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Research Article

Market structure and price transmission in the egg market of Fars province, Iran

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ABSTRACT- Price fluctuations, market structure, and price transmission can significantly affect the welfare of egg producers and consumers. The current study aims to evaluate price transmission and analyze its impact on the egg market in the Fars province (April 2016 to December 2021). The market structure was examined using several indices, i.e., the inverse number of firms, concentration ratios, Herfindal-Hirschman index, and Hall-Tiedman index at the pullet breeding and wholesale levels in the egg market. The price transmission between wholesale eggs and retail levels was investigated, employing error correction, threshold autoregressive, and momentum threshold autoregressive models. The results indicated an increasing trend in the average annual changes in the percentage of wholesale and retail prices, with an increase in the standard deviation of average monthly prices. Thus, the results revealed severe fluctuations during this study. Market structure at the pullet breeding and wholesale levels indicated a state of multilateral monopoly and monopolistic competition. Furthermore, the analysis demonstrated asymmetric price transmission from wholesale to retail. Due to the non-competitive market structure and the observed asymmetry in price transmission, egg producers and consumers have to bear higher costs.

INTRODUCTION

Price fluctuations have become a prominent feature of several agricultural food markets in the Fars province recently. Market structure and price transmission across different market levels usually affect these fluctuations (Rahmani, 2021; Rahmani et al., 2022). The market structure plays an essential role in determining the prices of commodities, and different market levels have interconnections through pricing and the mechanism of price transmission. Market structure refers to the economic features of the market. Identifying these features allows for an explanation of the pricing nature, competition within the market, potential competitive corporate activities, barriers to entry, possible strategic patterns of competitive behavior, and the likelihood of collusion (Nikolaev, 2013). Any market structure can represent a state between perfect monopoly and perfect competition. The increase in concentration at various supply chain stages and interference in the pricing process can reduce market efficiency. This interference also leads to incomplete price transmission, hindering consumers from reaping the benefits of price reductions from upstream to downstream levels (Fousekis et al., 2016).

Empirical studies reveal that the market structure of many agricultural food products, particularly beyond the producer level in the supply chain, does not adhere to perfect competition (Farajzadeh and Bakhshoodeh, 2011; Nikolaev, 2013, Rahmani, 2019; Rahmani and Esmaeili, 2010; Tahri et al., 2018). Therefore, applying standard economic theories of a perfectly competitive market in such conditions necessitates caution.

Commodity exchange across different spaces, forms, and times can limit the potential for prices along the market chain to drift arbitrarily or jump far apart. When prices in one market dimension (such as the regional market, the farm market, or the current and future markets) exceed arbitrage costs, rational marketing agents tend to buy in the market where prices are low. They will then transfer or transform the commodities to eliminate or adjust the price discrepancy. In other words, according to the law of one price and arbitrage, price transmission occurs between different regions among links in the supply chain. Price transmission refers to the extent and speed at which localized or exogenous shocks in one market generate effects in other markets (Von Cramon-Taubadel & Goodwin, 2021; Liu et al., 2023). The manner in which price changes (both speed and magnitude of adjustment) transmit across different market chains depends on the involvement of marketing agents in the market and the market structure.

Numerous studies have affirmed asymmetric price transmission short-term across the supply chain for food

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and agricultural products. This asymmetry is particularly notable in the pricing dynamics of the retail market for vegetables in the USA (Ward, 1982). Retail prices tend to respond more swiftly to wholesale price increases than decreases due to the factors such as market structure and the perishability of vegetables. Competitive pressures among retailers during a rise in farm prices may not necessarily lead to higher retail prices. Conversely, retailer competition during price decline can drive retail prices down. Additionally, repricing costs contribute to the rigidity of retail prices during a price decline in farm products (Azzam, 1999).

Peltzman (2000) conducted a comprehensive analysis of 282 commodities, including 120 agricultural products, revealing the prevalence of asymmetric price transmission, often described as the ‘rocket and feather’ phenomenon. It describes a situation in which price increases are transmitted rapidly like a rocket launching, while price decreases descend gradually like a falling feather. The asymmetry results from a fragmented wholesale distribution system and is not merely an individual decision-maker’s response. Von Cramon-Taubadel (1998) and Abdulai (2002) attributed asymmetric price transmission in the pork markets of Germany and Switzerland to differing adjustment speeds in marketing margins when prices change. They observed that increases in producer prices, which lead to declines in marketing margins, are passed on more quickly to retail prices than decreases in producer prices, which result in increased marketing margins.

Meyer and Von Cramon-Thaubadel (2004) emphasized that asymmetric price transmission is not only a gap in economic theory but also serves political purposes by highlighting market failures. They outlined several causes behind this asymmetry, including non-competitive markets, adjustment costs, political interventions, asymmetric information, and inventory management.

A previous study by Hosseini et al. (2010) indicated that the impact of price increases and decreases in poultry farms on retail prices differ, becoming 1.2 and 0.82, respectively. They estimated the price transmission elasticity from poultry farms to retail to be 1.1 percent for every one percent increase in price and 0.69 percent for every one percent decrease in price. The impact of governmental egg market regulation policy on price transmission from poultry farms to retail has been positive but insignificant. Therefore, the governmental market regulation policy did not affect egg price fluctuations, especially in price reduction. Daneshvarkakhki and Heydari Kamalabadi (2012) found that subsidy targeting led to faster price increases and a slower decrease from wholesale to retail. The price transmission elasticities after subsidy targeting were lower than before subsidy targeting. Both Hosseini et al. (2010) and Daneshvarkakhki and Heydari Kamalabadi (2012) pointed to market structure and government policies as reasons for price fluctuation and asymmetric price transmission in the egg market in Iran.

Rasooli and Ghahremanzadeh (2013) found that wholesalers lose their tendency to react when a deviation from long-run equilibrium occurs in the Iranian egg market. In contrast, retailers respond to upward and downward deviations from long-run equilibrium, with their response to upward deviations being 3.6 times greater than downward deviations. Therefore, price transmission in the egg market is asymmetric, and retailers have market power for price adjustment.

Findings of Cunha and Wander (2014), regarding the bean market in São Paulo, Brazil, confirm that price increases at the farm level became transmitted intensely to wholesalers and retailers than price decreases. Therefore, the common bean market showed inefficiencies in price transmission along the chain, as price increases at the farm level generated higher impacts on retail prices, violating the absolute form of purchasing power parity.

Reziti (2014) demonstrated that from January 1998 to June 2014, the number of dairy farms in Greece decreased dramatically. As a result, the milk supply chain was a highly concentrated dairy sector, with price transmission between producer and consumer milk becoming asymmetric in both the short and long run. It implies that retailers exercise market power over producers.

In the milk market of Zanjan province, Iran, Ainollahi and Ghahramanzadeh (2015) found nonlinear adjustments between wholesale and retail prices. Retailers respond significantly to negative deviations from the long-run equilibrium, while wholesalers do not show sufficient inclination to react to these deviations. Therefore, policymakers should focus on producer and wholesale prices rather than retail prices to control fluctuations and volatility in milk prices.

