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The Asymmetric Vertical Price Volatility Spillover in the Citrus Market

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Abstract
The current study aims to elicit the vertical price uncertainty spillover between producer and wholesaler or trader prices in the citrus market, which has important implications for citrus producers, wholesalers, and consumers in terms of food security and affordability in the world in general and in Turkey in particular. In this study, daily data for the period between January 2009 and May 2020 were analyzed using the asymmetric VAR (1)-BEKK GARCH-M (1,1) method. The sample of this study was composed of local producer stock market prices and wholesale or trader stock market prices in Turkey, which may differ from the findings obtained from studies conducted in other countries due to the differentiation of country dynamics. All applied statistical tests confirm the chosen model and there is also Granger causality from producer prices to wholesale prices or vice versa. Uncertainty in producer prices for each citrus product leads to propagation risks in wholesale prices or vice versa, especially for lemon, which is on the table in all seasons, compared to other citrus products. We also found that uncertainties arising from the producer and wholesale market reduce citrus returns, indicating persistent uncertainties of risks such as alienating producers from production and consumers paying high prices.

Keywords Citrus · Uncertainty · Vertical price · GARCH · BEKK

Introduction

Citrus fruits are an important product group subject to production, consumption, industry, and trade in the world and Turkey, and their contribution to both the agricultural sector and the national economy is quite significant. While Brazil ranks first in world orange and tangerine exports with approximately 10 million 600 thousand tons, Spain comes second with approximately 3 million 500 thousand tons. Turkey ranks seventh with 1 million 100 thousand tons (FAO 2018). Similarly, Mexico ranks first in exports by meeting 21.80% of the world's lemon exports, while Turkey ranks fourth with an export share of 10.55%. Turkey achieved \$330 million in export revenue in return for 627 thousand tons of lemon exports in 2018 (TUIK 2018). In addition, while the Netherlands ranks first in exports by meeting 13.95% of the world's grapefruit exports, Turkey ranks sixth with an export share of 6.50% (FAO 2018).

Citrus is a critical export item in Turkey as it has an important economic value in the foreign trade balance of the country. For example, Turkey's citrus export in 2018 was approximately 2 million tons (approximately \$894 million) (TUIK 2018). Although there has been an increase of 18% in the amount of world citrus production in the last 10 years, Turkey achieved an increase of 30% during the same period, which is well above the world average (Uysal and Polatöz 2017), giving the country a significant role in international citrus markets. In 2018, Turkey became a major global citrus exporter, ranking in the top ten of all citrus varieties.

When the producer prices of the countries that have a say in citrus production and export in 2018 are examined, the orange producer prices of Mexico, Turkey, Spain, and Iran were \$ 111.70/ton, \$ 162.40/ton, \$ 273.80/ton, and

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$ 353.40/ton, respectively (FAO 2018). Producer prices for tangerines in Mexico, Turkey, Spain, Iran, and Japan were $ 140.90/ton, $ 169.20/ton, $ 309.00/ton, $ 501.00/ton, and $ 2659.80/ton, respectively (FAO 2018). Producer prices for lemons in Mexico, Turkey, South Africa, Spain, and Iran were $ 284.60/ton, $ 292.60/ton, $ 505.90/ton, $ 595.50/ton, and $ 2096.20/ton, respectively (FAO 2018). Producer prices for grapefruits in leading producers such as Mexico, Turkey, South Africa, Spain, and Vietnam were $ 148.60/ton, $ 183.80/ton, $ 396.20/ton, $ 275.10/ton, and $ 879.40/ton, respectively (FAO 2018). Although Turkey's producer prices are lower for oranges, tangerines, lemons, and grapefruit, Spain is expected to have an advantage over Turkey due to its membership in the EU, an important market, and the "single market" principle.

While the average consumer prices of oranges, lemons, and tangerines in Turkey were 1.09 Turkish Lira (₤), 1.87 ₤, and 0.83 ₤, respectively in 2009, they were 3.14 ₤, 6.34 ₤, and 1.73 ₤, respectively, in 2019 (TUIK 2020). There has been significant volatility in citrus prices in Turkey in recent years. The high volatility of citrus has been reflected in the fluctuating prices of oranges, tangerines, and lemons over the years. The reason for distinct price increases in citrus prices is due to different supply and demand structures. Orange exports, which were approximately 272 thousand tons in 2009, were 331 thousand tons in 2015 and 450 thousand tons in 2018, which was a record export amount. Demand increases, both domestic and foreign, pushed orange prices upwards. However, the difference in the rates of increase in the prices of oranges, lemons, and tangerines can also be due to factors such as production and consumption varying by years, the change in weather conditions, as well as how export figures are affected by political relations with Russia, where most citrus fruits are exported (BBC 2017). For example, although lemon production increased by 13% in 2016 compared to the previous year, the amount of exported lemons decreased by 4.62% in tons compared to the previous year (COMTRADE 2022). The other reason for the different price hikes can be expressed as the change in consumption of lemon, orange, tangerine, and grapefruit per capita over the years. While lemon consumption per capita increased by approximately 56% from 2009 to 2019, the increase in tangerine remained at 3.03%; and while an increase of 35.04% was observed in grapefruit, it is noteworthy that the rate of orange consumption decreased by 16% (TUIK 2022b; USDA 2022).[1]

