# TECHONEY

Development of a **blockchain-based ecosystem** that allows an **improved positioning of small producers of honey** on local and international markets

**WP1: HONEY INNOVATION AND LEARNING COMMUNITY LAB (HILE)**

**D1.5. Report on the formation strategy in the case studies**
**Task 1.5. Analysing the value chain price strategy and price transmission along the Honey chain**
**(R) (PU) (CREDA, M42)**

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| | AUTHOR | Zein Kallas (CREDA)<br>Selene Ivette Ornelas Herrera (CREDA)<br>Seval Mutlu Çamoğlu et al. (ORDU)<br>Yamna Errach et al. (INAT)<br>Christopher Stahl (LIST) | | |
| | REVIEWER | Zein Kallas (CREDA), Christoph Stahl (LIST) | | |
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# PROJECT ABSTRACT

**TECHONEY** project's main objective is to identify strategies and establish lines of resilience to the new challenges determined by the COVID-19 pandemic for beekeepers in the Mediterranean (Med) agricultural systems through the implementation, definition, enhancement and transfer of competitive, profitable, efficient and trustful honey supply-chain alternatives that address beekeepers' capacities and attractiveness to fulfil consumer needs on unexpected food market changes.

**TECHONEY** project proposes the development of a **traceability system to guarantee the quality and safety of honey within the supply chain** for more effective communication to consumers and to strengthen access to different markets (e-commerce, direct sales, etc.). This approach will be unfolded by the joint creation of two levels of interaction: **[1]** physical: characterization of honey; **[2]** "living laboratory": creation of a Honey Community Living Lab (HCLL) and a Honey Innovation and Learning Ecosystem (HILE) that will be the arena to collect information from beekeepers, stakeholders, and consumers to transfer and apply the new optimized models.

**TECHONEY** is structured in 4 main technological pillars: **[1]** creation of a consortium IoT blockchain platform that involves various actors in the honey supply chain to ensure transparency and traceability, in addition to reducing costs and ensure the traceability in the honey supply chain; **[2]** creation of a transformative learning community to ensure a smart-short-resilient shared supply chain; **[3]** characterization of the quality of honey to guarantee its traceability within the blockchain directly by consumers; **[4]** develop ICT tools for honey supply chain participants and consumers.

**TECHONEY** will be committed not only to promote the continuation of the direct sales of honey from producers to consumers even after the COVID crisis but also develop a common methodology and clear new optimized resilience protocol to be used by small-scale beekeepers and farmers, smallholders as a new business model with a more efficient added-value chain, sustainable with fair profit, accepted by final consumers, which will be replicable to other food products and supply chains. **TECHONEY** will help beekeepers to: **[1]** generate a traceability mechanism for honey produced in the Med. Area; **[2]** diversify markets and distribution channels offers business flexibility and freedom from dependence on a single market, which will reduce risk in the event of a crisis; **[3]** cooperate and pool resources among themselves (pooling of the workforce, etc.) for logistical flexibility and solidarity in the supply chain, which will also reduce the risks in the event of a crisis.

**TECHONEY** proposes to design and develop a multidimensional framework to analyse 6 full honey supply chains (farm to table) that will integrate economic, social and environmental indicators and a traceability system, with a bottom-up approach considering the stakeholders' perspectives. A consortium Blockchain, coupled with IoT (Internet of Things), system will be created to offer real-time tracking and complete traceability of honey along the supply chain from the characterization of honey in a certified laboratory, the retailer, until the end consumer.

The characterization of the quality and safety aspects of local honey through local certified laboratories jointly with the use of e-commerce and quality labelling schemes will increase the opportunity for beekeepers to be identified locally and allow them to gain access to new markets (foreign markets). The implementation of e-commerce with the mobile application will enable local honey to be better traced by consumers who attach more value to local food and local beekeepers. **TECHONEY** contributes to increasing farm profitability and increasing flexibility and risk mitigation capabilities. A

shared, short and circular supply chain will allow actors in the honey supply chain to access markets and have higher incomes, share resources and skills and save money by reducing costs (economies of scale), and increase the efficiency, sustainability and flexibility of processes to strengthen resilience and flexibility to face crises and lower risks. The learning community lab and the use of the blockchain network will secure the storing of records, will strengthen intellectual property rights, as well as bring transparency throughout the supply chain; it will reduce frauds, enhance food safety, and improve the communication between retailers and beekeepers. The traceability system offered will also allow consumers to give direct feedback to beekeepers. **TECHONEY** commits not only to promote a continuation of direct sales, but also develop a common methodology and clear new optimized resilience protocol to be used by small-scale beekeepers, farmers and smallholders as a new business model with a more efficient added-value chain, sustainable with fair profit, accepted by final consumers and replicable to other food products and supply chains.

Moreover, a **TECHONEY** web ICT tool consumer/farmer-centred will be developed, by testing and evaluating several machine and deep learning algorithms, providing small-scale beekeepers with key information on new markets and opportunities, contributing to a better decision making and to ensure the traceability of their product. Consumers will have exhaustive knowledge of the different honeys of the Med. area, knowing their traceability from the initial producer, guaranteeing the quality and safety of each product.

**TECHONEY** is a project coordinated by CITA (Spain) and funded through the PRIMA Section 2 Multitopic 2021 – Thematic Area 3 - Agrofood chain – Topic 2.3.1 Increasing the resilience of small-scale farms to global challenges and COVID-like crisis by using adapted technologies, smart agri-food supply chain and crisis management tools. (RIA*[5])" under the funding scheme of "Collaborative Project" and type of Action "Research and Innovation Actions (RIA)."

# 1. INTRODUCTION

The deliverable 1.5 is a report on the price formation strategy in the case studies corresponding to task 1.5 “Analysing the value chain price strategy and price transmission along the Honey chain”; It is led by CREDA as the main responsible for this report within work package 1 (WP1) and it involves the participation of all case study leaders from each Living Lab (Algeria, Luxembourg, Morocco, Spain, Tunisia and Türkiye) as well as an involvement of CITA as project leader and main coordinator of the TECHONEY project.

This study analyses the evolution of beekeepers' margins to consumers over time in order to understand how quickly honey prices are transmitted from the farm to the retail level and vice versa. The analysis also aims to verify whether there is symmetry in price transmission, the speed of transmission, and its magnitude. The supply chain was analyzed as an important component of price transmission models. Price data were collected from secondary data sets in the different case studies. Although the report should include the case studies in six countries, the econometric analysis of price transmission was limited to Spain and Turkey due to the lack of complete and reliable time series on honey prices at both the producer and consumer levels. In the remaining participating countries—Algeria, Luxembourg, Morocco, and Tunisia—sufficiently detailed or consistent historical data were not available to allow the application of the required analytical models. Therefore, the study was chosen to focus on two cases with robust information, thus ensuring the methodological validity and solidity of the conclusions obtained.

For the specific case of Spain, data on multiflora honey prices for producers and consumers were extracted from the Ministry of Agriculture, Fisheries, and Food's website under the section "Short-term Prices of Livestock Products for the 2009-2023 Seasons" (MAPA; 2023). Regarding the honey price data for the specific case of Turkey, these were obtained from the Turkish Statistical Institute (TUİK) and also include time series with monthly honey price data (in Turkish liras) for producers and consumers, for the period from January 2009 to December 2023.

# 2. CONTEXT ANALYSIS HONEY SECTOR

## 2.1 A GLOBAL VIEW OF THE BEEKEEPING SECTOR

Beekeeping, although a relatively small agricultural sector, plays a crucial role in sustaining global agri-food systems. In addition to providing honey and other derived products such as wax, propolis, and pollen, its true value lies in the vital role bees play as pollinators. This ecosystem service has a direct impact on the productivity of crops, fruits, vegetables, and wildlife, with its contribution estimated at

up to $80 billion annually in Europe alone (Financial Times). Beekeeping also stands out as one of the most climate-sustainable activities, due to its low inputs and emissions.

Despite its importance, the sector faces significant challenges, such as the increasing adulteration of honey in the supply chain, which raises concerns about the authenticity of bee products. As early as 2010, analytical studies revealed fraudulent practices (Chen et al., 2011), which has intensified surveillance and concern regarding the origin and quality of honey.

Internationally, the honey market has shown steady growth in recent decades. However, compared to other agri-food products, its trade volume remains small, accounting for less than 1% of total agri-food exports. In 2016, its value was estimated at approximately $2.2 billion (Pippinato, 2020), positioning the sector as a specialized niche within global food systems.

In a global context, the honey market presents complex dynamics marked by significant variations in prices, production, and trade. In 2025, honey export and import prices range between USD 1.44 and USD 10.33 per kilogram, depending on quality, origin, and variety. Retail prices, for example in the United States, reach up to USD 11.53 per pound, driven by rising production costs and demand for organic honey. The main producing countries include China (with over 460,000 tons annually), Turkey, Iran, India, and Argentina, which together represent a substantial share of global production. (https://blog.geohoney.com/top-10-honey-producing-countries-in-the-world).

Regarding international trade, China leads exports with a value of over USD 277 million, while countries such as the United States, Germany, and Saudi Arabia are among the largest importers. This global exchange reflects both sustained market growth and challenges related to product authenticity and sustainable practices in the supply chain. (https://www.gminsights.com/industry-analysis/honey-market)

## 2.2 The Spanish Beekeeping and Honey Sector

Spanish honey is known for its rich diversity of types and flavours. Its market is characterized by a strong tradition of beekeeping and honey production. Spain is one of the largest honey-producing countries in Europe and the world, with an annual production of over 32,000 tons in 2020. However, the beekeeping sector is currently experiencing a complex situation. By 2025, national production will have decreased by 21% compared to the previous four years, standing at around 27,000 tons, while imports have reached 29,000 tons, much of it at low prices, creating unfair competition. The local production cost of a kilo of honey ranges between €3 and €4, compared to an average import price of

€1.76/kg, which threatens the sustainability of the sector. With approximately 2.96 million hives in 2022 (European Commission, MSs notifications under Reg. 2015/1366), Spain maintains its European leadership in the number of beehives, although this figure has decreased by 9% in recent seasons. Although, compared to other agricultural goods and their economic output, the beekeeping sector accounts for around 0.44% of all livestock production in the country and 0.17% of the total agricultural production output. The total beekeeping sector annual production output (mainly honey, pollen and beeswax) in 2022 was estimated on 62 million Euro (MAPA, 2022).