Barikani and Amjadi (2015) indicated inefficiencies in price transmissions between the producer, wholesale, and retail levels in the citrus market (oranges, tangerines, and sweet lemons). They identified uncertainty, limited access to information, shifts in government policies, and market interventions as reasons for asymmetric price transmission in the Iranian citrus market.

Farajzadeh and Amiraslany (2018) found that export prices respond more to exchange rate increases than decreases when considering the Iranian export market. This asymmetric transmission effect of the exchange rate may serve as a potential source of market power for Iranian exporters.

Kamaruddin et al. (2021) showed a nonlinear cointegration of coffee prices between the global market and the Indonesian producer market. This asymmetric price transmission occurs in both long-term and short-term aspects, affecting not only the speed but also the magnitude and direction of price changes. The response of coffee prices in the producer market is higher and faster when world coffee prices decrease, indicating a failure to achieve a perfectly competitive market structure in Indonesia. Stability in the national economy makes Indonesian coffee producers more likely to benefit from increases in global coffee prices. However, during an economic recession in Indonesia, coffee producers suffered welfare losses due to the adverse shocks that affected world coffee prices. Therefore, policymakers should focus on economic growth and implement policies to promote perfect competition in domestic agricultural markets.

Panagiotou (2021) showed that over the past thirty years, the US pork industry has experienced significant changes, including increased concentration in packing, greater ownership of livestock, and a rise in marketing contracts linking packers with producers. Additionally, the Livestock Mandatory Reporting Act has shaped the supply chain, which has enhanced information flow and transparency. However, the researchers found asymmetry in the magnitude and speed of price transmission between farm-retail and wholesale-retail levels. Positive price shocks at farm and wholesale levels become transmitted to retail, with greater intensity than negative ones, indicating market inefficiencies potentially due to the market power. It means that retail prices are more responsive to increases than decreases, highlighting the growing bargaining power of retailers over wholesalers and affecting long-run margins and price ratios. Therefore, US pork consumers are more likely to experience price increases at the retail level following upstream price shocks.

However, some studies emphasize a competitive market structure for specific agricultural food products, showing symmetric price transmission. For instance, in the Iranian egg market, Hosseini and Permeh (2010) reported concentration ratios of 1.94%, 6.58%, 10.86%, and 17.05% for firms, suggesting a competitive market structure. The Herfindahl index decreased from 0.005 in 1996 to 0.003 in 2005, indicating increased competitiveness. Aziz Ahmad et al. (2016) found no dominant pricing power in the egg market in Central Java, Indonesia, supported by their research on the Herfindahl index. Additionally, Ghiasi and Ahmadi Shadmehri (2019) confirmed short and long-run symmetric price transmission in the saffron market in Iran. Aghabeygi et al. (2021) linked price shocks in corn, a primary input, to egg prices in the Iranian market.

Livestock and poultry products contribute essentially to fulfilling consumer protein needs. Eggs have a fundamental position in the Iranian diet. A notable proportion of Iranian egg production exists in eight provinces, including Fars province, which ranked eighth in 2019, with 48.4 thousand tons (Ministry of Agriculture Jihad, 2020).

In recent years, average egg prices at wholesale and retail levels, with their fluctuations, have increased in the Fars province. From 2016 to 2021, the average annual percentage increase in wholesale and retail egg prices exceeded 80%. During this period, the average standard deviation of the wholesale price of eggs rose from 2,520 in 2016 to 48,773 in 2021 (Rahmani et al., 2022). Moreover, the retail marketing margin increased within the egg market, going from 5,764 in 2016 to 26,430 Rials in 2021. Significant differences were observed in the average monthly wholesale egg prices in Fars province compared to other provinces in Iran, with prices being higher in nine provinces and lower in seventeen provinces. The retail marketing margin in the Fars province also significantly differed from that of other provinces, being higher in twenty-eight provinces and lower in one province. Thus, the retail marketing margin for eggs in the Fars province is higher than many other provinces, even where wholesale prices are lower or have no statistically significant difference. This scenario emphasizes how egg marketing agents affect price transmission in the market (Rahmani et al., 2022). Price fluctuations in eggs and production inputs pose substantial challenges to the poultry industry, disrupting the market balance annually. These fluctuations jeopardize producer income and worldwide food security, particularly in developing countries (Ivanic and Martin, 2018).

Despite governmental endeavors to regulate the egg market, definitive and complete success has not yet been achieved (Hosseini & Permeh 2010; Rahmani et al. 2022). The existence of an inappropriate structure in the upstream stages of the egg market (pullet breeding and wholesale) and price fluctuations of this commodity could affect marketing margins and vertical price transmission. This study considers price fluctuations, the market structure of the egg market at the pullet breeding and wholesale levels, and the price transmission of eggs from the wholesale to the retail level in Fars province, Iran. The present study contributes to the relevant literature from several aspects. First, it extends the knowledge of the reasons for price fluctuations at wholesale and retail levels regarding government policies in the input market. Second, while paying attention to the market and its continuity at different levels, it evaluates and analyzes market structure at the upstream level (pullet breeding). Third, by examining different models of price transmission and considering the nature of the data, it evaluates and analyzes price transmission from wholesale to retail levels in the egg market.

MATERIALS AND METHODS

Market structure

Concentration ratio-based indices enable assessments of the market structure, revealing how the market allocates among various firms. These indices provide insights into the degree of competition and monopoly within individual markets or the entire economy. The concentration level demonstrates an inverse relationship with the number of firms and a direct relationship with the unequal distribution of firm market shares (Hosseini and Permeh 2010). Multiple indices are available to calculate market concentration, each with advantages and disadvantages. In this study, we utilized indices such as the inverse number of firms, concentration ratios, Herfindahl-Hirschman (HH), and Hall Tiedman (HT) to calculate and analyze the market structure within the egg market at both the pullet breeding and wholesale levels.

The inverse index (IN) of the number of firms is a convenient metric for assessing market structure, calculated using Eq. (1).

$$\mathrm{IN} = \frac{1}{\mathrm{N}} \quad \text{Eq. (1)}$$

where N is the number of firms. This index is only based on the number of firms and does not account for distribution specifies (Clark, 1985).

The concentration ratios index (CR_i) is computed by summing the market shares of the i largest firms. For instance, when i equals 1 (CR_1), it calculates the output share of the largest firm relative to the entire market size. Likewise, for $i = n$, this index calculates the share of the n largest firms and is denoted as CR_n (Eq. (2)).

$CR_n = \sum_{i=1}^{n} D_i$, $i = 1.2. \dots . n$ Eq. (2)

where D_i is the market share of the *ith* firm and n is the number of the largest firms, typically chosen as 1, 4, 8, or 16. Suppose the index value of the 16 largest firms is small (nearing zero). Thus, it indicates conditions resembling perfect competition. If the index value for these largest firms is extremely close to 100, it signifies monopoly conditions (Nikolav, 2013).

Another index for evaluating the market structure is the Herfindahl-Hirschman index (HHI), calculated based on how the market size is distributed among firms. Unlike concentration ratios, this index uses information from all firms to calculate the degree of concentration (Eq. (3)).