Volatility in agricultural product prices due to economic and non-economic reasons in the world causes volatility in the prices of food products. The recent volatility surges in food prices have affected all actors in the agricultural value chain, from the agricultural production chain to wholesalers and consumers (Ait Sidhoum and Serra 2016). Although the economics literature has extensively explored how the food price chain is transmitted along the food marketing chain for many different food products, geographies, and periods, price volatility transmission has been largely ignored. As a result, little is known about how to price instabilities are transmitted along the food chain (Ait Sidhoum and Serra 2016). Considering the above-mentioned statistical data, price changes in the citrus market draw the attention of researchers. In this context, the lack of studies dealing with producer and wholesale price volatility in the orange, tangerine, lemon, and grapefruit markets in Turkey and the world further increases the importance of studies in this area. This study aims to determine the transmission (or transition dynamics) of price uncertainties between citrus producers and wholesalers, which is one of the main components of the food supply chain, with its direction and effects. For this reason, in this study, the transmission of uncertainty in producer and wholesale prices for four products (orange, tangerine, lemon, and grapefruit) in the Turkish citrus market has been examined, and preliminary information has been reached about how consumer prices, which is the final stage, will be formed with these uncertainties. Knowing price uncertainties serves as a roadmap for the producer to make dynamic investment decisions for the future and to establish food security while guiding the consumer to reach affordable and reliable food as much as their monetary budget allows.

This study consists of five chapters including the introduction. The second section summarizes the studies on price volatility, and the third section introduces the empirical methods and data sets to be applied to citrus price variables. While empirical results are reported in the fourth section, findings and policy recommendations regarding the originality of the study are presented in the last section.

Motivation and Literature Review

Price changes in food products have often been the subject of investigation in the literature. In particular, the answer to the question of the determinants of the downward and upward swings in food prices is constantly being examined by researchers. This is important because the weight of food products in the inflation basket is quite high, particularly in emerging and less developed countries. For instance, for Turkey in general, this figure is 22.77% for 2020 (TUIK 2020). In this context, determining the price dynamics of food products is crucially important for controlling inflation, especially food security. In recent years,

[1] In 2009, per capita consumption of lemon, orange, tangerine, and grapefruit was 3.99 kilogram (kg), 19.41 kg, 7.16 kg, and 0.57 kg, respectively. In 2019, realizations per person appear as 6.25 kg, 16.19 kg, 7.38 kg, and 0.78 kg, respectively.

researchers have emphasized that the causality of food price volatility is due to uncertainties in input prices (Abdelradi and Serra 2016; Chadwick and Bastan 2017; Chen et al. 2010; Gardebroek and Hernandez 2013; López Cabrera and Schulz 2016; Pala 2013).

Another reason for uncertainties in food prices can be expressed as disruptions in the food supply chain. For example, in Turkey, high price increases are observed until the food products reach the consumers from the producers. In 2019, the average producer price of orange was 1.05 ₺/kilogram (kg) while the average consumer price was 3.14 ₺/kg; the producer price of lemon was 1.65 ₺/kg while the consumer price was 6.34 ₺/kg; and the producer price of tangerine was 0.94 ₺/kg while the consumer price was 1.73 ₺/kg (TUIK 2020). In this context, as food products reach the consumer from the producer, a variety of costs are added to the consumer price, creating asymmetric relationships between producer and consumer prices. When the relevant literature is examined, the primary reason for this asymmetric relationship is the transportation costs arising from the spatial distribution (difference) put forwarded by Benson and Faminow (1985), as well as the presence of many intermediaries between the producer and the end consumer, resulting in a high marketing margin. As such, the costs of food products that are spatially transported from one region to another or exchanged among many intermediaries are reflected in consumer prices by wholesalers.

On the other hand, another factor affecting the pass-through from producer prices to wholesaler prices is price elasticity. Due to the low-price elasticity of agricultural products in contrast to unperishable goods, we can outline that there are asymmetrical relations between producer and wholesaler prices. Ward (1982) argued that manufacturers selling perishable goods cannot increase prices. Finally, another factor triggering the transmission of uncertainty between producer and wholesaler prices is the behavior of speculators. Speculators cause an increase in uncertainty by disrupting the price relations between producers and wholesalers, thus increasing the stickiness of inflation by applying upward pressure on consumer prices. Headey and Fan (2008) argued that speculative movements in agricultural products created uncertainties in spot prices.