**Regarding the market,** with in an annual estimated consumption between 0.66 to 0.9 kg per capita, Spain´s self-sufficiency is at a negative rate of under 85%. Important to mention that although the country has a favourable climate and landscape for beekeeping, the amount of harvested honey fluctuates as other crop yields per year.

While the yield per hive (10kg/hive in 2018) is below the European Union average (22kg in 2018) the production costs are more favourable with estimated 2,73€/kg compared to the average in the EU of 3,90/kg honey produced. This underlines the fact of economics of scale in production. Production data was assessed form global agricultural statistic database of FAO (FAOSTAT 2023, from the Ministry of Agriculture, Fisheries and Food MAPA, 2023 and the Observatory of Economic Complexity OEC). The Spanish honey production and beekeepers could produce, except 2017 every year more than 30 thousand kilograms in the years 2010 – 2020 (FAOSTAT, 2023).

## 2.3 The Turkish Beekeeping and Honey Sector

Türkiye ranks as one of the leading countries in global honey production, largely due to its rich flora, diverse climate conditions, and favourable geography. As of 2023, it stood second worldwide after China in total honey output (FAO, 2023). The beekeeping sector holds significant economic weight, with over 89,000 registered beekeepers and more than 8.7 million beehives (Turkstat, 2023). By the end of 2024, this number had exceeded 9 million hives, resulting in a total yield of approximately 95,492 tonnes of honey.

Beekeeping in Türkiye is carried out both through traditional practices and migratory systems, particularly concentrated in provinces such as Muğla, Ordu, and Adana. Despite strong domestic consumption, Türkiye exported only 8,657 tonnes of honey in 2024, generating close to USD 32 million, with Europe and North America as main destinations. Among Turkish provinces, Ordu led natural honey production in 2022 with over 19,098 tonnes, followed by Muğla with 6,577 tonnes and Sivas with 6,078 tonnes (Turkstat, 2023).

In 2023, the average honey yield per hive was 12.5 kg—slightly surpassing Spain, though still below the EU average. Regional disparities in production costs are noticeable, yet the country benefits from economies of scale and minimal pesticide use, favouring organic and multifloral production. Türkiye is notably the world's top producer of pine honey and continues to build its reputation for monofloral honeys like chestnut, lavender, and citrus. However, the sector faces growing challenges stemming from climate change, drought, and land-use shifts, all of which impact nectar availability and threaten production stability.

Most of the honey is consumed domestically, with the rest directed toward international markets (TEPGE, 2020). According to Turkstat, the consumer price of honey in December 2021 was 62.18 TL/kg, while producers received 56.73 TL/kg. In subsequent years, honey prices saw a continuous upward trend, influenced by Türkiye's inflationary economic climate.

In summary, while both Spain and Türkiye are major players in the honey sector, they face distinct challenges and market dynamics. Spain grapples with declining production and rising imports, whereas Türkiye maintains robust domestic output but is vulnerable to environmental pressures. These contrasts provide a valuable foundation for analyzing price transmission mechanisms in the following sections.

# 3. THEORETICAL FRAMEWORK

The exchange of goods across different geographic areas, product formats, and time periods is essential to avoid significant price discrepancies throughout the stages of the marketing chain. In the case of spatially dispersed markets, long-distance trade serves as the main link between them. Furthermore, when considering market forms, aspects such as vertical integration, transformation processes, and the value added of goods come into play. Storage also plays a decisive role in connecting prices across different periods, enabling deferred trade practices (von Cramon-Taubadel and Goodwin, 2021).

The study of price transmission—understood as the movement of price information through different marketing levels in a specific direction—is conditioned by the participation and behaviour of various economic agents (Bakucs and Szabó, 2007). This analytical tool is widely used to assess the functioning of agrifood markets, facilitating both the measurement of dispersion in vertical price relationships and the analysis of the mechanisms by which these prices are passed along the chain. Vertical price transmission refers to how price changes at one level of the supply chain (e.g., producer) affect prices

at another level (e.g., retailer- consumer). Asymmetry occurs when price increases are transmitted differently than price decreases—either in speed, magnitude, or direction (Meyer and von Cramon-Taubadel, 2004).

According to Gutiérrez-Salcedo et al. (2015), studying price transmission allows us to understand not only how prices are generated and how they are distributed among system actors, but also what factors influence these dynamics. This methodology is valuable for three main reasons: (1) it constitutes an indicator of market efficiency and competitiveness; (2) it allows us to anticipate and understand the response of the system and its agents to variations, as proposed by Babula et al. (1991) and Kwon (2001); and (3) it can indicate the need for regulatory intervention, especially in relation to the formulation of public policies within the agricultural sector (Rossini and Depetris, 2008).

The purpose of this study is to analyse how price transmission occurs in the different cases of the TECHONEY project. The research was structured in three main stages. First, a detailed description of the data was carried out to establish an initial framework for understanding. Next, a time-series-based predictive model (VAR model) was developed, which allowed the price of each component—whether producer or consumer—to be estimated based on its own historical values and those of the other end of the chain. Finally, this model was applied to implement a generalized impulse response function, which made it possible to observe how producer (or consumer) prices react to positive or negative shocks in consumer (or producer) prices. Furthermore, a test was made to determine whether these responses exhibited asymmetric behaviour.

This framework is especially relevant in agri-food systems such as honey, where seasonal production, product differentiation (e.g. mono-floral vs. multifloral), and consumer preferences strongly influence the formation and transmission of prices along the Honey value chain.

# 4. METHODOLOGY

The methodological choice of this study responds to the need to understand the dynamics of price formation and transmission in the beekeeping supply chain using rigorous quantitative tools. This econometric approach based on time-series captures the relationship between producer and consumer prices over time, offering an evolving view of market behavior. After assessing cointegration between the series, a VAR model is used, considered appropriate in contexts where a long-term relationship between variables is not verified (Kwon, 2001; Lütkepohl, 2005). This technique allows for the analysis of dynamic interdependencies and feedback effects between levels of the supply chain,

facilitating the identification of transmission patterns and potential asymmetries that affect value distribution. Previous studies in agricultural and food markets have demonstrated the usefulness of this approach in addressing imbalances in bargaining power and trade structure (von Cramon-Taubadel and Goodwin, 2021; Bakucs and Szabó, 2007; Rossini and Depetris, 2008; Gutierrez-Salcedo et al., 2015). Thus, the proposed methodological approach provides useful empirical evidence for the design of public policies aimed at improving trade efficiency and strengthening the position of small producers vis-à-vis the final consumer (Toribio and Del Hoyo, 2005; Ben-Kabia and Gil, 2008).

Econometric analyses were conducted using EViews statistical software, widely recognized in academic and professional research for its ability to perform time series estimations. In particular, the Engle-Granger test was performed by estimating ordinary least squares regression and then applying the ADF unit root test to the residuals. This environment facilitated the graphical and numerical interpretation of the results, ensuring the reliability of the analytical process and the reproducibility of the procedures.

### 4.1 THE STATIONARITY TEST

As Khan et al 2024 mention, the econometric models generally work if the series used in the analysis are stationary. However, most data set of economic variables are not stationary; the mean and variance are not constant over time (they present the unit root problem). The problem of data non-stationarity can generate biased results that cannot be interpreted (Khan et al., 2024).

To assess stationarity, different tests were performed, such as the Augmented Dickey-Fuller test (1979), and the Phillips-Perron test (1988).

1) The Augmented Dickey-Fuller test (ADF) is one of the most common techniques used to examine the stationarity of data. To a formal unit root test and autoregressive process of order 1 AR (1) is considered based on the specific model given below in equation 1 (Aguirre and Chávez., 2012):

$$Y_t = \alpha + \varphi Y_{t-1} + \varepsilon_t \quad (1)$$

Where:

$Y_t$ represents a times series at time t;

$Y_{t-1}$ corresponds to the first lag of the time series;

$\varepsilon_t$ is the error term;

$\alpha$, and $\varphi$ are constants.

Rewritten as:

$$\Delta Y_t = \alpha + \beta t + (\varphi\text{-}1)\, Y_{t-1} + \varepsilon_t \quad (2)$$

Where Δ is the operator in first difference, $\Delta Yt = (Yt - Yt\text{-}1)$. The null hypothesis $H_0$: ($\varphi$ - 1) = 0, corresponds to the presence of a unit root, acceptance of $H_0$ indicates that the time series is non-stationary. While alternative hypothesis $H_1$: ($\varphi$ - 1) < 0, indicates the no presence of unit root.

In the specifications of the model used to conduct the test, the constant α and the trend βt must be included in the model if the series shows a trend (deterministic or stochastic). When the behavior of the series does not reflect a trend and its "mean" is different from zero, only the constant α should be included. The constant α and the trend βt should not be included if the series fluctuates around a mean equal to zero.

One feature of the Dickey-Fuller test is that the disturbance term should not exhibit autocorrelation. Nevertheless, if autocorrelation is present, additional lagged values of Yt should be included in equation 1, (the number of lags must be sufficient so that the error term is approximately white noise). This modification results in the Augmented Dickey-Fuller (ADF) test which expands the Dickey-Fuller model by incorporating more complex higher-order autoregressive processes, as can be seen in the next equation (Equation 3):

$$\Delta Y_t = \alpha + \beta t + (\varphi\text{-}1)\, Y_{t-1} + \lambda \sum_{i=1}^{m} \Delta Y_{t-1} + \varepsilon_t \quad (3)$$

The DFA test statistic has the same asymptotic distribution as in DF, so the same critical values can be used.

b) Phillips and Perron (1988) introduced a methodological modification to unit root tests that extends the Dickey-Fuller approach without requiring additional lags in the regressions. Instead of altering the model specification, they adjusted the statistics used for the test, incorporating corrections that account for potential autocorrelation and heteroskedasticity in the errors. This strategy preserves the original form of the Dickey-Fuller regression, allowing for a more robust assessment of the presence of a unit root. The statistic is calculated from the following linear model:

$$\Delta Y_t = \alpha + \varphi Y_{t-1} + \varepsilon_t \quad (4)$$

Under de null hypothesis of $H_0$: $\varphi = 0$, $Y_t$ is a variable non-stationary and the alternative $H_1$: $\varphi < 1$, $Y_t$ is a stationary variable (Aguirre and Chávez., 2012).