$HHI = \sum_{i=1}^{n} (\frac{X_i}{X})^2 = \sum_{i=1}^{n} D_i^2$ Eq. (3)

where X_i is the volume of the commodity traded by firm *i*, X is the total commodity traded in the market, n is the number of firms in the market, and D_i^2 is the square of the share of firm *i* in the market. HHI can range from 0 to 1, representing many small firms to monopolistic ones. The value of HHI is $\frac{1}{n}$ when the share of all firms is equal (Nikolaev, 2013; Herfindal, 1959).

The Hall-Tiedman index (HTI) is calculated based on a comparison of relative ranks of firm shares in the market. Eq. (4) calculates this index.

$HTI = \frac{1}{2\sum_{i=1}^{n} R_i D_i - 1}$ Eq. (4)

where, R represents the rank of the *ith* firm in the market, and D_i is the share of that firm in the market. The value of this index ranges between 1 and $\frac{1}{n}$. The closer the index is to 1, the higher the concentration, indicating fewer firms and an unequal distribution of shares in the market (Nikolaev, 2013).

Price transmission

Analyzing the vertical price transmission within a commodity market requires three approaches, i.e., Houck, error correction, and threshold (Abdulai, 2002). The selection of the appropriate approach for studying the price transmission process depends on the statistical characteristics of the price time series. The summarized econometric method by Houck (1977) appears in Eq. (5).

$\Delta RP_t = \gamma_0 + \gamma^+ \sum_{t=1}^{\tau} \Delta WP_t^+ + \gamma^- \sum_{t=1}^{\tau} \Delta WP_t^- + \varepsilon_t$ Eq. *(5)*

where, ΔRP_t represents the change in retail prices, ΔWP_t^+ and ΔWP_t^- denote positive and negative changes in the wholesale price of eggs, respectively. γ_0 , γ^+, and γ^- are coefficients, *t* represents the time period, and ε_t represents the random error component. A symmetric price transmission is rejected if the coefficients $\gamma+$ and $\gamma-$ are significantly different.

Houck's model is applicable for stationary time series, and if the time series are not stationary, the estimated equation may not be reliable (Granger and Newbold, 1974). Banerjee et al. (1993) and Bettendorf and Verboven (2000) asserted that the estimated regression cannot be spurious if the investigated time series are cointegrated. In other words, the existence of a long-term relationship between price series is a necessary condition for using the error correction approach, which is why this approach is considered superior to others. In the error correction approach, we used methods described by Engel and Granger (1987), Granger and Lee (1989), Von Cramon–Taubadel and Fahlbusch (1994), and Von Cramon–Taubadel and Loy (1996). Thus, examining the vertical price transmission between the wholesale and retail levels involved estimating the cointegration relationship between the retail and wholesale price series. Using the Engel-Granger (1987) method, the long-run equilibrium relationship between retail and wholesale prices can result from Eq. (6).

$RP_t = \beta_0 + \beta_1 WP_t + u_t$ Eq. (6)

where RP_t represents the retail price, WP_t represents the wholesale price, and u_t signifies the short-run deviation from the long-run equilibrium relationship. Also, u_t is a component of distribution that may exhibit autocorrelation. Under such conditions, the autocorrelation process can be assessed using Eq. (7).

$\Delta u_t = \rho u_{t-1} + \varepsilon_t$ Eq. (7)

If $\rho \neq 0$, Eq. (6) and Eq. (7) imply the existence of the error correction model (ECM), expressed in its standard form as Eq. (8) (Engle and Granger, 1987):

$\Delta RP_t = \gamma_0 + \gamma_1 \Delta WP_t + \gamma_2 \sum_{l=1}^{k} \Delta WP_{t-l} + \gamma_3 \sum_{l=1}^{m} \Delta RP_{t-k} + \gamma_4 ECT_{t-1} + \varepsilon_t$ Eq. (8)

where the error correction term (ECT) is defined as $ECT_{t-1} = u_{t-1} = RP_{t-1} - \beta_0 - \beta_1 - WP_{t-1}$ and γ_0 to γ_4 represents coefficients. Also, ε_t is the disturbance term, and the remaining variables previously defined.

Granger and Lee (1989) proposed corrective modifications to Eq. (8). These modifications enabled the conduct of an asymmetric transmission test among cointegrated variables. In their study on a US industry inventory, ECT was divided into two components, ECT^+ and ECT^-, outlined in Eq. (9).

$\Delta RP_t = \gamma_0 + \gamma_1 \Delta WP_t + \gamma_2 \sum_{l=1}^{k} \Delta WP_{t-l} + \gamma_3^+ D_{1t}^+ ECT_{t-1}^+ + \gamma_3^- D_{1t}^- ECT_{t-1}^- + \varepsilon_t$ Eq. (9)

where $D_{1t}^+ = 1$, if $ECT_{t-1} > 0$, and zero otherwise. Also, $D_{1t}^- = 1$, if $ECT_{t-1} < 0$, and zero otherwise. Since $ECT = ECT^+ + ECT^-$, symmetry evaluation is performed using an F test and the associated null hypothesis. Furthermore, Von Cramon-Taubadel, and Loy (1996) divided the simultaneous reaction component into two parts, i.e., positive and negative (Eq. (10)):

$\Delta RP_t = \gamma_0 + \gamma_{1l}^+ D_{2t}^+ \sum_{l=1}^{m} \Delta WP_{t-l+1} + \gamma_{1l}^- D_{2t}^- \sum_{l=1}^{k} \Delta WP_{t-l+1} + \gamma_2^+ D_{1t}^+ ECT_{t-1}^+ + \gamma_2^- D_{1t}^- ECT_{t-1}^- + \varepsilon_t$ Eq. (10)

where $D_{2t}^+ = 1$, if $WP_{t-1+1} > 0$, and zero otherwise. Also, $D_{2t}^- = 1$, if $WP_{t-1+1} < 0$, and zero otherwise. Eq. (10) allows testing of short-run and long-run symmetry hypotheses specified by Eq. (11) and Eq. (12) using the standard F test.

$H_0: \sum_{l=1}^{m} \gamma_{1l}^+ = \sum_{l=1}^{m} \gamma_{1l}^-$ Eq. (11)

$H_0: \gamma_2^+ = \gamma_2^-$ Eq. (12)

Accepting the null hypothesis indicates that increases and decreases in the wholesale price, both in the short and long run, are equally transferred to the retail price (Acquah and Ndzebah Dadzie, 2010; Aghabeygi et al., 2021).

