$$

Unit cost including by products:

$$(TC - Iw - Ip)/HP$$

where TC = Total Cost; Iw = Revenue from wax sales; Ip = Revenue from pollination services; and HP = Honey production.

4) *Employment generated*

The estimation of labor requirements allows the quantification of direct employment generated by beekeeping activity, thereby providing an indicator of its contribution to rural socioeconomic development.

Within the present socioeconomic analysis, employment generation was estimated by calculating the total labor requirements associated with each production system, including tasks specifically related to transhumance where applicable. The labor hours assigned to each production system correspond to the average values obtained from the surveys conducted across the different beekeeping farms.

To standardize labor measurement, employment was expressed in terms of Agricultural Work Units (AWU), with one AWU defined as 230 working days per year, equivalent to 1840 annual working hours. This indicator is widely used in agricultural and livestock economic analyses to assess labor demand and employment generation (Egea Clemente et al., 2025; García Castellanos et al., 2026).

3. Results and Discussion

The investment requirements associated with each production system were estimated using the baseline technical information obtained from field surveys and complementary bibliographic sources. Tables 2-4 present the corresponding initial and long-term investment requirements by budget category, together with the total investment associated with each farm type.

Depreciation was calculated on the basis of acquisition cost, residual value (where applicable), and the estimated useful life of each asset; these parameters are detailed in the corresponding tables.

Table 5 presents the cost structure of the three beekeeping systems analyzed in this study. For each production model, costs are reported in both absolute and relative terms, allowing an assessment of the proportional contribution of each cost component to the overall production cost.

Table 2. Investment and Amortization: Non-transhumance system.

	Initial Investment (€)	Useful Life (years)	Residual Value (€)	Amortization (€·year ⁻¹)
Layens-type hives	28,875	12	0	2436
Initial swarms	43,200	25	0	1750
3500 kg cargo vehicle	38,000	18	7600	1710
Van-type vehicle	20,000	8	4000	2025
Warehouse/handling shed	8600	30	0	290
On-site extraction equipment	5525	10	0	559
Honey shipment	1710	2	0	866
Clothing and accessories	925	4	0	234
Legalization, fees, signage	750	25	0	30
	147,585			9901

The fixed cost of each item, expressed in €·year⁻¹, includes the opportunity cost.

Table 3. Investment and amortization: local transhumance system.

	Initial Investment (€)	Useful Life (years)	Residual Value (€)	Amortization (€·year ⁻¹)
Layens-type hives	28,875	12	0	2436
Initial swarms	43,200	25	0	1750
3500 kg cargo vehicle	68,000	15	7600	3672
Van-type vehicle	20,000	8	4000	2025
Warehouse/handling shed	8600	30	0	290
On-site extraction equipment	5525	10	0	559
Honey shipment	2025	2	0	1025
Clothing and accessories	1028	4	0	260
Legalization, fees, signage	750	25	0	30
	178,003			12,048

The fixed cost of each item, expressed in €·year⁻¹, includes the opportunity cost.

Table 4. Investment and amortization: long distance transhumance system.

	Initial Investment (€)	Useful Life (years)	Residual Value (€)	Amortization (€·year ⁻¹)
Layens-type hives	28,875	12	0	2436
Initial swarms	43,200	25	0	1750
3500 kg cargo vehicle	118,000	15	7600	6372
Van-type vehicle	20,000	8	4000	2025
Warehouse/handling shed	10,750	30	0	363
On-site extraction equipment	6464	10	0	655
Honey shipment	2835	2	0	1435
Clothing and accessories	1203	4	0	304
Legalization, fees, signage	793	25	0	32
	232,120			15,372

The fixed cost of each item, expressed in €·year⁻¹, includes the opportunity cost.

Table 5. Cost structure of the three beekeeping system analyzed.

Concept	No transhumance		Local transhumance		Long-distance transhumance	
	Absolute Cost (€)	Relative Cost (%)	Absolute Cost (€)	Relative Cost (%)	Absolute Cost (€)	Relative Cost (%)
Fixed costs (FC)						
Layens-type hives	2436	3.85%	2436	3.71%	2436	3.29%
Initial swarms	1750	2.77%	1750	2.66%	1750	2.36%
Freight vehicle	1710	2.71%	3672	5.59%	6372	8.60%
Van-type vehicle	2025	3.20%	2025	3.08%	2025	2.73%