### 4.2 The Cointegration analysis

Testing for cointegrations begins with an assessment of whether or not the analyzed series are of the same "order of integration". The order of integration, denoted I(d), refers to the number of times a series must be differentiated to obtain a stationarity series (Gutierrez-Salcedo et al., 2015). Once it is established that all variables have the same order of integration, the existence of integration relationships is contrasted. To determine the existence of long-term equilibrium relationships between producer and consumer prices of multifloral honey in Spain and Turkey, the Engle and Granger (1987) methodology and the Phillips - Ouliaris test (1988) was applied. These analyses were performed in two stages:

1. First stage: A linear regression was estimated between the two-price series using ordinary least squares (OLS), assuming that one of the series is the dependent variable (price for consumer) and the other the explanatory variable (price for producer).
2. Second stage: The residuals from this regression were extracted and a unit root factor (AFD) test was applied to assess their stationarity. The presence of unit roots in the residuals would indicate the absence of cointegration.

If the results obtained shows that the residuals are non-stationary, it suggests that the series are not cointegrated.

### 4.3 VAR Model

The VAR model is selected as the primary analysis tool due to its ability to capture the dynamic interdependencies between multiple economic variables over time, without the need to establish prior causal relationships (Sims, 1980). In the context of this study, the VAR models allows us to examine how prices are transmitted between different levels of the marketing chain (producer and consumer) and to detect potential feedback effects between them.

The application of the VAR is especially appropriate when time series with similar frequencies (monthly, quarterly, annual) are available, as is the case with producer and consumer price records in the honey sector. Using this approach, it is possible to:

• Identify the direction and speed of price adjustment in the face of exogenous changes or shocks at either end of the chain.

• Estimate dynamic relationships between prices, considering time lags in the response of economic agents.

Furthermore, the model allows for the development of scenario simulations that analyze how a change in consumer price can affect producer price (or vice versa), providing valuable information for the design of public policies and commercial strategies in the beekeeping sector. In general, a VAR model of order n follows the next specification:

$$Y_t = A_0 + \sum_{i=1}^{m} A_i Y_{t-i} + GW_t + u_t \qquad (5)$$

where $Y_t$ is a kx1 column vector; m is the order of the VAR model, or number of lags of each variable in each equation, and $u_t$ is a kx1 vector of innovations, that is, processes without autocorrelation, with $Var(u_t) = \sum$; constant. $GW_t$ is a vector of exogenous variables (Novales, 2017). This methodological choice is supported by specialized literature on the analysis of agrifood markets with fragmented structures and transitory price fluctuations (von Cramon-Taubadel and Goodwin, 2021). The Vector Autoregression (VAR) model often faces challenges due to extended lag lengths. Longer lag structures demand the estimation of numerous parameters and result in fewer degrees of freedom (Michieka et al., 2013). Hence, it's essential to strike a proper balance between the lag length and the degrees of freedom (number of independent variables that can vary in the sample) (Khan et al., 2024). Optimal lag selection should correspond to the lowest values of the Akaike Information Criterion (AIC), the Schwarz Criterion (SC) and the Hannan - Quinn criterion. These are represented respectively by Equations (6), (7) and (8) below.

$$AIC = -2\frac{l}{N} + 2\frac{m}{N} \qquad (6)$$

$$SC = -2\frac{l}{N} + m\frac{\log(N)}{N} \qquad (7)$$

$$Hannan\text{-}Quinn = -2\frac{l}{N} + 2\frac{k\log(\log(N))}{N} \qquad (8)$$

where $l = -\frac{Nk}{2}(1 + log2\pi) - N\frac{N}{2}\log|\sum|$, N is the total number of observations, m corresponds to the number of variables in the model, and k is the number endogen variables.

### 4.4 Impulse response function (IRF)

Impulse response functions are useful for studying the interactions between variables in a vector autoregressive model (Lütkepohl, 2018). Generalized impulse response functions (IRFs) and asymmetry tests are incorporated to assess the degree of efficiency, integration, and competitiveness of the multifloral honey market in Spain and Turkey. The IRF allows for the analysis of the dynamic relationship between consumer and producer prices, considering that responses to shocks depend not only on the size and sign of the shock, but also on the system's history at the time of impact (Galvão, 2003). For each innovation in the model, as many response functions as endogenous variables are generated, forming a k × k matrix that is usually represented graphically. The IRF function is defined as:

$$IRF\ (h, \delta, \omega_{t-1}) = E\ [P_{t+h} \mid e_t = \delta, \omega_{t-1} - E_{t+h} \mid \omega_{t-1}] \quad (9)$$

Where h = 0, 1... H represents the forecast horizon, P is the response variable at horizon h, $e_t = \delta$ is a vector denoting a specific shock to the system, and $\omega_{t-1}$ contains the histories of the series. This methodology also allows for the evaluation of the presence of asymmetric price adjustments in response to different types of shocks.

## 5. EMPIRICAL RESULTS

The results of the analyses and the findings from each individual case study are presented below. Previously, Table 1 displays the content of each time series along with the sources of the data, which were obtained from the official websites of relevant ministries in each country.

**Table 1.** Time series description

| Country | Product | Serie | Coin | Frequency | Years | Data origin |
|---|---|---|---|---|---|---|
| Spain | Multifloral honey | PGM<br>PEM | Euro (€) | Monthly data (all year) | 2009- 2023 | Ministry of Agriculture, Fisheries, and Food's |
| Turkey | Multifloral honey | PEMT<br>PGMT | Turkish lira (₺) | Monthly data (all year) | 2009- 2024 | Turkish Statistical Institute (TUİK) |

PGM, PGMT - Bulk price/producer price
PEM, PEMT - Packaged price/consumer price/market price

### 5.1 Empirical Results Case Study Spain

#### 5.1.1 Descriptive Statistics and Correlation

For case study of multiflora honey prices for Spain, the descriptive statistics and correlation among variables are shown in Table 2 and Table 3. Table 2 presents the descriptive statistic of variables used

in this study regarding 180 observations about the producer and consumer price for kilogram of multifloral honey in Spanish market. Descriptive statistics show that for PGM the mean, standard deviation, minimum, and maximum values are 3.02, 0.48, 2.09, and 3.93 respectively. And for PEM are 4.82, 0.72, 3.56, and 6.55 respectively. The descriptive statistics show higher values for PEM. The correlation analysis (Table 3) allows to see that PGM is positive correlated to PEM (0.804).

**Table 2.** Descriptive statistics

| Variable | Obs. | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|
| PGM | 180 | 3.02 | 0.48 | 2.09 | 3.93 |
| PEM | 180 | 4.82 | 0.72 | 3.56 | 6.55 |

Source(s): Author's own calculation

**Table 3.** Correlation analysis

| Variable | PGM | PEM |
|---|---|---|
| PGM | 1.000 | |
| PEM | 0.804 (0.7461 - 0.8507) * | 1.000 |

* Confidence interval:
Source(s): Author's own calculation

Since multifloral honey prices are presented in different currencies depending on the country of origin, and considering that the analysis is conducted using regression models, a logarithmic transformation was applied to the data (logarithm of PEM and PGM). This decision reduces scale effects and facilitates proportional comparisons, while also improving the statistical stability of the models used.

The results are presented below in a visual manner to facilitate the initial understanding of the dynamics of the relationship between the logarithmic of both variables (LGPGM- LGPEM). Figure 1 allows observe patterns such as similar increases and decreases movements of the series along the chosen period, indicating a positive trend in both series, which could Indicate they are not stationary.

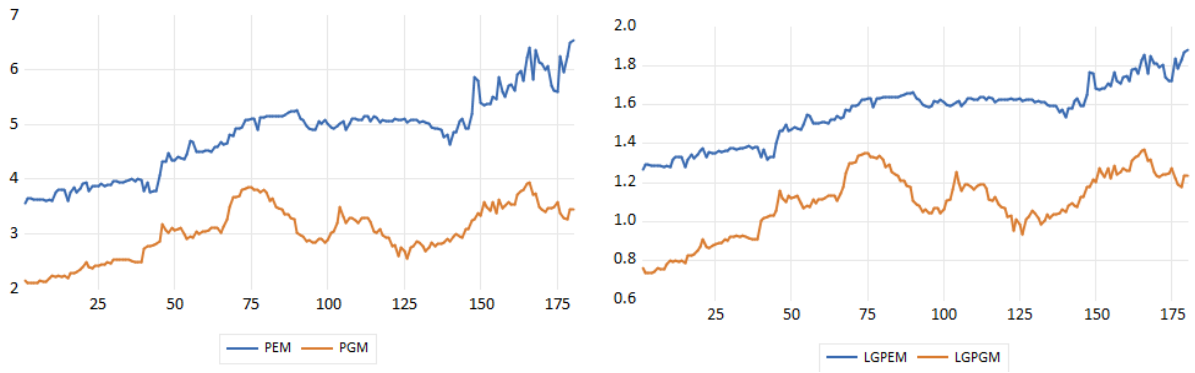


**Figure 1**. Original and Log trends of consumer and producer multifloral honey price on Spain (Source(s): Author's own calculation)

Complementing the analysis with the unit root test with the augmented Dickey-Fuller test (ADF) and the Phillips Perron tests (Table 4), we can argue that LGPEM and LGPGM series have a unit root and therefore both are not stationary.