One considering point is that if in the ECM model, the price transmission is consistent with asymmetric cointegration, a simultaneity problem exists between wholesale and retail prices. Therefore, in Eq. (8), if the variables RP_t and WP_t are simultaneous, the estimated equation will be biased and inconsistent. In other words, the estimated parameters in Eq. (8) can be validly inferred if weak exogeneity is observed relative to WP_t (Hahn, 1990). Weak exogeneity in the ECM (Eq. (8)) is assessed based on the significance of the parameter γ_4 (Boswijk and Urbina, 1997). Enders and Granger (1998) argued that the Engle-Granger and Johansson tests are invalid if the adjustment is asymmetric. They contend that when these tests are used to analyze price transmission from wholesale to retail, the implicit assumption is that the price responses are symmetric. Enders and Granger (1998) introduced an alternative error correction specification called the threshold autoregressive (TAR) model. In this model, Eq. (7) is written as follows (Eq. (13)):

$$\Delta u_t = \begin{cases} \rho_1 u_{t-1} + \varepsilon_t \; if \; u_{t-1} \geq 0 \\ \rho_2 u_{t-1} + \varepsilon_t \; if \; u_{t-1} < 0 \end{cases} \quad \text{Eq. (13)}$$

A necessary condition for u_t to be stationary is:

$- 2 < (\rho_1, \rho_2) < 0$

Enders and Granger (1998) demonstrated that if sequences ρ_1 and ρ_2 are stationary, they possess an approximate multivariate normal distribution. The adjustment process can be quantified as follows (Eq. (14)):

$$\Delta u_t = I_t \rho_1 u_{t-1} + (1 - I_t)\rho_2 u_{t-1} + \varepsilon_t \quad \text{Eq. (14)}$$

In Eq. (14), I_t is the Heaviside indicator function defined as Eq. (15).

$$I_t = \begin{cases} 1 \; if \; u_{t-1} \geq 0 \\ 0 \; if \; u_{t-1} < 0 \end{cases} \quad \text{Eq. (15)}$$

where 0 indicates a critical threshold. Models utilizing Eq. (14) and Eq. (15) are known as TAR models. In these models, the threshold cointegration test investigates the threshold behavior of the equilibrium error. If the system converges, $u_t = 0$ can be considered as the long-run equilibrium value of the sequence. When u_t exceeds the equilibrium value, the adjustment value is $\rho_1 u_t$, and if u_t is less than the equilibrium value, the adjustment value is $\rho_2 u_t$. Thus, the equilibrium error behaves like a threshold autoregression value.

Considering that $\rho_1 = \rho_2$ leads to symmetric adjustment, the Engel–Granger method is a particular variant of Eq. (14) and Eq. (15). Assuming the existence of the cointegration vector in Eq. (6), the error correction representation in Eq. (8) can be expressed as Eq. (16).

$$\Delta RP_t = \rho_{1,1} I_t u_{t-1} + \rho_{2,1}(1 - I_t)u_{t-1} + \sum_{l=1}^{k} \gamma_2 \Delta WP_{t-l} + \varepsilon_t \quad \text{Eq. (16)}$$

where $\rho_{1,1}$ and $\rho_{2,1}$ are adjustment coefficients for positive and negative discrepancies, respectively. Enders and Granger (1998) demonstrated that it is possible to incorporate the intervals of changes in the u_t sequence in Eq. (14) to transform it into a process with order p (Eq. (17)):

$$\Delta u_t = I_t \rho_1 u_{t-1} + (1 - I_t)\rho_2 u_{t-1} + \sum_{i=1}^{p-1} \beta_i \Delta u_{t-l} + \varepsilon_t \quad \text{Eq. (17)}$$

In Eq. (17), diagnostic tests of residual sequences, such as autocorrelation, partial autocorrelation, and model selection criteria such as *AIC*, *SCB*, and *HQC* are required to determine an optimal number of lags.

Instead of estimating Eq. (14) with the Heaviside indicator based on Eq. (15), which depends on the u_{t-1} level, we can allow the decay rate to depend on the changes in the previous period's u_{t-1}. In this case, the Heaviside indicator can manifest as Eq. (18).

$$I_t = \begin{cases} 1 \; if \; \Delta u_{t-1} \geq 0 \\ 0 \; if \; \Delta u_{t-1} < 0 \end{cases} \quad \text{Eq. (18)}$$

According to Enders and Granger (1998), replacing the Heaviside indicator based on Eq. (15) with Eq. (18) is appropriate when the adjustment is asymmetric. Models estimated using Eq. (6), Eq. (8), and Eq. (18) are referred to as momentum threshold autoregression (M-TAR) models.

For the TAR model, if, for example, $-2 < \rho_1 < \rho_2 < 0$, the negative phase of the u_t sequence is considerably more stable than the positive phase. In the case of the M-TAR model, if, for example, $|\rho_1| < |\rho_2|$, the M-TAR model exhibits relatively less decay for positive values of Δu_{t-1} compared to the negative values of Δu_{t-1}. Consequently, in the TAR model, the degree of autoregressive decay is contingent upon the state of the variable of interest, while in the M-TAR model, the degree of autoregressive decay hinges on the difference of the first lag of the variable of interest.

The vertical price transmission between wholesale and retail levels was analyzed using the ECM, TAR, and M-TAR models. The necessary data comprised average monthly nominal prices for eggs at both wholesale and retail levels, as well as characteristics of pullet breeding and wholesale firms (such as capacity and production volume) in the Fars province of Iran. The average monthly wholesale and retail prices from April 1, 2016, to the end of December 2021 were obtained from the database of the State Livestock Affairs Logistic Company (Https://old.iranslal.com/index.php/fa/features/2013-01-31-07-23-52/daily-price.html). Data regarding the characteristics of pullet breeding and wholesale firms, i.e., capacity, packaging amount, and sales, were extracted from statistical documents of the cooperative company of laying hens and the livestock production affairs deputy (https://fajo.ir/site/index.php/).

RESULTS AND DISCUSSION

Changes in wholesale and retail prices and marketing margins

The results present monthly averages of wholesale and retail prices, the retail marketing margin per year, and the minimum, maximum, standard deviation, and percentage changes of the annual average egg prices during the reviewed period (Table 1). Fig. 1 and Fig. 2 illustrate wholesale and retail price changes during the reviewed period, and specifically for 2016 and 2020. The average annual wholesale and egg retail prices increased from 36,269 and 43,852 Rials in 2016 to 169,908 and 213,258 Rials in 2021, respectively. Additionally, the average retail marketing margin increased from 7,583 Rials in 2016 to 43,350 Rials in 2021. Throughout the reviewed period, the average monthly wholesale and retail prices and the retail marketing margin were multiplied by 4.68, 4.86, and 5.72 times, respectively. Therefore, during the period under review, the retail price experienced a more severe increase.

The average percentage change in wholesale and retail prices consistently increased throughout the months of each year and over the entire period under consideration. During the review period, the lowest average monthly prices were observed from April to July, while the highest average monthly prices were noted from January to April. One contributing factor to the higher prices of eggs during these months was the increased consumption by households and industries, likely due to the cooler weather and a broader range of consumption options compared to other months.

The average annual increase rate for wholesale and egg retail prices during the investigated period was 38.12% and 38.87%, respectively. In contrast, the average annual inflation rate for the same period stood at 33.8% (Central Bank of Iran, 2022). This indicates that the increase in both wholesale and retail egg prices surpassed the overall inflation rate during this timeframe.

The average annual wholesale price changes fluctuated, ranging from a slight 0.85% increase in 2019 compared to 2018, and then to a significant 68.48% increase in 2020, compared to 2019. The corresponding amounts for the retail price were 5.56% and 67.36%, respectively. Thus, it indicated a resistance in the market in the direction of reducing the price to lower price levels in the retail market, and implicitly, it can be a manifestation of asymmetric price transmission. Accordingly, these changes have been discussed following quantitatively and more precisely.

The annual standard deviation values for average wholesale and retail egg prices in the period under review increased from 6148.06 and 8746.44 in 2016 to 41313 and 37061.77 in 2021, respectively.