There are a bulk of studies in the literature examining the relationship between producer, wholesaler, and consumer prices for food products (Ait Sidhoum and Serra 2016; Ben-Kaabia and Gil 2007; Ferrer-Pérez and Gracia-de-Rentería 2020; Gervais 2011; Goodwin and Harper 2000; Jurkėnaitė and Paparas 2019; Lass 2005; Serra and Goodwin 2003). Since most of these studies were conducted for the red meat market, there are limited studies on the fruit market in the literature. Assefa et al. (2015) conducted an extensive literature review on vertical price volatility pass-through in agricultural products and emphasized that there is volatility pass-through between producer, wholesaler, and consumer prices. On the other hand, studies in the literature generally empirically test the asymmetrical relationships between producer prices and consumer prices (Ait Sidhoum and Serra 2016; Serra and Goodwin 2003). However, there are limited studies examining producer, wholesaler, and consumer prices for orange, lemon, tangerine, and grapefruit products (citrus fruits). For example, in comparative studies on imported fruit and vegetable products following the European Union entry price system (EPS), Goetz and Grethe (2009) found that citrus products were less important in the EPS system. In another study, Götz et al. (2014) obtained some empirical findings on asymmetric price pass-through in export citrus products in Israel.

Naseer et al. (2019) found that the modern marketing channels of producers increased profit with 300 citrus producers in Pakistan, while Hassan and Simioni (2004) investigated the retail and transportation of agricultural products, namely wholesale prices, using the threshold value cointegration method, and elicited the existence of asymmetrical relations between the wholesaler and retail prices. Ait Sidhoum and Serra (2016) using the BEKK-GARCH method, found evidence of a volatility pass-through between producer, wholesaler, and consumer prices for the tomato market. Jurkėnaitė and Paparas (2019) suggested that there is an asymmetric pass-through between producer and retail prices of tomato and cucumber products, as well as empirical findings showing that producer and retail prices of tomato and cucumber products are cointegrated in the long run. Similar findings are also seen in the research by Girapunthong et al. (2003) and Munyeka (2014). Bakucs et al. (2007) revealed that there are asymmetrical pass-through effects between producer, wholesaler, and consumer prices on vegetables in Hungary. The uncertainty pass-throughs between agricultural inputs-outputs and retail prices were analyzed by Apergis and Rezitis (2003) using analysis of variance (GARCH). According to their findings, the uncertainties that occurred in retail prices increased the uncertainty in the output prices of agricultural products. Another similar study was conducted by Rezitis and Stavropoulos (2011) on the volatility pass-through between producer and consumer prices in the poultry sector, emphasizing that there is asymmetric volatility pass-through between producer and consumer prices. On the other hand, Ahmed (2018) elicited that there was a positive relationship between producer, wholesaler, and retail prices for the tomato market after the Arab Spring. In their studies, Abdallah et al. (2020), Dong et al. (2018), Mai et al. (2018), Pozo et al. (2020), and Rezitis (2019) reached empirical findings on vertical price pass-through in agricultural products.

As the above literature review shows, while many studies find vertical price pass-through in other agricultural products (beef and lamb, tomato, milk, and dairy products) within the scope of first and second-moment analyses for agricultural products in various countries, there are hardly any studies investigating price pass-through on vertical price transmission in the supply chain of citrus products in the context of the second-moment. In this context, the present study is expected to fill just such a major gap in the international and national literature. In particular, the use of the Vector Autoregressive (VAR)-Generalized Multivariate Autoregressive Conditional Heteroscedasticity of Baba, Engle, Kraft, and Kroner method (hereafter, VAR-GARCH-BEKK-M), which allows both first and second-moment analysis, strengthens the findings of the current study. With these aspects, the study is a valuable addition to the literature.

The Econometric Model

In this study, the relationship between producer and wholesale prices (lemon, tangerine, orange, grapefruit)[2] were introduced into the mean equation outlined below. The mean equation applies the VAR (1)—BEKK GARCH-M (1,1) method, pioneered by Engle and Kroner (1995), for estimating the returns of the two variables (Arouri et al. 2011, 2012; Gardebroek and Hernandez 2013; Hasanov et al. 2016; Ling and McAleer 2003; Mensi et al. 2013, 2014). The mean equation used in this study is:

$$R_{i,t} = \mu_i + \sum_{j=1}^{p} \Phi_{i,j} R_{i,t-1} + \sum_{i=1}^{2} \Psi_i \sqrt{h_{i,t-1}} + \varepsilon_{i,t-1}, \quad \text{where } i = 1, ..., 2 \text{and} \varepsilon_{i,t-1} = H_{i,t-1}^{1/2} \eta_{i,t-1}, \tag{1}$$