**Table 4**. Unit root test

| **Country** | Test | Time series | t -statistic | Probability | Decision |
|---|---|---|---|---|---|
| Spain | ADF | LGPEM | 1.850 | 0.066 | non-stationary |
| | | LGPGM | 0.913 | 0.903 | non-stationary |
| | PP | LGPEM | -0.669 | 0.850 | non-stationary |
| | | LGPGM | -1.931 | 0.318 | non-stationary |

Source(s): Author's own calculation

Additionally, as a previous step to the cointegration analysis, the standard ADF unit root test and the Phillips Perron tests on the first differentiation of the series were performed. The results indicated that the null hypothesis about the existence of a unit root in the LGPEM and LGPGM series in the first difference must be rejected, confirming that both differentiated series are integrated of order one "I(1)" (Table 5).

**Table 5.** Unit root test on first differences

| **Country** | Test | Time series | t -statistic | Probability | Decision | Integration order |
|---|---|---|---|---|---|---|
| Spain | ADF | D(LGPEM) | -16.198 | 0.000 | stationary | I(1) |
| | | D(LGPGM) | -14.162 | 0.000 | stationary | I(1) |
| | PP | D(LGPEM) | -16.651 | 0.000 | stationary | I(1) |
| | | D(LGPGM) | -14.166 | 0.000 | stationary | I(1) |

Source(s): Author's own calculation

### 5.1.2 Stationarity and Cointegration Analysis

Once it has been confirmed that both series integrated of the same order and they are stationary in first differences, we can continue with the analysis by performing the estimation of the long-term model and analysing the residues to identify if there is a cointegration relation between the LGPEM and LGPGM.

The results of the model indicate that both the constant and LGPGM (the producer price) are significant. The coefficient of the LGPGM indicates that an increase of 1% in the producer price, the consumer price (LGPEM) will increase 0.77%, this result seems to make sense since the long-term increase in the producer price can increase the price of honey in the market. Given that the value of R2 (0.6905) is high and the Durbin Watson statistic (0.146) is much lower compared to R2, we can believe that there is a spurious relationship so, there is not a cointegration relationship (Engle, and

Granger, 1987). In addition, the value of the t-statistic (19.93) is extremely significant since it is not close to a value of 2 or 3.

Therefore, the stationarity test of the residues was performed using the Engle and Granger cointegration test (parametric test) and the Phillips-Ouliaris test (nonparametric test), to confirm if there is a large term relationship between the LGPEM and LGPGM variables and confirm or not if they are co-integrated. Table 6 contains the results of cointegration analyses, including findings of Engle and Granger residual cointegration test and Phillips-Ouliaris residual cointegration test. The no statistical significance of the results of the cointegration tests shows that the null hypothesis should not be rejected, confirming the **no existence of cointegration**. Further analysis is then performed based on the results of these tests.

**Table 6**. Cointegration analyses (stationarity test of the residuals)

| Country | Test | t -statistic | Probability | Residual variance |
|---|---|---|---|---|
| Spain | Engle and Granger | -2.055 | 0.501 | 0.001 |
| | Phillips-Ouliaris | -1.761 | 0.650 | 0.001 |

Source(s): Author's own calculation

The next stage of the analysis is to determine the most appropriate lag. To determine the optimal number of (lags) we perform a lag specification analysis, the results according to the most common criteria Akaike information criterion (AIC), Schwartz information criterion (SC) and Hannan-Quinn information criterion (HQ) indicate that the appropriate number of lags are 1 or 2 (Table 7).

**Table 7.** Optimal lag selection criterion

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 260.7720 | NA | 0.000187 | -2.907551 | -2.871800 | -2.893053 |
| 1 | 768.7225 | 98.7791* | 0.000001 | -8.569916 | -8.462665* | -8.526423* |
| 2 | 772.9466 | 8.20874 | 6.49E-07* | -8.572434* | -8.393682 | -8.499945 |

* Indicates the number of significant lags in the model by the criterion

Source(s): Author's own calculation.

Additionally, the selection of 2 lags in the model was done considering the VAR Stability conditions and residual diagnostics (autocorrelations). The Autocorrelation Test of the residuals allows us to accept the null hypothesis, which indicates that there is no correlation in the system with 2 lags.

**Table 8.** VAR residual serial correlation LM tests

| Lag | LRE* stat | df | Probability |
|---|---|---|---|
| 1 | 2.7329 | 4 | 0.604 |
| 2 | 4.4418 | 4 | 0.350 |

Source(s): Author's own calculation

The inverse roots of the AR characteristic polynomial were all within the unit circle (Figure 2) Therefore, confirming our VAR system is stable, which suggests that the estimates are stationary in all periods.

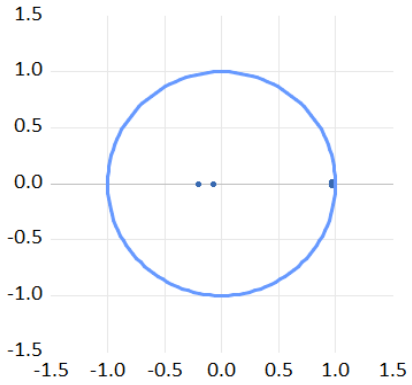


**Figure 2 .** Inverse roots of the AR characteristic polynomial
(Source(s): Author's own calculation)

### 5.1.3 VAR Model Estimation

Ones the lags were defined the VAR model was applied. VAR results are shown in Table 9. The descriptive lagged variables are on horizontal axis. The Vector Autoregression (VAR) estimates reveal dynamic interdependencies between consumer honey prices (LGPEM) and producer honey prices (LGPGM).

**Consumer Price Dynamics (LGPEM Equation):**

The consumer price of honey is significantly influenced by its own past values. The coefficients show specifically that: The first lag of LGPEM has a strong positive effect (coefficient = 0.737, t-stat = 9.69), indicating that a 1% increase in consumer price in the previous period leads to a 0.74% increase in the current period. The second lag also contributes positively (coefficient = 0.204, t-stat = 2.71), though with a smaller magnitude.

Producer prices also play a role: The first lag of LGPGM has a positive coefficient (0.747), suggesting a 0.75% increase in consumer prices for every 1% rise in producer prices in the previous period. However, the associated t-statistic (1.05) indicates this effect is not statistically significant. The second lag of LGPGM shows a slight negative influence (coefficient = -0.020, t-stat = -0.27), but again, this effect is statistically insignificant.

**Producer Price Dynamics (LGPGM Equation):**

Producer prices are primarily driven by their own past values: The first lag of LGPGM has a strong and significant positive effect (coefficient = 0.921, t-stat = 11.96), indicating high persistence in producer

pricing. The second lag has a smaller and statistically insignificant effect (coefficient = 0.064, t-stat = 0.81). The influence of consumer prices on producer prices is minimal and statistically weak.

Model Fit and Diagnostics: Both equations exhibit high explanatory power ($R^2 \approx 0.97$), indicating that the model captures most of the variation in the data. The F-statistics are large and highly significant, confirming the overall validity of the regressions.

**Table 9**. Vector Autoregression Estimates

| | LGPEM | LGPGM |
|---|---|---|
| LGPEM(-1) | 0.737097 | -0.070767 |
| | 0.07604 | 0.08219 |
| | [9.69323] | [-0.86106] |
| LGPEM(-2) | 0.203875 | 0.055321 |
| | 0.07513 | 0.0812 |
| | [2.71371] | [0.68132] |
| LGPGM(-1) | 0.74713 | 0.921067 |
| | 0.07127 | 0.07703 |
| | [1.04830] | [11.9573] |
| LGPGM(-2) | -0.019707 | 0.063648 |
| | 0.07289 | 0.07878 |
| | [-0.27036] | [0.80790] |
| C | 0.035939 | 0.043985 |
| | 0.02304 | 0.0249 |
| | [1.56013] | [1.76666] |
| R-squared | 0.967927 | 0.966887 |
| S.E equation | 0.02721 | 0.029408 |
| F-statistic | 1305.254 | 1262.891 |
| Log-likelihood | 391.5086 | 377.6793 |
| Observations | 178 | 178 |

Source(s): Author's own calculation

### 5.1.4 Impulse Response Analysis

The ability to understand the dynamic behaviour of systems using impulse-response graphs is a valuable tool that researchers use to evaluate, build, and optimize systems in various domains. In the context of honey pricing, impulse response functions (IRFs) derived from the estimated VAR model provide critical insights into how consumer and producer prices react over time to shocks in each other.

This analysis allows us to trace the effect of a one-time innovation (shock) in either the consumer price (LGPEM) or producer price (LGPGM) on the future values of both variables. By observing the magnitude, direction, and duration of these responses, we can better understand the transmission mechanisms between market levels and assess the persistence of price changes.

Key aspects explored in the impulse response analysis include:

Response of LGPEM to a shock in LGPGM: Evaluating how a sudden change in producer prices influences consumer prices over subsequent periods.

Response of LGPGM to a shock in LGPEM: Assessing whether consumer price fluctuations feed back into producer pricing behaviour.

Stability and convergence: Determining whether the system returns to equilibrium after a shock or exhibits prolonged divergence.

The following section presents the impulse response graphs and interprets the dynamic interactions between consumer and producer honey prices over time. These IRFs trace the effect of a one-time shock in either variable on the future values of both, offering valuable insights into the transmission mechanisms within the honey market.

The results reveal that consumer prices (LGPEM) respond positively and persistently to their own innovations, indicating strong inertia and suggesting that past price movements continue to influence future pricing behaviour (The initial response is strong and remains above zero for most of the horizon, Since the response line stays outside the confidence bands early on, the effect is statistically significant in the short term, that implies that consumer prices exhibit inertia—past shocks continue to influence future prices, suggesting price stickiness or delayed market adjustment) (Figure 3).

In contrast, the response of consumer prices to producer price shocks (LGPGM) is modest and short-lived, with statistical significance observed only in the immediate term. This implies that while upstream price changes do affect retail prices, the transmission is limited, potentially due to buffering mechanisms such as inventory management or pricing contracts.

On the producer side, LGPGM exhibits a strong and sustained response to its own shocks, reflecting high internal momentum and the lasting impact of supply-side factors. However, producer prices appear largely insulated from consumer-level shocks, as the response of LGPGM to LGPEM innovations remains statistically insignificant throughout the forecast horizon.