Notably, the annual fluctuations in egg prices were more pronounced in the latter years of the review period, specifically in 2020 and 2021.

This heightened volatility can be attributed to several factors. Firstly, there were currency restrictions affecting the timely supply of essential inputs such as corn and soybean meal due to the economic sanctions imposed on the country. This, in turn, resulted in fluctuations in import quantities of these vital inputs. Additionally, disparities between official and free market prices of the imported inputs contributed to suboptimal allocation in production processes (Rahmani, 2021; Aqhabeygi et al., 2021). Consequently, governmental interventions, such as providing inputs at subsidized prices or offering discounted currency rates, ultimately exacerbated the fluctuations in egg prices. It is anticipated that a reduction in government intervention will likely mitigate the price fluctuation of egg commodities.

Table 1. Egg price and marketing margin descriptive statistics in the review period (Rials)

Descriptive statistics	Year					
	2016	2017	2018	2019	2020	2021*
Average monthly wholesale price	36269	48913	66193	66758	112462	169908
Average annual wholesale price changes (%)**	-	34.86	35.33	0.85	68.46	51.8
Minimum average monthly wholesale price	29125	34556	57322	43266	75083	106200
Maximum average monthly wholesale price	50683	73500	79073	82433	171500	220700
Standard deviation of average monthly wholesale price	6148.06	12178	6661	1239.83	34891.14	41313
Average monthly retail price	43852	55993	84019	88689	148426	213258
Average annual retail price changes (%)**	-	27.69	50.05	5.56	67.36	43.68
Minimum average monthly retail price	34258	45764	70931	60966	96000	158400
Maximum average monthly retail price	64083	83333	99412	101333	207250	262750
Standard deviation of average monthly retail price	8746.44	11867	8198.56	12853.49	38454.57	37061.77
Average retail marketing margin	7583	7080	17826	21931	35964	43350

* The study period's end was the end of December 2021. ** Percentage change of the average annual price relative to the previous year.

Source: Research data and author's calculations.

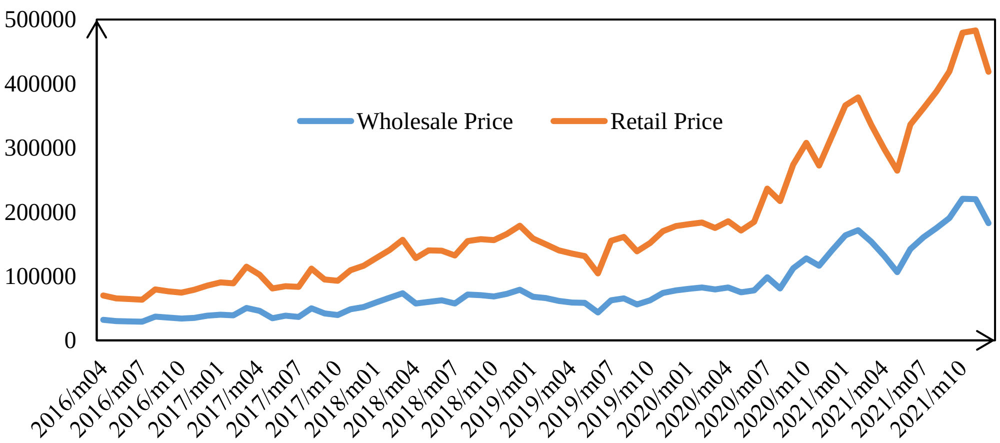

Fig.1. Monthly average price of eggs (April 2016 to December 2021).

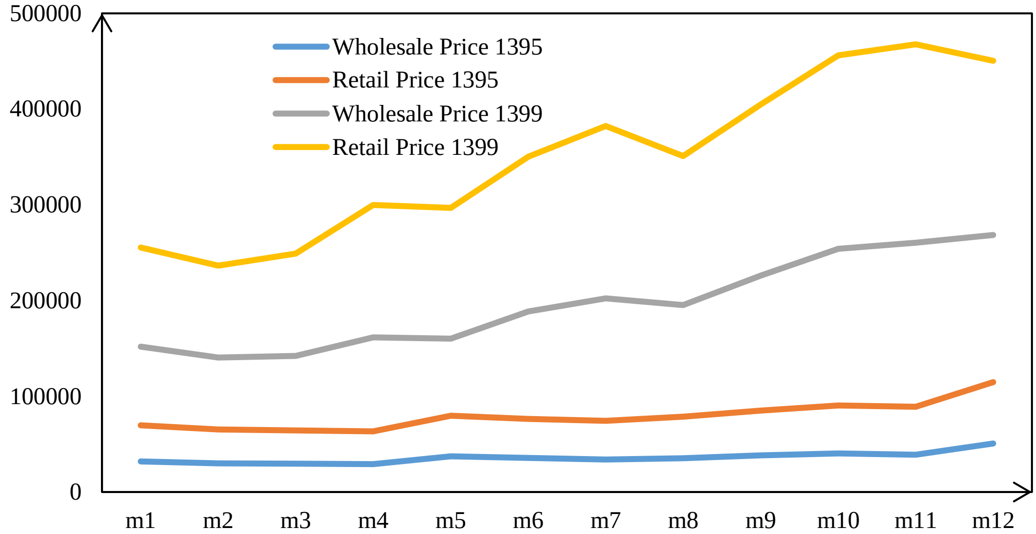

Fig. 2. Monthly average wholesale and retail prices of eggs in 1395 and 1399 (solar years) (April 2016 to March 2017 and April 2020 to March 2021 Gregorian years).

Market structure

The average, maximum, minimum, and variance values representing the share of pullet breeding and wholesale egg firms in the market are summarized in Table 2. Additionally, the results show the share of firms from small to large and their cumulative frequency (Fig. 3 and Fig. 4). As can be seen, the minimum and maximum shares of pullet breeding firms are 0.69% and 28.84%, respectively, while for egg wholesale firms, they are 0.18% and 26.5%, indicating a similar distribution regarding the minimum and maximum share.

On average, pullet breeding firms have a share of 6.67% with a variance of 48.66, whereas egg wholesale firms exhibit an average share of 1.85% with a variance of 13.54. Thus, the average share and dispersion of pullet breeding firms in this market surpass that of wholesale egg firms. Pullet breeding firms typically fall within the 0.69% to 10% share range, while wholesale egg firms predominantly fall within the 0.26 to 5% range (Fig. 3 and Fig. 4).

The results indicate indices for the inverse number of firms, concentration ratios, Herfindahl-Hirschman (HH), and Hall Tiedeman (HT) (Table 3). In December 2021, the Fars province had 15 pullet breeding firms, resulting in an inverse value of 0.07 for the number of firms.

Table 2. Descriptive statistics of pullet breeding and egg wholesale firms' market share

Descriptive statistics	Pullet breeding firms	Egg wholesale firms
Concentration ratio of largest firm (CR_1) (%)	6.67	1.85
Maximum share of firms (%)	28.84	26.5
Minimum share of firms (%)	0.69	0.18
Variance of the share of firms	48.66	13.54

Source: Research data and author's calculations.