where $R_{i,t} = \left[R_{i,t}^{pr}\, R_{i,t}^{w}\right]'$ (e.g., where superscript *pr* and *w* stand for producer and wholesale, respectively) shows the return for producers and wholesalers for each four citrus products in question[3] and Φ_i represents the estimated parameters of the lagged return series in each $R_{i,t-1}$ mean equation by a 2×2 matrix dimension. Ψi represents the effect of the lagged time-varying conditional variance of the return on its return with the 2×2 matrix size in each mean return equation. While $\mu_i = [\mu_{i,1}, \mu_{i,2}]'$ shows a vector of constant coefficients in each citrus return mean equation, $\eta_{i,t-1} = \left[\eta_{i,t-1}^{p}\, \eta_{i,t-1}^{w}\right]'$ is a vector of independently and identically distributed lagged random noises corresponding to each return variable in the mean equation. The H matrix is defined below.

The time-varying conditional variances of the above equations are estimated using VAR (1)-BEKK GARCH (1, 1). The algebraic presentation of VAR (1)-BEKK GARCH (1, 1) is:

$$H_{i,t} = C_i C'_i + A_{\prime i} \varepsilon_{t-1} \varepsilon'_{t-1} A'_i + B_i H_{t-1} B'_i + D_i \vartheta_{t-1} \vartheta'_{t-1} D'_i \tag{2}$$

where $H_{i,t}$ is a 2×2 matrix representing the time-varying conditional variance-covariance matrix, C_i is a 2×2 upper triangular constant coefficient matrix for an ith citrus product, and A, B, and D are each a 2×2 parameter matrix for each citrus product. The matrices A, B, and D show the estimators expressing the impacts of short-term shocks and long-term volatilities and asymmetry, respectively. The matrix form of Eq. 2 can be further displayed as:

$$H_{i,t} = C_i C'_i + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \varepsilon_{i,t-1} \varepsilon'_{i,t-1} \begin{bmatrix} a_{11} & a_{21} \\ a_{12} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} H_{i,t-1} \begin{bmatrix} b_{11} & b_{21} \\ b_{12} & b_{22} \end{bmatrix} + \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix} \vartheta_{i,t-1} \vartheta'_{i,t-1} \begin{bmatrix} d_{11} & d_{21} \\ d_{12} & d_{22} \end{bmatrix} \tag{3}$$

When we suppress the superscript i for each citrus product, the analytical forms of the time-varying conditional variances of each return equation in Eq. 3 are:

$$\begin{aligned} h_{jj,t} = & c^*_{jj} + \left(a_{j1}^2 \varepsilon_{1,t-1}^2 + 2a_{j1} a_{j2} \varepsilon_{2,t-1} \varepsilon_{1,t-1}\right) \\ & + \left(a_{j2}^2 \varepsilon_{2,t-1}^2\right) + \left(b_{j1}^2 h_{11,t-1} + 2b_{j1} b_{j2} h_{21,t-1}\right) \\ & + \left(b_{j2}^2 h_{22,t-1}\right) \\ & + \left(d_{j1}^2 \vartheta_{1,t-1}^2 + 2d_{j1} d_{j2} \vartheta_{2,t-1} \vartheta_{1,t-1}\right) \\ & + \left(d_{j2}^2 \vartheta_{2,t-1}^2\right) \quad , j = 1,2 \end{aligned} \tag{4}$$

Since Eq. 4 is nonlinear, it is differentiated to each variable (e.g., ε, *h*, and ϑ) in the model to obtain the marginal effects for each citrus product in question. The delta method is used to obtain standard errors. The estimation of the VAR (1)-BEKK GARCH (1, 1) model is estimated using the quasi-maximum likelihood (QML) method, assuming the conditional distribution of a joint Gaussian log-likelihood function with t-distribution for observations *t* and four variables in question. The log-likelihood function with normal distribution then takes the following form:

$$\log\text{–}L = -0.5x \sum_{t=1}^{T} \left[k \log(2\pi) + \ln |H_{i,t}| + \varepsilon'_{i,t} H_{i,t}^{-1} \varepsilon_{i,t}\right] \tag{5}$$

[2] The data employed in the present study refer to the orange species as Washington, the Grapefruit species as Starruby, the Tangerine species as Satsuma, and the Lemon species as Interdonat.

[3] Each commodity's return is computed as $R_{i,t} = 100 * \ln\left(\frac{P_{i,t}}{P_{i,t-1}}\right)$, where P stands the producer and wholesaler real price series for a citrus product in question (e.g., lemon, tangerine, orange, and grapefruit).

We obtain robust parameters by maximizing the above log-L function using Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm.