Continued

Warehouse/handling shed	290	0.46%	290	0.44%	363	0.49%
On-site extraction equipment	559	0.89%	559	0.85%	655	0.88%
Honey shipment	866	1.37%	1025	1.56%	1435	1.94%
Uniforms and auxiliary supplies	234	0.37%	260	0.40%	304	0.41%
Legalization, fees, signage	30	0.05%	30	0.05%	32	0.04%
Total fixed costs	9901	15.66%	12,048	18.34%	15,372	20.74%
Variable costs (VC)						
Supplemental feeding	16,649	26.34%	12,949	19.71%	7399	9.99%
Land-based lease	254	0.40%	254	0.39%	254	0.34%
Administrative concession for transhumance	-	-	386	0.59%	548	0.74%
Animal health	4187	6.62%	4187	6.37%	4187	5.65%
ADSG veterinary expenses	365	0.58%	365	0.56%	609	0.82%
Transportation of beehives for transhumance	-	-	1269	1.93%	2233	3.01%
Migrations/transhumance stays	-	-	1880	2.86%	5400	7.29%
Maintenance	676	1.07%	980	1.49%	1510	2.04%
Insurance	1764	2.79%	1967	2.99%	2271	3.06%
Labor	29,415	46.54%	29,415	44.77%	34,317	46.31%
Total variable costs	53,309	84.34%	53,651	81.66%	58,728	79.26%
Total costs (TC)	63,210	100.00%	65,699	100.00%	74,100	100.00%
Unit cost including by-products (€/kg)	4.95		4.13		3.74	
Unit cost without by-products (€/kg)	5.27		4.38		3.95	

Within the initial investment structure, two major components stand out: physical infrastructure—primarily hives and initial swarms—and transport vehicles. Together, these two categories account for between 88.0% and 90.5% of total investment in the non-transhumant and long-distance transhumance systems, respectively. However, the relative contribution of hives and swarms declines progressively from the non-transhumant system (48.8%) to the long-distance transhumance system (31.0%), while the opposite trend is observed for vehicle-related investment. Transhumant production systems require substantially higher investment in transport equipment, both in absolute and relative terms. In the case of long-distance transhumance, vehicles represent up to 59.5% of total initial investment (**Tables 2-4**). Storage facilities and extraction equipment rank next in importance, although their contribution remains considerably lower.

The investment-per-hive indicator, used here as a proxy for production capacity, ranges from €197 per hive in non-transhumant systems to €309 per hive in

long-distance transhumance systems, with local transhumance occupying an intermediate position at €237 per hive. The cost structure reveals an activity characterized by a relatively high proportion of fixed costs (FC), ranging from 15.66% in the non-transhumant system to 18.34% in local transhumance and 20.74% in long-distance transhumance (Table 5). These results confirm that more productive systems, particularly those involving transhumance, require greater capital investment and consequently exhibit higher relative fixed costs, largely associated with the need for larger and more specialized transport vehicles.

Production systems differ substantially depending on the technological level adopted, the combination of production factors employed, and whether transhumance is practiced, resulting in distinct fixed-cost structures. Similar variability has been reported in other Mediterranean regions, where fixed costs range from 8.8% in Türkiye (Dogan & Adanacioglu, 2021) to 10% in Greece (Makri et al., 2015) and 20.3% in Egypt (Alropy et al., 2019).

By comparison, in other Mediterranean livestock systems such as dairy sheep and goat farming, fixed costs generally account for slightly more than 5% of total costs (García García, 2024). These intensive indoor systems require high initial investment; however, much of that investment—particularly in buildings, facilities, permits, and breeding stock—has a long useful life, resulting in relatively low annual depreciation costs.

Among variable costs, labor is the dominant component, accounting for between 44.8% and 46.5% of total production costs. This finding is consistent with previous studies reporting labor as the largest cost component in other beekeeping systems, including Bosnia and Herzegovina (41%) (Nikolić et al., 2022) and Türkiye (48%) (Aydin et al., 2019). Moreover, absolute labor costs tend to increase in transhumant systems, as also reported by Dogan & Adanacioglu (2021). Similar patterns have been identified by Feketéné Ferenczi et al. (2023) and Tubene et al. (2023). Given its structural nature, labor costs offer limited scope for reduction; improvements in economic efficiency therefore depend primarily on increasing productivity through economies of scale (Alropy et al., 2019; Tubene et al., 2023) and through greater technological efficiency in transport and honey extraction equipment.

Supplemental feeding constitutes the second most important cost component, representing 26.3% of total costs in non-transhumant systems. However, its relative importance decreases markedly in transhumant systems, particularly in long-distance transhumance, where it accounts for only 10.0% of total costs, despite the additional expenses associated with transport, travel, and temporary stays at destination sites (Table 5). When these transhumance-related expenses are combined with feeding costs, the resulting share reaches 24.5% in local transhumance and 20.3% in long-distance transhumance. This indicates that, although transhumance reduces feeding costs, the overall reduction is only partially offset by new logistical expenditures. Therefore, the economic viability of transhumance depends fundamentally on the productivity gains achieved through increased honey

yields per hive. Other studies have similarly identified feeding as a major variable cost component, accounting for approximately 25% - 30% of total production costs (Aydin et al., 2019; Dogan & Adanacioglu, 2021; Feketéné Ferenczi et al., 2023; Makri et al., 2015). In this regard, Aydin et al. (2019) emphasized the strategic importance of selecting suitable locations for transhumant apiaries.