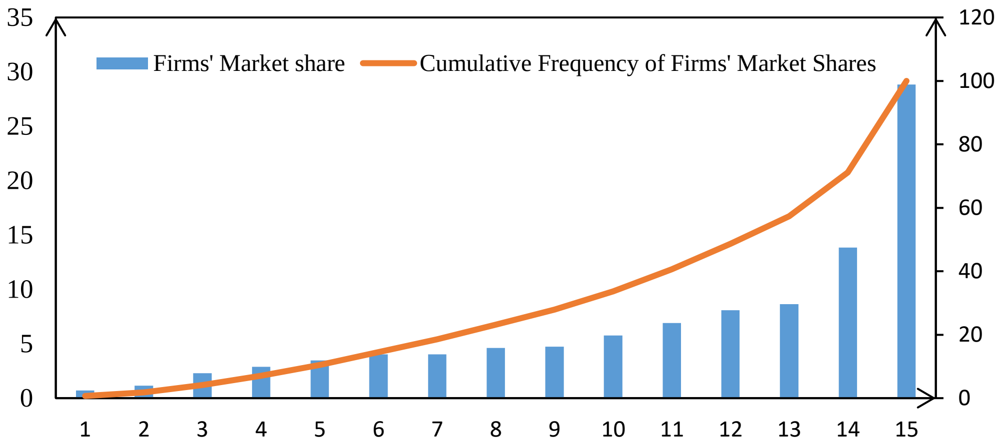

Fig. 3. Market share of pullet breeding firms.

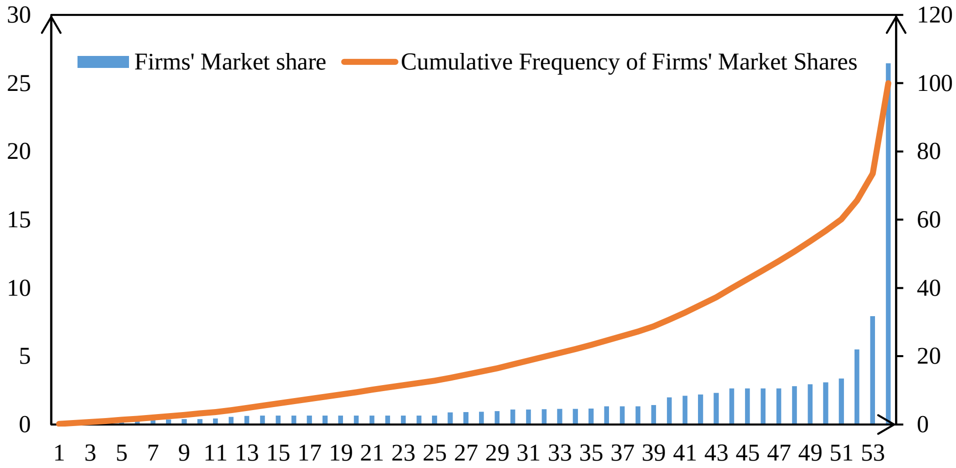

Fig. 4. Market share of egg wholesale firms.

Table 3. Market structure evaluation indices for pullet breeding and egg wholesale firms in the Fars province

Indices	Pullet breeding firms	Egg wholesale firms
Inverse number of the firms	0.07	0.02
Concentration ratio for largest firms (CR_1)	28.8	26.5
Concentration ratio for 4 largest firms (CR_4)	59.4	35.8
Concentration ratio for 8 largest firms (CR_8)	81.4	46.3
Concentration ratio of 8 largest firms (CR_{16})	-	59.5
Herfindal-Hirschman (HH)	0.135	0.046
Invers Herfindal-Hirschman (IHH)	7.41	21.74
Hall-Tidman (HT)	0.109	0.037

Source: Research data and author's calculations.

The concentration ratio index for one, four, and eight pullet breeding firms are 28.8%, 59.4%, and 81.4%, respectively. These figures indicate that the market shares for one, four, and eight of the largest firms in Fars province are 28.8%, 59.4%, and 81.4%, respectively. Based on the inverse index of the number of firms and the concentration ratio index, we can infer that the pullet breeding market in Fars province exhibits a multilateral monopoly structure. Given that there are 15 pullet breeding firms in Fars province and the market share for the eight largest firms exceeds 80%, the remaining seven collectively hold less than a 20% market share. The Herfindahl-Hirschman index was 0.135, with its inverse equaling 7.41, indicating an open multilateral monopoly structure. Additionally, the Hall-Tiedman index is computed as 0.109, referring to a relatively high market concentration. Indeed, the distribution of market share among firms is not well-balanced.

Hence, all the available market structure analysis indices affirm the presence of a multilateral monopoly structure for pullet breeding firms. It is imperative to recognize that due to the significant investment requirements and fixed costs, achieving a high level of market competitiveness may not always be feasible, resulting in an inevitable monopoly degree within the market.

In December 2021, the Fars province was home to 54 laying hen firms dealing with egg packaging and wholesale distribution. Consequently, the inverse index of the number of firms was 0.02. The results on the concentration ratio index indicate that the market share for one, four, eight, and sixteen of the larger firms amounted to 26.5%, 35.8%, 46.3%, and 59.5%, respectively (Table 3). The dominant entity in the market is a supply chain that features the largest pullet breeding unit with a capacity of 250 thousand pieces, three egg production units with a capacity of 1.2 million pieces, and an extensive distribution network.

Based on the values derived from the inverse number of firms and the concentration ratios, the market structure at the wholesale level exhibited characteristics of monopolistic competition and open multilateral monopoly. The Herfindahl-Hirschman index value stands at 0.046, with its inverse equaling 21.74, confirming the presence of a monopolistic competition structure within this market. Since the Hall-Tiedman index was 0.037, it indicated that the wholesale egg market a lower concentration than the pullet breeding market, and the market share distribution among these firms is relatively competitive.

The findings of this study contrast with those of Hosseini and Permeh (2010) as well as Aziz Ahmad et al. (2016) regarding the egg production and export market in Iran and the egg market at various levels of the supply chain in the Bani Yomas region of Indonesia, describing them as competitive. However, our results align with studies conducted by Hosseini et al. (2010), Daneshvarkakhki and Heydari-Kamalabadi (2012), and Rasooli and Ghahramanzadeh (2013), all categorizing the egg market in Iran as non-competitive.

Hosseini and Permeh (2010) analyzed the market structure in 2005. Over recent years, we have observed the establishment of larger firms, leading to increased concentration ratios. While government intervention through market regulation policies has escalated, these factors contribute to a shift in the structure of the egg market compared to previous years. In the subsequent sections, we further assess the market structure by considering the concept of price transmission.

Price transmission

To investigate the vertical price transmission of eggs from wholesale to retail, we initiated the analysis by conducting a stationary test on the time series of average monthly prices. The generalized Dickey-Fuller test with intercept and trend yielded results that aimed at verifying the stationary nature of the variables (Table 4). Both time series were found to follow an I (1) process, indicating that the first difference of the series is stationary at the 1% level. Consequently, it is expected that there exists a long-run relationship between the two series. To confirm the presence of such long-run relationships, we employed Johansen's test.