Data and Preliminary Analysis

Citrus[4] prices were obtained from the Adana Commodity Exchange database. Daily data for the period between January 2009 and May 2020 were used to examine the volatility between the series. In the analyzed period, there were 658 data points for lemons, 644 for tangerines, 703 for oranges, and 698 for grapefruit. The reason for the differences in the data is determined by whether there was a trade between buyers and sellers in the local stock market during the period under review. If more than one transaction occurred between buyers and sellers in a day, the data were obtained by taking the average price of that day. The observation values of the citrus number are more than 500, which is suitable for the GARCH model (Hwang and Pereira 2006). A selection of descriptive statistics of price and return series are given in Table 1.

According to Table 1, the highest return was obtained in wholesale prices in the lemon, tangerine, and grapefruit markets, while producer pricing saw the highest return in the orange market. In addition, when the unconditional variances of the citrus markets obtained from the returns of the producer and wholesale prices were examined, it was seen that the returns of the producer prices had higher volatility than the returns of the wholesale prices. The fact that the wholesale or trader prices of all food products are less volatile than the producer prices can be attributed to the limited flexibility of these foods by developing a special sales strategy in which they are less durable than other agricultural products. In addition, the fact that the number of wholesalers or traders is very low compared to the citrus producers or that they have an oligopoly structure among themselves may be the factors limiting price volatility. In addition, transactions made in the stock market do not increase product prices when food prices increase, and they do not decrease when agricultural product prices decrease (Alexandri 2011). On the other hand, the involvement of supermarkets or hypermarkets in stock market transactions limits the number of intermediaries and consequently limits price volatility across themselves. Also, such price hikes may be due to fluctuations in the product supply depending on weather conditions as well as the changes in the prices of the inputs used in the production of agricultural products. The skewness coefficients of the return series have an asymmetrical distribution. The kurtosis coefficient reveals that the series exhibit a leptokurtic (fat-tail) distribution. The leptokurtic distribution of the return series indicates that the series may exhibit an ARCH effect. Jarque-Bera statistics show that the other return series are not normally distributed except for orange and grapefruit markets. Ljung–Box statistics, which show whether the return series have autocorrelation or not, show the presence of autocorrelation in the producer and wholesale price return series

Table 1 Descriptive statistics

Statistics	Producer-lemon	Wholesale-lemon	Producer-tangerine	Wholesale-tangerine	Producer-orange	Wholesale-orange	Producer-grapefruit	Wholesale-grapefruit
Mean	0.223	0.267	0.243	0.252	0.193	0.115	0.107	0.134
Std. Dev	42.466	37.262	46.470	43.529	48.305	44.598	44.884	43.762
Skewness	0.069	0.190	–0.038	0.001	–0.018	–0.096	0.321	0.003
Kurtosis	3.650	2.437	0.776	4.465	0.572	0.169	1.573	0.378
Jarque-Bera	365.428***	166.620***	16.339***	535.006***	9.630***	1.933	83.935***	4.166
Q (6)	164.499***	167.244***	173.786***	148.263***	158.809***	180.352***	194.890***	184.463***
LM-Arch (6)	21.917***	27.560***	15.712***	26.066***	12.757***	11.270***	18.481***	15.687***
ADF	–30.225***	–29.666***	–31.745***	–27.914***	–32.672***	–30.130***	–33.043***	–31.810***
KPSS	0.003	0.005	0.003	0.003	0.002	0.002	0.002	0.002
Correlation:								
Producer	1.000	–	1.000	–	1.000	–	1.000	–
Wholesale	0.326	1.000	0.399	1.000	0.345	1.000	0.392	1.000

LM-ARCH and ADF, and KPSS stand for Lagrange Multiplier ARCH test, Augmented Dickey-Fuller unit root test, and Kwiatkowski, Phillips, Schmidt and Shin unit root test, respectively. Q is statistics of Ljung–Box for the null hypothesis of no autocorrelation for a series. The LM-statistic tests a set of series for multivariate ARCH effects

*, **, and *** are statistically significant at 10%, 5%, and 1%, respectively

[4] Citrus data used in this study are freshly consumed fruits.