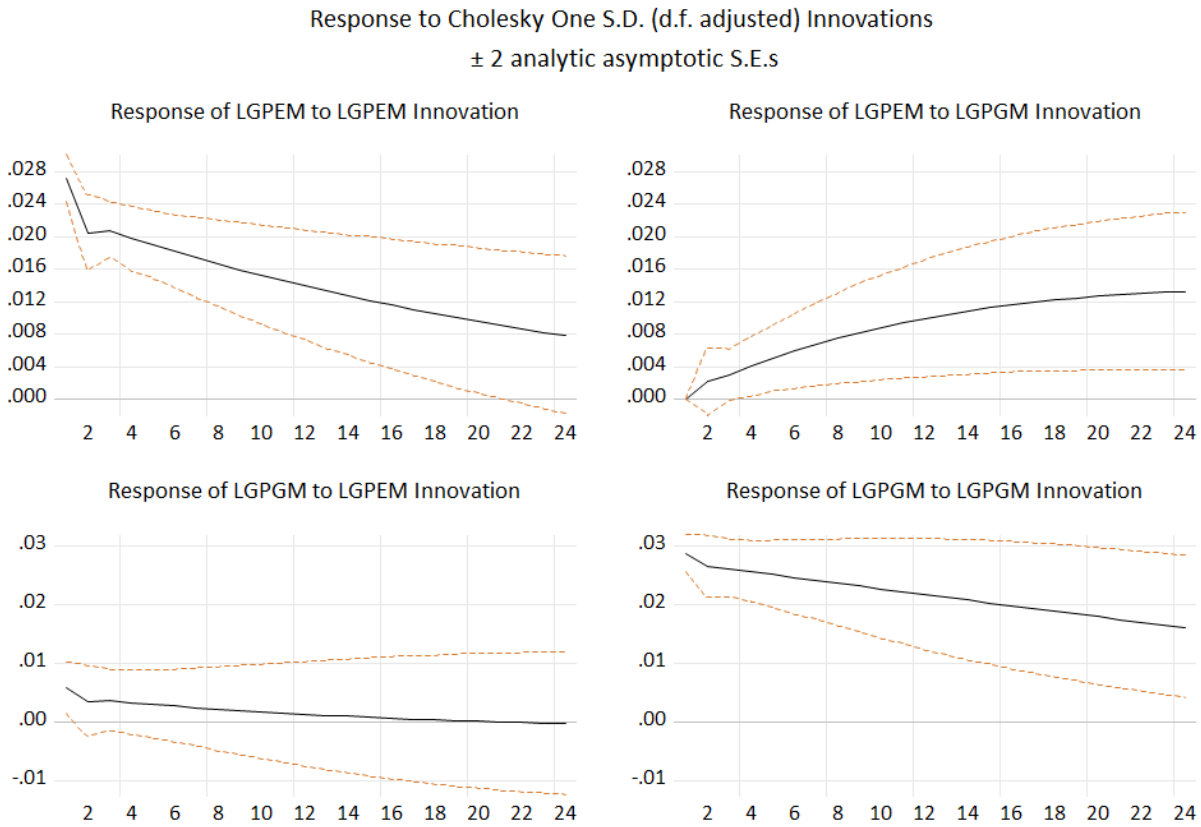


**Figure 3**. The impulse response graphs
(Source(s): Author's own calculation)

In the graphs:

- The x-axis represents the periods (in months)
- The y-axis shows the percentage of variation
- The magnitude of the shock is one standard deviation (a shock of one standard deviation from the LGPGM producer price has a gradual positive effect on the LGPEM consumer price).
- The red dots correspond to the confidence limits of the standard error, whose range is defined as +/- 2 standard errors (SE). The breadth of the confidence limits indicates that there is a lot of error in the estimation.

These findings suggest an asymmetric price transmission structure, where producer prices influence consumer prices more than the reverse. Overall, the impulse response analysis highlights the persistence of price dynamics at both levels and underscores the importance of producer-level factors in shaping consumer market outcomes.

### 5.1.5 Variance Decomposition

As part of the dynamic analysis of the VAR model, variance decomposition was applied to assess the relative importance of different shocks in the evolution of variables over time. This method quantifies the extent to which fluctuations in a variable can be explained by its own innovations or by disturbances in other variables in the system. The decomposition is performed using the moving average representations of the VAR model, which facilitates the identification of the origin of the shocks and their cumulative impact over the considered time horizon.

In this study, the variance decomposition of the LGPEM variable (consumer price of honey) was specifically analyzed to better understand how the sources of variability are distributed in the Spanish honey market. The results indicate that, in the twelfth period of analysis, 99.27% of the variability of LGPEM is explained by its own innovations, demonstrating strong internal dependence and persistence in its behaviour.

On the other hand, the contribution of LGPGM (honey producer price) to the change in LGPEM concentration is marginal, representing only 0.72% over the same period. This low proportion suggests that shocks from the producer level have a limited impact on consumer price dynamics in the short term.

These findings are visually supported by the variance decomposition graphs shown in Figure 4. The graphical results of the variance decomposition obtained using the Cholesky method adjusted for degrees of freedom, offer a clear view of the dynamic influence between consumer prices (LGPEM) and producer prices (LGPGM) in the Spanish honey market.

The first graph, corresponding to the variance decomposition of LGPEM, shows that during the first nine periods, the variability of this variable is almost entirely explained by its own innovations, with a contribution exceeding 99%. However, starting in the tenth period, a slight influence of LGPGM begins to emerge, reaching a marginal share in explaining the variance of LGPEM. This behaviour suggests that, although the consumer price exhibits high persistence and autonomy in the short term, in the long term it can be affected by shocks in the producer price.

The second graph, on the other hand, shows the variance decomposition of LGPGM. This shows that LGPGM maintains a strong self-dependence across the 12 periods analysed, explaining almost 100% of its own variance. The influence of LGPEM on LGPGM is practically zero, indicating that producer prices do not respond significantly to changes in consumer prices. This asymmetry in influence—where

producer prices slightly affect consumer prices over time, but not vice versa—suggests a one-directional dynamic in the Spanish honey market.

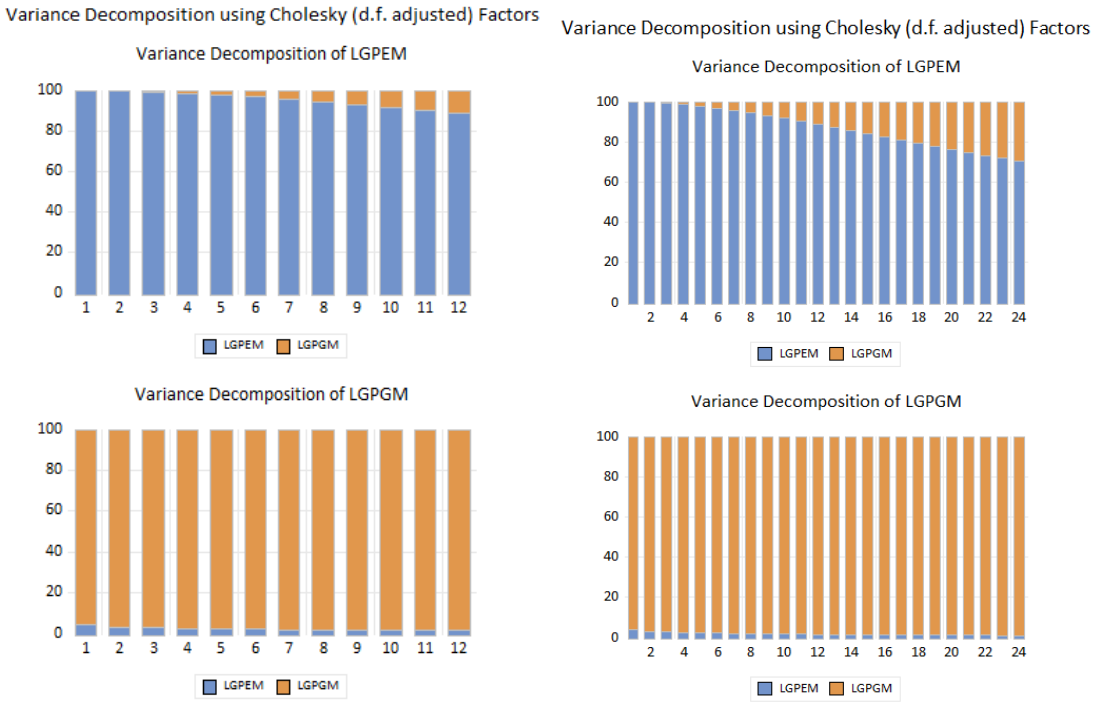


**Figure 4**. The variance decomposition graph
(Source(s): Author's own calculation)

### 5.1.6 Granger Causality Test

Finally, the results of the Granger causality test (Table 10) provide further evidence of the directional relationship between producer and consumer honey prices. Based on a two-lag specification and 180 observations, the test rejects the null hypothesis that LGPGM does not Granger cause LGPEM (F-statistic = 3.15, p = 0.0454), indicating that past values of producer prices contain predictive information about future consumer prices. Conversely, the null hypothesis that LGPEM does not Granger cause LGPGM cannot be rejected (F-statistic = 0.45, p = 0.6385), suggesting that consumer prices do not Granger cause producer prices. These findings confirm a unidirectional causality from producer to consumer prices, reinforcing the asymmetric transmission structure observed in the VAR and impulse response analyses.

**Table 10**. Pairwise Granger Causality

| Null Hypothesis | Obs. | F-statistic | Probability |
|---|---|---|---|
| LGPGM does not Granger causes LGPEM | 178.000 | 3.148 | 0.045 |
| LGPEM does not Granger causes LGPGM | | 0.450 | 0.639 |

Source(s): Author's own calculation

### 5.1.7 Conclusions for Spain case of study

The results of the Spain case of study provide a comprehensive understanding of the **dynamic relationship between consumer and producer honey prices** in the Spanish market. The estimated VAR model reveals that consumer prices (LGPEM) are significantly influenced by their own past values, with strong and persistent effects observed across both the first and second lags. This indicates a high degree of inertia in consumer pricing, suggesting that historical price movements continue to shape current pricing behaviour. Although producer prices (LGPGM) also contribute to consumer price dynamics, their influence is statistically weak and short-lived, particularly in the immediate term. This limited transmission may be attributed to market mechanisms such as inventory buffering, pricing contracts, or delayed pass-through effects.