Johansen's test utilizes both trace and maximum eigenvalue tests, thus ascertaining the number of cointegration vectors. The results of this test with intercept (no trend) meant to posit the existence of at least one cointegration relationship (Table 5). The calculated statistics for both the trace and maximum eigenvalue tests were 23.18 and 20.74, respectively—both exceeding the 5% critical level of these statistics, which are 15.49 and 14.26, respectively. Consequently, we reject the null hypothesis that suggested no cointegration relationship.

The results indicating the optimal number of lag lengths appear in Table 6. According to the Schwartz (SC) and Hannan-Quinn (HQ) criteria, the optimal lag length was one.

After determining the optimal lag length, we estimated the ECM of price transmission from wholesale to retail (Eq. (9)). The results of this estimation appear in Table 7. The estimated constant holds a value of -1377.43 ($P \leq 0.05$). The variables influencing the retail price encompass the increasing and decreasing series of prices at the wholesale level in the current period, as well as the increasing series of the error correction term from the long-run equilibrium relationship.

The estimated coefficients for the increase (ΔWP_t^+) and decrease (ΔWP_t^-) series of the wholesale price were 1.12 and 0.76, respectively ($P \leq 0.01$). Therefore, a one-unit increase in wholesale price during the current period leads to a corresponding 1.12-unit increase in the retail price. A one-unit decrease in the wholesale price during the current period results in a 0.76-unit decrease in the retail price.

The estimated coefficients for the first lag of the increase (ΔWP^+_{t-1}) and decrease (ΔWP^-_{t-1}) series of the wholesale price are 0.24 and -0.20, respectively, despite their statistical insignificance. Thus, an increase in the wholesale price during the previous period does not influence the subsequent retail price significantly, and similarly, a decrease in the wholesale price during the previous period does not significantly impact the price during the current period.

In summary, one conclusion is that an increase in the wholesale price to a specified extent causes an increase in the retail price. However, a decrease in the wholesale price by the same amount leads to a smaller decline in the retail price. This observation suggests an asymmetric price transmission from wholesale to retail or that the price transmission from wholesale to retail is asymmetric. Given the lack of significance in the coefficients of variables with a lag, there is no asymmetry in the timing or speed of price transmission; rather, the asymmetry lies in the magnitude of price transmission.

The estimated coefficient for the incremental series of the error correction term (ECT^+) is -0.20 and is significant at the ten percent level. The negative and significant coefficient for the increasing series of the error correction term in the long-run relationship indicates that positive fluctuations moderated over the long run. The estimated coefficient is smaller and tends to adjust within five periods. On the other hand, the estimated coefficient for the decreasing series of the error correction term (ECT^-) is -0.24 and is insignificant.

Table 4. Results of unit root test of the variables

Variable	Level Value			First difference		
	t-Statistic	Critical values	Probability	t-Statistic	Critical values	Probability
Wholesale Price (WP)	2.14	3.16	0.51	7.1	3.16	0.000***
Retail Price (RP)	1.8	3.16	0.69	6.97	3.16	0.000***

*** P value indicates significance at 1 percent level
Source: Research data and author's calculations.

Table 5. Results of Johansen cointegration test

Null Hypothesis	Trace Statistic	0.05 Percent critical value	Max-Eigen Statistic	0.05 Percent critical value
None**	23.18	15.49	20.74	14.26
At most 1	2.43	3.84	2.43	3.84

** Denotes rejection of hypothesis at the 0.05 level.
Source: Research data and author's calculations.

Table 6. Results of optimal lag length selection

Lag	LR	FPE	AIC	SC	HQ
0	NA	1.83 e+17	45.42	45.49	45.45
1	235.95*	4.34 e+15	41.68	41.88[a]	41.76[a]
2	8.78	4.24 e+15	41.66	41.99	41.79
3	7.26	4.24 e+15[a]	41.65[a]	42.12	41.84

* Optimal lag length.
Source: Research data and author's calculations.

Table 7. Results of error correction model (ECM) model (dependent variable ΔRP_t)

Variables	Estimated Coefficients	T Statistic	Diognostic statistics	Values
Constant	-1377.43**	-2.17	F	59.77***
ΔWP_t^+	1.12***	11.60	Adjusted R^2	0.84
ΔWP_t^-	0.76***	9.65	Durbin -Watson	1.86
ΔWP_{t-1}^+	0.24^{ns}	0.24	LM	5.62***
			Wald (Asymmetric short-run transmission)	4.15
ΔWP_{t-1}^-	-0.21^{ns}	-1.17		
				0.02
ECT^+	-0.20*	-1.8	Symmetric long-run transmission	0.20
ECT^-	-0.24^{ns}	-1.44		0.84

Ns:indicates Not significant, *: indicates significance at the 10 percent level, **: indicates significance at the 5 percent level, ***: indicates significance at the 1percent level.
Source: Research data and author's calculations.

Therefore, the response of the retail price to deviations from long-run values differs for positive and negative deviations. While a positive deviation results in a decrease in the retail price, a negative deviation does not elicit a reciprocal reaction. These discrepant reactions could result from the consistent price hike during the study period. The long-run trend maintained an upward trend, though without anticipating a reaction involving price reduction.

When a correlation exists between the variables RP_t and WP_t, the estimated coefficients in the ECM become biased and inconsistent. Thus, it is imperative to conduct a weak exogeneity test. The exogeneity test was performed using an appropriate number of lags determined by SCB, AIC, and HQC statistics (Eq. (8); Table 8). As illustrated, the impact of the EC_{t-1} variable on ΔRP_t was statistically significant. Consequently, the error correction terms have a significant influence over deviations from the long-run equilibrium relationship, revealing bias and inconsistency in the ECM model results.

The TAR model is utilized as an alternative to address simultaneity bias and asymmetric price transmission. The results of the long-run equilibrium relationship appeared using the TAR model (Eq. (16) in the research method), along with an appropriate number of lags based on SCB, AIC, and HQC statistics (Table 9). The t, F, and χ^2 statistics indicated that the null hypothesis asserting the equality of $\rho_{1,1}$ and $\rho_{2,1}$ is rejected. Thus, it indicated asymmetric price transmission from wholesale to retail. Notably, $\rho_{1,1}$ surpasses $\rho_{2,1}$ in value, underscoring the greater stability of the positive phase in the u_t series compared to the negative phase.

Considering the significant influence of ΔWP_t, ΔWP_{t-1}, and ΔWP_{t-2} variables on ΔRP_t, especially the substantial impact of the positive phase of the u_t series, we established the equilibrium relationship using the M-TAR model (Eq. (6), Eq. (16), and Eq. (18) in the research methodology). The appropriate number of lags was determined according to SCB, AIC, and HQC statistics, while showing the results of this estimation (Table 10). The t, F, and χ^2 statistics allow the rejection of the null hypothesis, which posits the equality of $\rho_{1,1}$ and $\rho_{2,1}$. Therefore, the price transmission from wholesale to retail exhibits an asymmetric pattern. Furthermore, since the absolute value of $\rho_{1,1}$ is greater than that of $\rho_{2,1}$, it indicates a relatively more significant discount in the Δu^-_{t-1} series compared to the Δu^+_{t-1} series.