Together, labor and supplementary feeding costs account for as much as 72.9% of total production costs in non-transhumant systems. In transhumant systems, however, the greater weight of vehicle-related fixed costs reduces the relative importance of this combined category, lowering it to 64.5% in local transhumance and 56.3% in long-distance transhumance. Comparable proportions have been reported in other livestock sectors, such as intensive dairy goat systems in south-eastern Spain, where labor and feeding jointly account for between 76% and 80% of total production costs (García García, 2024).

Animal health treatment represents another relevant cost component, amounting to €4187 annually and accounting for approximately 6% of total costs across all production systems. Insurance costs—including both hive and vehicle coverage—also increase with the scale and technical complexity of the operation, reaching 3% of total costs in long-distance transhumance systems. Similarly, maintenance costs are primarily influenced by vehicle type and account for up to 2% of total costs in long-distance transhumance systems (Table 5). These findings further illustrate the additional cost burden associated with transhumant management systems.

As reported in other European regions, honey remains the principal product and primary source of income for beekeeping operations (Dogan & Adanacioglu, 2021; Feketéné Ferenczi et al., 2023; Ferreira-Golpe et al., 2021; Makri et al., 2015). Nevertheless, by-products and complementary services—such as surplus wax sales and pollination services—provide additional income that, although modest, is not economically negligible (Makri et al., 2015). Table 5 shows that unit production costs are sensitive to this supplementary income. In the present study, the difference ranges from €0.21/kg in long-distance transhumance systems to €0.32/kg in non-transhumant systems. Although relatively small, these margins may determine the economic viability of an operation; notably, more productive and transhumant systems appear less dependent on supplementary revenues.

The results clearly indicate that transhumance systems achieve lower unit production costs, primarily because increased productivity more than compensates for the additional operational expenses associated with mobility. In semi-arid Mediterranean conditions, the unit cost of honey production in non-transhumant systems (€4.95/kg) is considerably higher than in local (€4.13/kg) and long-distance transhumance systems (€3.74/kg) (Table 5). From the perspective of cost analysis and cost accounting adopted in this study, the long-distance transhumance system exhibits the lowest unit production cost and is therefore the most economically competitive. After accounting for recent increases in input prices,

these results remain consistent with those reported in previous studies (Aydin et al., 2019; Dogan & Adanacioglu, 2021; Tosun & Oğuz, 2021).

These findings suggest that transhumance is an essential adaptive strategy in semi-arid Mediterranean regions, as it improves productivity, reduces dependence on supplemental feeding, lowers unit production costs, and ultimately enhances economic viability and competitiveness. As noted by Ferreira-Golpe et al. (2021), transhumance is much less common in northern Spain, where climatic conditions and floral resources are more favorable, than in southern and south-eastern regions such as Murcia, where professionalized and larger-scale transhumant operations predominate (Ministerio de Agricultura, Pesca y Alimentación, 2025).

The production systems analyzed generate between 1.51 Agricultural Work Units (AWU) in local transhumance and non-transhumant systems and 1.77 AWU in long-distance transhumance systems. These jobs are directly linked to rural areas, highlighting the social importance of beekeeping activity. Labor requirements per hive are higher in the long-distance transhumance system (425 hives/AWU) than in the local transhumance and non-transhumant systems (497 hives/AWU). Nevertheless, these values are relatively high and reflect the high level of professionalization and the operational scale of the regional beekeeping sector (Ministerio de Agricultura, Pesca y Alimentación, 2025).

As previously noted by Makri et al. (2015), the aging rural population and the lack of generational renewal remain major structural challenges for the sector. In this context, ensuring the economic viability of beekeeping—given its recognized socioeconomic and environmental importance—should constitute a strategic policy priority (Ferreira-Golpe et al., 2021).

Finally, several authors have emphasized the importance of strengthening cooperation among professional beekeepers, particularly in the marketing of bee products and in strategic collective actions such as the development of quality labels, technical training, and joint access to financial support (Aydin et al., 2019; Ceyhan et al., 2017). Producer associations and interprofessional organizations can play a decisive role in promoting more balanced and transparent commercial relationships across the value chain, in line with the objectives of regulatory frameworks such as Spain's Law 16/2021 on the Food Chain (Egea Clemente et al., 2025), which transposes Directive (EU) 2019/633 of the European Parliament and of the Council.

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Author Contributions

Conceptualization, methodology, formal analysis, investigation, resources, B.G.G,

J.G.G. and I.G.M.; writing—original draft preparation, writing—review and editing, B.G.G, J.G.G., I.G.M and F.C.L.; funding acquisition J.G.G. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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