Producer prices, on the other hand, exhibit strong internal momentum, being primarily driven by their own past values. **The influence of consumer prices on producer pricing is negligible**, highlighting an **asymmetric structure in price transmission**: while producer-level shocks can affect consumer prices to some extent, the reverse is not observed. This asymmetry underscores the dominant role of supply-side factors in shaping retail price outcomes.

The impulse response analysis further supports these findings. Consumer prices respond positively and significantly to their own shocks, maintaining elevated levels over time, whereas their response to producer price shocks is modest and fades quickly. Producer prices show a robust and sustained reaction to their own innovations but remain largely unaffected by consumer-level disturbances. These dynamics suggest that the honey market operates with a clear downstream transmission mechanism, where changes at the production level may influence retail prices, but not vice versa.

The variance decomposition analysis complements the impulse response findings by quantifying the relative contribution of each variable to the observed variability. In the second period of analysis, 99.27% of the variance in LGPEM is explained by its own innovations, confirming its strong internal dependence. The contribution of LGPGM to LGPEM's variance is minimal (0.72%), reinforcing the conclusion that producer price shocks have limited short-term impact on consumer price behaviour. Similarly, the decomposition of LGPGM shows that its variance is almost entirely self-explained across all periods, with virtually no influence from consumer prices.

Overall, **the results highlight a market structure characterized by high persistence and limited bidirectional transmission between consumer and producer prices**. These insights have important

implications for pricing strategies, market regulation, and policy design, particularly in ensuring price stability and transparency across the honey supply chain.

#### 5.1.8 Policy recommendations

The results of the VAR analysis and variance decomposition suggest that the consumer price of honey (LGPEM) exhibits high persistence and autonomy in the short term, while producer prices (LGPGM) have a marginal influence on consumer prices in the long term. This dynamic indicates that policies aimed at stabilizing consumer prices should focus on factors internal to the retail market, such as distribution chain efficiency, price transparency, and **strengthening product traceability**. Furthermore, given that producer prices do not respond significantly to changes in consumer prices, specific measures to improve beekeeper profitability are recommended, such as tax incentives, technical support, and promoting the added value of local honey. These actions could contribute to greater sustainability of the sector without generating distortions in the final market.

### 5.2 Empirical Results Case Study Turkey

#### 5.2.1 Descriptive Statistics and Correlation

In the case of Turkey's multifloral honey market, Tables 11 and 12 summarize the descriptive statistics and the correlation between the key variables analyzed.

Table 11 outlines the statistical characteristics derived from 180 observations concerning producer and consumer prices per kilogram of multifloral honey in Turkey. For the producer price (PGMT), the average value is 40.17 (Turkish lira), with a standard deviation of 38.46, a minimum of 14.90, and a maximum of 203.45. In contrast, the consumer price (PEMT) shows slightly higher figures: a mean of 46.44, standard deviation of 40.20, minimum of 20.56, and maximum of 220.85. These results suggest that consumer prices tend to be higher and more dispersed than producer prices.

**Table 11.** Descriptive statistics (Turkey time series consumer and producer multifloral honey prices)

| Variable | Obs. | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|
| PGMT | 180 | 40.17 | 38.46 | 14.90 | 203.45 |
| PEMT | 180 | 46.44 | 40.20 | 20.56 | 220.85 |

Source(s): Author's own calculation

Table 12 displays the correlation coefficients, revealing a strong positive relationship between PGMT and PEMT, with a coefficient of 0.992. This high correlation implies that changes in producer prices are closely mirrored by changes in consumer prices.

**Table 12**. Correlation analysis Turkey Series

| Variable | PGMT | PEMT |
|---|---|---|
| PGMT | 1.000 | 0.992 |
| PEMT | 0.992 | 1.000 |

* Confidence interval: (0.9893554 - 0.9940811)
Source(s): Author's own calculation

To enhance model robustness and enable proportional comparisons, a logarithmic transformation was applied to both PGMT and PEMT. This approach helps mitigate scale-related distortions and improves the statistical properties of the data.

Figure 5 illustrates the temporal behavior of the original producer and consumer price (left figure) and log-transformed price variables (LGPGMT and LGPEMT). The visual representation highlights synchronized upward and downward movements throughout the observed period, suggesting a shared positive trend. This pattern may indicate that the series are non-stationary.

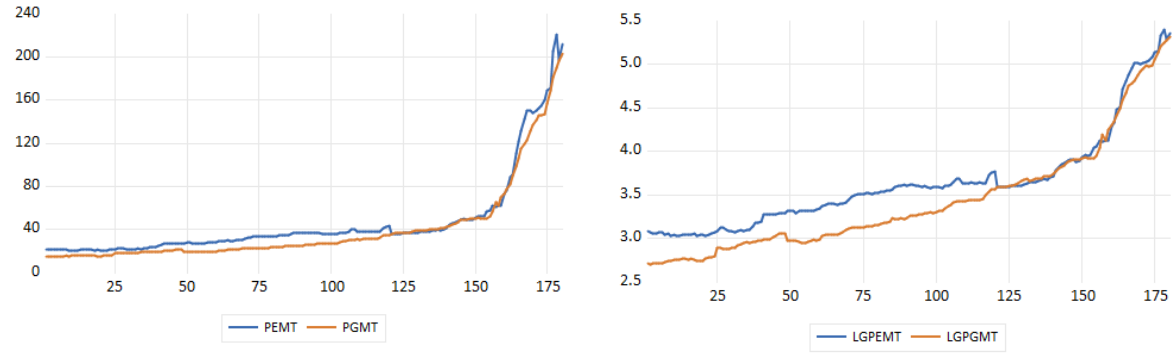


**Figure 5**. Original and Log trends of consumer and producer multifloral honey price on Turkey
Source(s): Author's own calculation

To further support the analysis, unit root tests were conducted using both the Augmented Dickey-Fuller (ADF) and Phillips-Perron methodologies, as shown in Table 13. The results indicate that the logarithmic series LGPEMT and LGPGMT exhibit characteristics of non-stationarity, as both tests fail to reject the presence of a unit root. This suggests that the time series for producer and consumer prices in Turkey do not remain stable over time and are influenced by persistent trends or shocks.

**Table 13.** Unit root test

| Country | Test | Time series | t -statistic | Probability | Decision |
|---|---|---|---|---|---|
| Turkey | ADF | LGPEMT | 4.734 | 1.000 | non-stationary |
| | | LGPGMT | 3.247 | 0.9997 | non-stationary |
| | PP | LGPEMT | 3.760 | 1.000 | non-stationary |
| | | LGPGMT | 5.087 | 1.000 | non-stationary |

Source(s): Author's own calculation

As a preliminary step before conducting the cointegration analysis, the ADF and Phillips-Perron unit root tests were applied to the first-differenced forms of the LGPEMT and LGPGMT series. The

outcomes, presented in Table 14, show that the null hypothesis of a unit root can be rejected for both variables in their first differences. This confirms that the transformed series are stationary at the first difference level, indicating they are integrated of order one, or I(1).

**Table 14.** Unit root test on first differences

| Country | Test | Time series | t -statistic | Probability | Decision | Integration order |
|---|---|---|---|---|---|---|
| Turkey | ADF | D(LGPEMT) | -6.595 | 0.000 | stationary | I(1) |
| | | D(LGPGMT) | -3.285 | 0.001 | stationary | I(1) |
| | PP | D(LGPEMT) | -11.508 | 0.000 | stationary | I(1) |
| | | D(LGPGMT) | -8.924 | 0.000 | stationary | I(1) |

Source(s): Author's own calculation

### 5.2.2 Stationarity and Cointegration Analysis

After confirming that both LGPEMT and LGPGMT series are integrated of the same order and exhibit stationarity in their first differences, the next step involves estimating the long-run relationship between them and analysing the residuals to assess the presence of cointegration.

The regression results reveal that both the intercept and the producer price variable (LGPGMT) are statistically significant. Specifically, the coefficient for LGPGMT suggests that a 1% increase in producer prices corresponds to a 0.85% rise in consumer prices (LGPEMT). This finding aligns with economic intuition, as sustained growth in producer prices is likely to exert upward pressure on retail honey prices over time.

Despite the high $R^2$ value (0.96), the Durbin-Watson statistic (0.113) is notably low, which raises concerns about the validity of the relationship and suggests the possibility of spurious regression. Additionally, the t-statistic (68.03) is highly significant, reinforcing the strength of the estimated coefficient.

To validate whether a genuine long-term equilibrium relationship exists between LGPEMT and LGPGMT, cointegration tests were applied to the residuals. These included the Engle-Granger test (parametric) and the Phillips-Ouliaris test (non-parametric), both aimed at determining whether the residuals are stationary and thus confirming—or rejecting—the presence of cointegration between the two variables.

Table 15 presents the outcomes of the cointegration tests, specifically the Engle-Granger residual-based approach and the Phillips-Ouliaris test. Both tests yield results that lack statistical significance, indicating that the null hypothesis of no cointegration cannot be rejected. This suggests that there is no long-term equilibrium relationship between LGPEMT and LGPGMT. Consequently, the subsequent

analysis proceeds under the assumption that the series are not cointegrated, following the implications of these test results.

**Table 15.** Cointegration analyses (stationarity test of the residuals)

| Country | Test | t -statistic | Probability | Residual variance |
|---|---|---|---|---|
| Turkey | Engle and Granger | -2.215 | 0.418 | 0.001 |
| | Phillips-Ouliaris | -2.058 | 0.499 | 0.001 |

Source(s): Author's own calculation

The following step in the analysis involves identifying the optimal lag length for the model. To achieve this, a lag selection procedure was carried out using three widely accepted criteria: the Akaike Information Criterion (AIC), the Schwarz Criterion (SC), and the Hannan-Quinn Criterion (HQ). Based on the outcomes shown in Table 16, all three criteria converge in suggesting that a lag length of five is the most suitable for capturing the dynamics between the variables.