Table 2 VAR, GARCH-in-mean, asymmetric BEKK model

Estimate	Producer-lemon	Wholesale-lemon	Producer-tangerine	Wholesale-tangerine	Producer-orange	Wholesale-orange	Wholesale-grapefruit	Wholesale-grapefruit
Conditional mean equation								
Constant (μ)	–7.335 (6.078)	**–10.908** **(5.414)**	**–48.951***** **(16.550)**	9.384 (16.244)	**–49.687***** **(15.456)**	**–59.443***** **(7.595)**	**33.178**** **(16.258)**	**–39.549***** **(9.914)**
$\Gamma_{i1,t-1}$	**–0.792***** **(0.043)**	0.039 (0.037)	**–0.796***** **(0.042)**	–0.053 (0.039)	**–0.891***** **(0.039)**	0.044 (0.038)	**–0.827***** **(0.043)**	–0.014 (0.036)
$\Gamma_{i1,t-2}$	**–0.546***** **(0.052)**	0.044 (0.046)	**–0.580***** **(0.050)**	0.040 (0.045)	**–0.789***** **(0.054)**	0.033 (0.052)	**–0.628***** **(0.053)**	0.037 (0.044)
$\Gamma_{i1,t-3}$	**–0.353***** **(0.056)**	0.076 (0.047)	**–0.363***** **(0.049)**	0.014 (0.045)	**–0.610***** **(0.061)**	0.007 (0.058)	**–0.455***** **(0.059)**	–0.056 (0.054)
$\Gamma_{i1,t-4}$	**–0.235***** **(0.055)**	**0.122***** **(0.042)**	**–0.196***** **(0.039)**	**0.058*** **(0.036)**	**–0.362***** **(0.061)**	0.064 (0.057)	**–0.370***** **(0.054)**	**–0.097*** **(0.054)**
$\Gamma_{i1,t-5}$	**–0.128**** **(0.051)**	**0.102**** **(0.040)**	–	–	**–0.176***** **(0.053)**	**0.095**** **(0.049)**	**–0.222***** **(0.049)**	**–0.083*** **(0.050)**
$\Gamma_{i1,t-6}$	–0.026 (0.037)	**0.065**** **(0.032)**	–	–	**–0.093**** **(0.039)**	**0.066**** **(0.036)**	**–0.091***** **(0.038)**	–0.049 (0.039)
$\Gamma_{i2,t-1}$	–0.026 (0.060)	**–0.834***** **(0.044)**	–0.002 (0.050)	**–0.650***** **(0.044)**	0.055 (0.049)	**–0.843***** **(0.047)**	–0.013 (0.039)	**–0.863***** **(0.037)**
$\Gamma_{i2,t-2}$	–0.077 (0.077)	**–0.634***** **(0.068)**	0.025 (0.051)	**–0.502***** **(0.044)**	0.052 (0.066)	**–0.656***** **(0.061)**	–0.003 (0.052)	**–0.716***** **(0.047)**
$\Gamma_{i2,t-3}$	–0.043 (0.078)	**–0.518***** **(0.065)**	–0.007 (0.049)	**–0.432***** **(0.044)**	–0.003 (0.071)	**–0.544***** **(0.065)**	0.011 (0.056)	**–0.552***** **(0.051)**
$\Gamma_{i2,t-4}$	–0.051 (0.071)	**–0.370***** **(0.051)**	–0.005 (0.042)	**–0.226***** **(0.036)**	0.005 (0.069)	**–0.415***** **(0.063)**	0.064 (0.056)	**–0.420***** **(0.053)**
$\Gamma_{i2,t-5}$	–0.038 (0.066)	**–0.191***** **(0.046)**	–	–	0.028 (0.060)	**–0.284***** **(0.055)**	0.048 (0.049)	**–0.293***** **(0.048)**
$\Gamma_{i2,t-6}$	–0.062 (0.046)	**–0.114***** **(0.036)**	–	–	0.056 (0.041)	**–0.131***** **(0.039)**	0.024 (0.038)	**–0.175***** **(0.036)**
Ψ_{i1}	–0.230 (0.333)	**0.649**** **(0.292)**	**3.283***** **(0.953)**	0.371 (0.779)	**4.068***** **(0.657)**	**4.563***** **(0.322)**	**2.301***** **(0.311)**	**–0.449**** **(0.219)**
Ψ_{i2}	**0.584**** **(0.274)**	–0.328 (0.262)	**–1.912**** **(0.950)**	–0.650 (0.518)	**–2.920***** **(0.542)**	**–3.167***** **(0.365)**	**–3.337***** **(0.272)**	**1.696***** **(0.302)**
Conditional variance equation								
c_{1i}	**14.747***** **(2.491)**	–	4.087 (3.290)	–	**11.359***** **(1.619)**	–	–2.130 (3.931)	–
c_{2i}	**10.603***** **(2.820)**	–0.0002 (7.219)	–12.492 (16.057)	**20.056*** **(12.539)**	**11.910***** **(2.508)**	0.004 (10.749)	**–14.263***** **(1.423)**	**6.522***** **(2.568)**
a_{1i}	**–0.169***** **(0.052)**	0.075 (0.100)	–0.014 (0.054)	0.017 (0.080)	**–0.090***** **(0.027)**	–0.044 (0.035)	**0.219***** **(0.053)**	**0.212***** **(0.035)**
a_{2i}	0.216 (0.167)	**0.381***** **(0.119)**	**0.240***** **(0.066)**	**0.393***** **(0.111)**	0.012 (0.045)	**0.197***** **(0.046)**	**–0.141***** **(0.038)**	–0.031 (0.029)
b_{1i}	**0.470***** **(0.060)**	**–0.525***** **(0.045)**	**1.023***** **(0.026)**	**0.285***** **(0.069)**	**0.882***** **(0.024)**	**–0.184***** **(0.024)**	**0.994***** **(0.013)**	**0.111**** **(0.045)**
b_{2i}	**0.576***** **(0.072)**	**0.780***** **(0.063)**	**–0.257***** **(0.101)**	**0.417***** **(0.154)**	**0.123***** **(0.028)**	**0.959***** **(0.035)**	**–0.125***** **(0.044)**	**0.792***** **(0.055)**
d_{1i}	–0.045 (0.066)	**–0.381***** **(0.080)**	**0.286***** **(0.061)**	**0.228**** **(0.121)**	**0.064**** **(0.032)**	0.049 (0.047)	**0.300***** **(0.053)**	–0.039 (0.070)
d_{2i}	**0.596***** **(0.102)**	**0.502***** **(0.148)**	–0.120 (0.083)	**–0.290**** **(0.144)**	**0.188***** **(0.042)**	**0.197***** **(0.069)**	0.036 (0.059)	**0.171***** **(0.048)**
Diagnostic tests								
Q (6)	**19.005** **[0.004]**	**18.331** **[0.005]**	12.993 [0.043]	33.095 [0.000]	11.750 [0.067]	11.804 [0.066]	5.282 [0.508]	11.505 [0.074]
Q (12)	**26.472** **[0.009]**	**24.032** **[0.020]**	17.480 [0.132]	43.385 [0.000]	27.264 [0.007]	17.639 [0.127]	11.013 [0.527]	33.527 [0.000]