The results of the symmetry tests for price transmission based on ECM, TAR, and M-TAR models reveal asymmetric egg price transmission from wholesale to retail in the Fars province (Table 7, Table 9, and Table 10). Consequently, an increase in wholesale prices has a more pronounced impact on retail prices than a decrease does. This asymmetry in price transmission can be attributed to various factors, i.e., the non-competitive market structure at different levels of the supply chain, the perishability of eggs without adequate processing facilities in the Fars province, government intervention in the input market, and the significant bargaining power held by retailers.

The results of this study are similar to those conducted by Hosseini et al. (2010), DaneshvarKakhaki and Heidari Kamalabadi (2012), and Rasooli and Ghahramanzadeh (2013); however, they differ from previous findings by Aziz Ahmad et al. (2016). In their studies, they highlighted the reasons for asymmetry in price transmission, including market structure inadequacies in the egg market in Iran, government policy failures in market regulation, and the considerable bargaining power held by retailers in the egg market. Conversely, the symmetry observed in price transmission in a study by Aziz Ahmad et al. (2016) in the Banyumas region of Indonesia was traceable to an optimal competitive structure of the egg market and the absence of dominant pricing powers.

CONCLUSION

In the food market, aspects such as market structure, pricing strategy, price fluctuations, and the price transmission process are pivotal considerations from both economic and political perspectives. These elements profoundly influence the welfare of producers, consumers, and other marketing stakeholders. The economic evaluation and analysis of these aspects, serving as indicators of market efficiency, offer valuable insights for decision-making and policy formulation.

Table 8. Results of weak exogenity test (dependent variable: ΔRP_t)

Variabels	Coefficients	t Statistics	Diognostic statistics	Values
Constant	997.66^{ns}	1.60	F	98.46***
ΔWP_t	0.93***	18.50	*Adjusted* R^2	0.85
ΔRP_{t-1}	0.23*	1.69	*Durbin-Watson*	2.08
ΔWP_{t-1}	-0.31**	-2.31	*AIC*	19.87
EC_{t-1}	-0.17**	-1.98	SC	20.03
			HQ	19.93

ns: indicates not significant,*: indicates significance at the 10 percent level, **: indicates significance at the 5 percent level, ***: indicates significance at the 1 percent level.

Source: Research data and author's calculations.

Table 9. Results of threshold autoregressive (TAR) model (dependent variable ΔRP_t)

Variabels	Coefficients	t Statistics	Diognostic statistics	Values
$\rho_{1,1}$	-0.009^{ns}	-0.11	*Adjusted* R^2	0.86
$\rho_{2,1}$	-0.44***	-3.02	*Durbin-Watson*	1.78
ΔWP_t	0.92***	18.44	*AIC*	19.87
ΔWP_{t-1}	-0.011**	-2.16	*SBC*	20.03
ΔWP_{t-2}	-0.09**	-1.83	HQC	19.93
Hypothesis test:		Standard Error:	t Statistics	2.53**
$\rho_{1,1} = \rho_{2,1}$	0.43	0.17	F Statistics	6.39**
			χ^2 Statistics	6.39**

ns: indicates not significant,*, **, *** indicating significance at the 10, 5, and 1 percent level, respectively.

Source: Research data and author's calculations.

Table 10. Results of momentum threshold autoregression (M-TAR) model (dependent variable ΔRP_t)

Variabels	Coefficients	t Statistics	Diognostic statistics	Values
$\rho_{1,1}$	0.39**	2.98	*Adjusted* R^2	0.86
$\rho_{2,1}$	-0.11^{ns}	-0.69	*Durbin-Watson*	2.07
			AIC	19.84
ΔWP_t	0.85***	17.29	*SBC*	19.94
			HQC	19.88
Hypothesis test:		Standard Error:	t Statistics	2.35**
$\rho_{1,1} = \rho_{2,1}$	0.50	0.21	F Statistics	5.53**
			χ^2 Statistics	5.53**

ns: indicates not significant, *, **, *** indicating significance at the 10, 5, and 1 percent level, respectively.

Source: Research data and author's calculations.

The Fars province boasts a substantial egg production capacity of 48.4 thousand tons and holds a significant position in the Iranian egg production cycle. Eggs constitute a fundamental component in the food basket for people in the Fars province and across Iran. This study explored price fluctuations, market structure, and price transmission within the egg market. The results indicated an increasing trend of the average monthly prices of wholesale, retail, and retail marketing margin for eggs during the examined period (April 2016 to December 2021), surpassing the average inflation rate. Thus, the policy of providing subsidized currency for importing corn and soybean meal, which is aimed at keeping egg prices affordable for consumers, has not yielded the desired effectiveness. Moreover, government intervention in this commodity market has taken the form of input subsidies and has heightened price fluctuations. Governmental attempts to establish a foundation for consumer support have adversely affected consumers due to increased price fluctuations. Therefore, we recommended minimizing such governmental interventions in the market.

Due to the higher egg consumption in the second half of the year compared to the first half, which affects price increases, the average monthly wholesale and retail prices consistently peak during the latter part of the year. Therefore, supporting investments in egg conversion and processing industries to utilize surplus eggs from the first half of the year in the latter half could effectively mitigate price fluctuations, achieve price transmission symmetry, enhance producer income, and reduce consumer expenses. It is important to note that advocating for government involvement in the market is not the intent or recommendation; rather, evaluating and facilitating private sector participation is encouraged.

The structure of pullet breeding and wholesale markets in Fars province is characterized by multilateral monopoly and monopolistic competition, respectively. Price transmission from wholesale to retail is asymmetric. It is important to note that continuous economic instabilities can create a context favoring asymmetric transmission in the egg market, inhibiting the possibility of utilizing long-run symmetric transmission. In other words, as long as the long-run trend of the economy remains unstable, achieving symmetric transmission and its effectiveness will be difficult. Consequently, due to the non-competitive structure of the market and asymmetric price transmission, egg producers pay more than the cost price, i.e., the total amount of money it costs a firm to produce a given product for pullets and marketing services. Consumers also bear higher costs than the production and marketing services costs. Thus, enhancing the competitiveness of these markets could lead to the provision of pullets at a lower cost, reducing production costs, wholesale and retail prices, and retail marketing margin. These measures could achieve symmetrized price transmission and improve benefits for both producers and consumers. However, given the considerable investment required for these improvements and their high opportunity cost, a specific degree of monopoly may be unavoidable in the current conditions of the Iranian economy. It is anticipated, with greater economic stability, that a portion of this natural monopoly will diminish, ultimately enhancing market efficiency.

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CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Conceptualization, Roham Rahmani; methodology, Roham Rahmani; software, Roham Rahmani; validation, Roham Rahmani; formal analysis, Roham Rahmani; investigation, Roham Rahmani; resources, Roham Rahmani; data curation, Roham Rahmani; writing—original draft preparation, Roham Rahmani; writing—review and editing, Roham Rahmani; visualization, Roham Rahmani; supervision, Roham Rahmani; project administration, Roham Rahmani; funding acquisition, Roham Rahmani.

DECLARATION OF COMPETING INTEREST

The authors declare no conflicts of interest.

ETHICAL STATEMENT

None.

DATA AVAILABILITY

All relevant data will be made available from the author on request.

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