**Table 16.** Optimal lag selection criterion

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 703.4825 | NA | 6.73E-07 | -8.204474 | -8.167730 | -8.189565 |
| 1 | 735.7629 | 63.4281 | 6.76E-07 | -8.535239 | - 8.425005 * | - 8.49051 * |
| 2 | 739.4324 | 7.12443 | 6.50E-07 | -8.531373 | -8.347650 | -8.456800 |
| 3 | 746.8247 | 14.1793 | 6.70E-07 | -8.571049 | -8.313837 | -8.466683 |
| 4 | 748.2273 | 2.65751 | 6.48E-07 | -8.540670 | -8.209968 | -8.406485 |
| 5 | 755.1152 | 12.88963 * | 6.69E-07* | - 8.574446 * | -8.170256 | -8.410443 |

* Indicates the number of significant lags in the model by the criterion

Source(s): Author's own calculation

In addition to the information criteria, the choice of five lags was further supported by evaluating the stability conditions of the VAR model and conducting residual diagnostics. Specifically, the residual autocorrelation test confirmed the adequacy of the lag structure: the null hypothesis of no autocorrelation was accepted (see Table 17), indicating that the system with five lags does not exhibit significant serial correlation and meets the necessary stability requirements.

**Table 17.** VAR residual serial correlation LM tests

| Lag | LRE* stat | df | Probability |
|---|---|---|---|
| 1 | 1.6714 | 4 | 0.796 |
| 2 | 1.9909 | 4 | 0.737 |
| 3 | 2.8818 | 4 | 0.578 |
| 4 | 3.2188 | 4 | 0.522 |
| 5 | 1.1676 | 4 | 0.883 |

Source(s): Author's own calculation

As a component of the VAR model validation, the inverse roots of the autoregressive characteristic polynomial were examined. As shown in Figure 6, all roots lie within the unit circle, confirming the

stability of the VAR system. This result implies that the model's estimates remain stationary across all time periods, ensuring the reliability of the dynamic relationships captured.

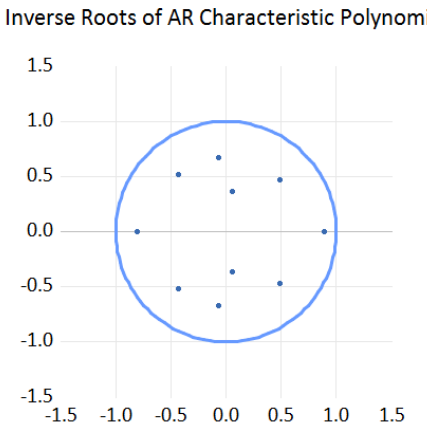


**Figure 6**. Inverse roots of the AR characteristic polynomial
(Source(s): Author's own calculation)

### 5.2.3 VAR Model Estimation

With the lag structure firmly established, the Vector Autoregression (VAR) model was estimated to explore the temporal dynamics between the variables. Table 18 presents the results, where the lagged explanatory variables are displayed along the horizontal axis. The VAR output reveals significant intertemporal relationships between the logarithmic consumer price (LGPEMT) and the logarithmic producer price (LGPGMT) of multifloral honey in Turkey, indicating how past values of each variable contribute to the evolution of the other over time.

**Producer Price Dynamics** (D(LGPGMT) Equation):

The short-term behaviour of producer prices is influenced by both its own past changes and, to a lesser extent, by lagged changes in consumer prices. Among the lagged producer price terms, the third lag (D(LGPGMT(-3))) shows a moderately positive effect (coefficient = 0.123, t-stat = 1.50), although it does not reach conventional levels of statistical significance. The fifth lag also contributes positively (coefficient = 0.099, t-stat = 1.23), suggesting some delayed influence. The first lag of consumer prices (D(LGPEMT(-1))) is statistically significant (coefficient = 0.186, t-stat = 3.37), indicating that short-term changes in consumer prices may have a feedback effect on producer prices. Other lags of consumer prices show weaker and mostly insignificant effects.

**Consumer Price Dynamics** (D(LGPEMT) Equation):

Consumer prices exhibit stronger short-term responsiveness to changes in producer prices. The first lag of D(LGPGMT) has a substantial and statistically significant impact (coefficient = 0.482, t-stat =

4.30), suggesting that a 1% increase in producer prices in the previous period leads to a 0.48% increase in consumer prices. The fifth lag also shows a meaningful positive effect (coefficient = 0.404, t-stat = 3.55), indicating that producer price changes can have delayed effects on consumer pricing. Among the consumer price lags, only the third lag (D(LGPEMT(-3))) is statistically significant (coefficient = -0.016, t-stat = -0.18), though the magnitude is minimal and the direction is negative.

Model Fit and Diagnostics: Compared to the levels model, the explanatory power of the differenced VAR is lower, with $R^2$ values of 0.30 for the producer price equation and 0.29 for the consumer price equation. Nonetheless, both equations pass the overall significance test, as indicated by the F-statistics (6.92 and 6.58, respectively), suggesting that the model captures relevant short-term dynamics between the variables. The log-likelihood values and standard errors are consistent with a well-specified model in differences.

**Table 18.** Vector Autoregression Estimates

| | D(LGPGMT) | D(LGPEMT) |
|---|---|---|
| D(LGPGMT(-1)) | 0.105309 | 0.481776 |
| | 0.07955 | 0.112 |
| | [1.32378] | [4.30168] |
| D(LGPGMT(-2)) | 0.019961 | 0.019409 |
| | 0.08385 | 0.11805 |
| | [0.23805] | [0.16441] |
| D(LGPGMT(-3)) | 0.123307 | 0.178886 |
| | 0.08222 | 0.11576 |
| | [1.49964] | [1.54532] |
| D(LGPGMT(-4)) | 0.002562 | -0.134191 |
| | 0.08244 | 0.11606 |
| | [0.03108] | [-1.15622] |
| D(LGPGMT(-5)) | 0.09936 | 0.403702 |
| | 0.08073 | 0.11366 |
| | [1.23077] | [3.55199] |
| D(LGPEMT(-1)) | 0.186261 | 0.097927 |
| | 0.05521 | 0.07773 |
| | [3.37339] | [1.25978] |
| D(LGPEMT(-2)) | 0.038773 | -0.046346 |
| | 0.06167 | 0.08682 |
| | [0.62876] | [-0.53383] |
| D(LGPEMT(-3)) | 0.145142 | -0.015536 |
| | 0.06048 | 0.08514 |
| | [2.39993] | [-0.18247] |
| D(LGPEMT(-4)) | -0.008288 | 0.046153 |
| | 0.06476 | 0.09117 |
| | [-0.12798] | [0.50623] |
| D(LGPEMT(-5)) | -0.007821 | -0.125156 |
| | 0.06379 | 0.08981 |
| | [-0.12260] | [-1.39352] |
| C | 0.005375 | 0.000114 |
| | 0.00226 | 0.00318 |
| | [2.37990] | [0.03571] |

| | | |
|---|---|---|
| R-squared | 0.29804 | 0.287548 |
| S.E equation | 0.023253 | 0.032736 |
| F-statistic | 6.92068 | 6.5787 |
| Log-likelihood | 413.258 | 353.7396 |
| Observations | 174 | 174 |

Source(s): Author's own calculation. [] t-statistic

### 5.2.4 Impulse Response Analysis

The impulse response functions (IRFs) illustrate the dynamic interactions between consumer and producer prices in response to one-standard-deviation shocks, over a horizon of 24 periods (Figure 7). The shaded bands represent ±2 analytic asymptotic standard errors, providing a visual gauge of statistical significance.

**Response of D(LGPGMT) to Own Shock (Top Left):** Producer prices exhibit a sharp and immediate positive response to their own innovation, peaking in the first few periods and gradually declining. The response remains within the confidence bands, indicating statistical significance in the short term and a fading effect over time.

**Response of D(LGPGMT) to Consumer Price Shock (Top Right):** The reaction of producer prices to a shock in consumer prices is modest and largely contained within the confidence intervals. This suggests that consumer price innovations have a limited and statistically weak influence on producer prices in the short run.

**Response of D(LGPEMT) to Producer Price Shock (Bottom Left):** Consumer prices respond strongly and positively to producer price shocks, with the effect peaking early and remaining significant for several periods. This confirms the transmission mechanism from producer to consumer prices, consistent with the regression results.

**Response of D(LGPEMT) to Own Shock (Bottom Right):** The response of consumer prices to their own innovation is positive but less pronounced than in the producer price case. The effect diminishes quickly and remains within the confidence bands, indicating a short-lived and moderate self-response.