Table 2 (Continued)

Estimate	Producer-lemon	Wholesale-lemon	Producer-tangerine	Wholesale-tangerine	Producer-orange	Wholesale-orange	Wholesale-grapefruit	Wholesale-grapefruit
McLeod-Li (6)	2.758 [0.838]	3.669 [0.721]	7.802 [0.252]	7.601 [0.268]	9.256 [0.159]	5.200 [0.518]	5.995 [0.423]	2.382 [0.881]
McLeod-Li (12)	4.306 [0.977]	9.138 [0.691]	11.711 [0.469]	10.724 [0.552]	20.730 [0.054]	10.088 [0.608]	12.054 [0.441]	6.869 [0.866]
ARCH (6)	0.458 [0.839]	0.608 [0.723]	1.264 [0.271]	1.251 [0.278]	1.571 [0.152]	0.875 [0.512]	0.981 [0.437]	0.371 [0897]
ARCH (12)	0.345 [0.980]	0.721 [0.731]	0.921 [0.525]	0.842 [0.607]	1.610 [0.084]	0.661 [0.789]	0.952 [0.494]	0.511 [0908]
MV Q-statistic (6)	45.241 [0.005]		48.424 [0.002]		27.361 [0.287]		18.774 [0.763]	
MV Q-statistic (12)	65.743 [0.045]		80.980 [0.002]		52.560 [0.301]		56.510 [0.186]	
MV Q^2-statistic (6)	9.869 [0.995]		25.403 [0.384]		31.782 [0.132]		14.501 [0.934]	
MV Q^2-statistic (12)	25.835 [0.996]		39.907 [0.790]		59.302 [0.127]		36.916 [0.877]	
MV ARCH-statistic (6)	30.270 [0.996]		62.300 [0.204]		56.090 [0.396]		44.820 [0.808]	
MV ARCH-statistic (12)	75.960 [0.991]		97.710 [0.751]		119.700 [0.207]		99.590 [0.706]	
MV $ARCH^2$-statistic (6)	4.580 [1.000]		66.930 [0.112]		46.090 [0.769]		7.340 [1.000]	
MV $ARCH^2$-statistic (12)	13.040 [1.000]		114.010 [0.327]		109.100 [0.452]		34.920 [1.000]	
Hypotheses testing								
Causality tests for return of producer and wholesale prices	4.083 [0.665] W → Pr 9.667 [0.139] Pr → W		0.837 [0.933] W → Pr 0.396 [0.051] Pr → W		5.059 [0.536] W → Pr 9.000 [0.173] Pr → W		2.820 [0.830] W → Pr 11.945 [0.063] Pr → W	
No GARCH (H_0: $a_{ij} = b_{ij} = d_{ij} = 0$ for all i, j = 1,2)	5561.445 [0.000]		13674.635 [0.000]		77772.494 [0.000]		56911.522 [0.000]	
No GARCH-M effect (H_0: $\Psi_{ij} = 0$, for all i, j = 1,2)	11.838 [0.018]		3608.264 [0.000]		6005.792 [0.000]		427.234 [0.000]	
No asymmetry (H_0: $d_{ij} = 0$ for all i, j = 1,2)	83.349 [0.000]		50.211 [0.000]		84. 707 [0.000]		81.839 [0.000]	
Diagonal GARCH (H_0: All off-diagonal elements of A, B, and D are jointly zero)	477.297 [0.000]		123.391 [0.000]		80. 555 [0.000]		76.717 [0.000]	