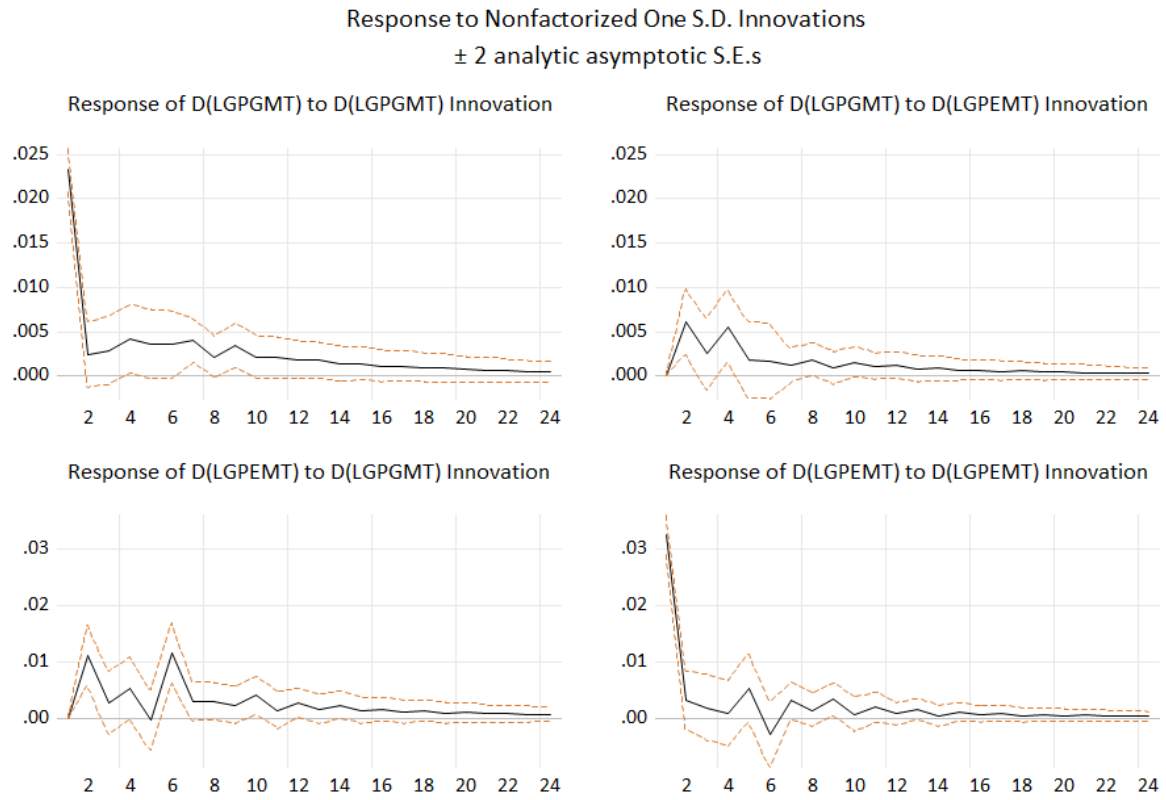


**Figure 7.** The impulse response graphs
(Source(s): Author's own calculation)

These results reveal an asymmetric short-term price transmission mechanism between producer and consumer prices. Changes in producer prices exert a stronger and more statistically significant influence on consumer prices than vice versa, as evidenced by both the regression estimates and the impulse response functions. While consumer price shocks have limited impact on producer pricing, producer-level innovations generate persistent and notable responses in consumer prices over several periods.

Overall, the analysis underscores the dominant role of producer price dynamics in shaping consumer market behaviour. The impulse response functions confirm the persistence of price adjustments and highlight the delayed but meaningful transmission from upstream to downstream pricing. These findings have important implications for understanding inflationary pressures and the responsiveness of consumer markets to cost-side shocks.

### 5.2.5 Variance Decomposition

The variance decomposition results provide further insight into the relative importance of producer and consumer price shocks over time. For the consumer price equation (D(LGPEMT)), the proportion of forecast error variance explained by its own innovations reaches approximately 75.5% by period 9, stabilizing around 74.4% at period 12 and slightly declining to 73.0% by period 24. This indicates that

consumer prices are predominantly driven by their own shocks in the short and medium term, although the influence of producer price shocks gradually increases over time—from 24.5% at period 9 to 27.0% at period 24.

Conversely, the producer price equation (D(LPGPMT)) shows a consistently high level of self-explained variance, with over 88.8% attributed to its own innovations at period 9 and remaining above 88% through periods 12 and 24. The contribution of consumer price shocks remains modest, never exceeding 12%. These findings reinforce the asymmetric transmission structure observed earlier, confirming that producer prices are largely self-driven, while consumer prices exhibit a growing sensitivity to upstream cost pressures over longer horizons.

The graphical results from the variance decomposition analysis (figure 8), based on Cholesky-adjusted factors, visually reinforce the asymmetric transmission dynamics between producer and consumer prices.

- **Variance Decomposition of D(LGPGMT):** The bar chart shows that the variance in producer price changes is overwhelmingly explained by its own innovations (blue bars) across all horizons. From period 2 to 24, the contribution of consumer price shocks (orange bars) remains minimal, never exceeding a small fraction of the total variance. This confirms the strong autoregressive nature of producer prices and their relative independence from consumer price fluctuations.
- **Variance Decomposition of D(LGPEMT):** In contrast, the decomposition of consumer price changes reveals a more dynamic structure. Initially, the variance is largely explained by its own shocks (orange bars), but as the horizon extends, the influence of producer price shocks (blue bars) becomes increasingly significant. By period 9, producer prices account for roughly 25% of the variance, and this share grows to nearly 27% by period 24. This gradual shift highlights the delayed but growing impact of upstream cost pressures on consumer pricing.

Together, these visual results complement the numerical findings and underscore the asymmetric nature of price transmission: producer prices are self-driven, while consumer prices become increasingly sensitive to producer-level shocks over time.

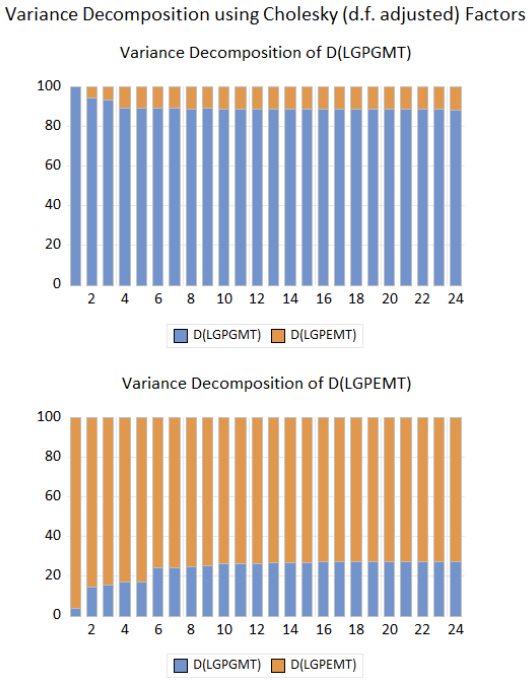


**Figure 8.** The variance decomposition graph
(Source(s): Author's own calculation)

### 5.2.6 Granger Causality Test

The results from the pairwise Granger causality test (Table 19) provide statistical confirmation of the directional relationship between producer and consumer prices. The null hypothesis that producer prices (LGPGMT) do not Granger-cause consumer prices (LGPEMT) is rejected at a high level of significance (F-statistic = 4.704, p-value = 0.0005), indicating that past values of producer prices contain predictive information for future movements in consumer prices. Conversely, the null hypothesis that consumer prices do not Granger-cause producer prices is also rejected (F-statistic = 3.303, p-value = 0.0072), though with slightly lower statistical strength. These findings suggest a bidirectional causality, with a stronger and more robust influence from producer to consumer prices, consistent with the asymmetric transmission dynamics observed in the VAR and variance decomposition analyses.

**Table 19.** Pairwise Granger Causality

| Null Hypothesis | Obs. | F-statistic | Probability |
|---|---|---|---|
| LGPGMT does not Granger causes LGPEMT | 175.000 | 4.704 | 0.0005 |
| LGPEMT does not Granger causes LGPGMT | | 3.303 | 0.0072 |

Source(s): Author's own calculation

### 5.2.7 Conclusions Turkey case of study

The econometric analysis of multifloral honey prices in Turkey reveals a clearly asymmetric price transmission structure between the producer and consumer levels. The results of the multilevel VAR

model show that consumer prices are strongly influenced by their own past values, but also respond significantly to producer prices, albeit with less statistical significance. In contrast, producer prices exhibit high persistence and autonomy, with little sensitivity to consumer prices.

The first-difference model confirms this dynamic in the short term: consumer prices react more strongly and significantly to previous changes in producer prices, especially in the first and last lags. In contrast, producer prices show a weak and statistically insignificant response to changes in consumer prices.

Impulse response function analysis reinforces this asymmetry, showing that producer price shocks generate persistent and significant responses in consumer prices, while consumer price shocks have marginal effects on producer prices. The variance decomposition confirms that, over a 24-period horizon, consumer prices become progressively more sensitive to changes in producer prices, reaching a contribution close to 27% in period 24. In contrast, producer prices maintain a high proportion of variance explained by their own changes (more than 88%).

Finally, the Granger causality test indicates a bidirectional relationship between both variables, although more strongly in the producer-to-consumer direction, which statistically validates the existence of price transmission from the primary level to the final market.

### 5.2.8 POLICY RECOMMENDATIONS

Given that consumer prices for multifloral honey in Turkey are significantly influenced by producer prices, especially in the medium and long term, it is recommended that price stabilization policies focus on the primary segment of the chain. This includes monitoring and regulating production costs by implementing tracking mechanisms for key inputs (such as bee feed, transportation, and packaging) that directly affect producer prices. Support for beekeeping production by designing subsidy or incentive programs for small producers to reduce price volatility at source and, therefore, soften its impact on the final consumer. **Transparency in the supply chain by promoting traceability** and transparency in price formation among producers, intermediaries, and retailers to avoid speculative distortions. Strategic storage policies, through the consideration of create technical honey reserves during periods of high production to cushion the effects of seasonal shortages and stabilize prices.

These measures would help improve the efficiency of the multifloral honey market in Turkey, reduce consumer price volatility, and protect both beekeepers and households from unexpected shocks in the value chain.

## 5.3 General Limitations and Future Research

This study presents several limitations that should be acknowledged. First, the analysis did not incorporate prices of substitute products such as sugar, artificial sweeteners, or imported honey. These products exert competitive pressure on honey demand and pricing, and their exclusion may limit the model's ability to capture the full spectrum of market interactions within the Spanish and Turkish sweetener markets.

Second, the scope of the analysis was restricted to the vertical relationship between producer and consumer prices. Structural and contextual factors—such as seasonality, agricultural policy interventions, trade flows, and evolving consumption patterns—were not explicitly modelled. These elements can significantly influence price dynamics and the degree of asymmetry in transmission mechanisms.

For future research, we recommend expanding the analytical framework to include cross-price elasticities with substitute and complementary goods to better reflect competitive dynamics. Institutional and structural variables, including policy measures, market concentration, and trade liberalization effects and Behavioural and demand-side indicators, such as consumer preferences, income elasticity, and sustainability concerns. Incorporating these dimensions would enhance the explanatory power of econometric models, provide a more holistic understanding of price formation, and support the design of evidence-based public policies aimed at improving efficiency, transparency, and resilience in the honey value chain..

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