Q and Q^2 are statistics of Ljung–Box for the null hypothesis of no autocorrelation for a series in question on standardized and standardized squared residuals, respectively. MV Q-statistic and MV Q^2-statistic are Hosking's multivariate portmanteau Q-statistics on the standardized and standardized squared residuals, respectively, in diagnosing the null hypothesis of no autocorrelation in all series for lag one through specified lags. The LM-statistic tests a set of series for multivariate ARCH effects. Under the null hypothesis that the series are mean zero, not serially correlated with a fixed covariance matrix

W whosale, *Pr* producer price

*, **, and *** are statistically significant at 10%, 5%, and 1%, respectively

of all products. This illustrates that past behavior affects the price return series of agricultural products within the scope of the cobweb theorem. When examining the individual series for the ARCH effect, all products in the citrus market show great fluctuation (heteroscedasticity) in producer and wholesale price returns-squared series over time, which further indicates that the pass-through relationships between return series should be examined with the help of GARCH models that allow second-moment analysis.

Table 1 also illustrates the correlation coefficients between the producer and wholesale price return variables of the products in the citrus market. As seen in the table, the correlation coefficients obtained between producer and wholesale price returns are quite similar at 0.326, 0.399, 0.345, and 0.392 for lemon, tangerine, orange, and grapefruit, respectively. Finally, unit root tests proposed by Dickey and Fuller (1979) and Kwiatkowski et al. (1992) were applied to determine the stationarity status of the series, and the results are presented in Table 2. According to the ADF and KPSS unit root test, the return series was found to be stationary at the I (0) level with a 1% significance level. On the other hand, Akaike and Bayesian information criteria were used to determine the lag length in citrus prices, and the lag length was generally determined as one (1) in the series. From now on, the VAR notation will be VAR (1).

Results and Discussion

The usability of the mean equality of the Vector Error Correction Model (VECM) was tested in the study. However, since it was determined that the price series whose natural logarithm was taken were stationary at different levels, analyses were continued using the VAR (1)-GARCH-BEKK-M (1,1) method by taking the returns of the price series.

The results of the VAR (1)-GARCH-BEKK-M (1,1) model of volatility pass-throughs between the return series are also shown in Table 2. The Ljung–Box Q test was applied to each return series and the results showed no signs of autocorrelation in producer prices, except for the grapefruit market, with 6 lag lengths at 1%, 5%, and 10% significance levels. Furthermore, there was no autocorrelation concern in producer prices in tangerine and grapefruit markets and wholesale prices in the orange market with 12 lag lengths. On the other hand, by applying the McLeod-Li test to the residual-squared series, only the orange market encountered autocorrelation in the residual squares at the 12 lag length and 10% significance level, while the other residual square series did not show any autocorrelation signs at the 6 and 12 lags (Table 2), providing strong evidence for the use of the GARCH model.

The multivariate Hosking's portmanteau multivariate MV-Q statistical test results applied to standardized residual squares indicate unfortunately the presence of an autocorrelation problem in the series with lag lengths of 6 and 12 simultaneously in the lemon and tangerine markets, which is consistent with the previous Ljung-Box Q results for the lemon and tangerine markets. On the other hand, multivariate Hosking's portmanteau multivariate MV-Q2 statistical test applied to standardized residual squares determined that it was free of autocorrelation in series with lag lengths of 6 and 12 simultaneously. As a result of the LM test results applied to individual and simultaneous standardized residual and residual squares, it can be stated that the ARCH effect disappears as a result of the GARCH return model.

Table 2 also illustrates the causal relationships between the producer and wholesale prices of the products in the citrus market analyzed with the VAR model. One-way causality relationships were determined from producer prices to wholesale prices in tangerine and grapefruit markets by applying the Granger causality test. In their study, Reziti and Panagopoulos (2006) established a causality relationship between consumer prices to producer prices in the fruit market. Ait Sidhoum and Serra (2016) analyzed the tomato market and argued that there are bidirectional causality relationships between producer, retail, and consumer prices. In addition, within the framework of their analysis, Aguiar and Santana (2002) and Jurkėnaitė and Paparas (2019) determined that there is a causal relationship from producer prices to retail prices in the tomato market. In this context, the Granger causality test findings obtained for the tangerine and grapefruit markets are compatible with the relevant literature. When the marketing margin (consumer prices-producer prices) for orange, lemon, and tangerine products in Turkey, particularly between the years 2016–2022, is analyzed, it is noteworthy that there has been a negative marketing margin for oranges and lemons in recent months. On the other hand, the high marketing margin in tangerine (TUIK 2022a, c) explains the causality from producer prices to consumer prices. Since the elasticity of supply in agricultural products is very low or even close to zero, producers cannot react quickly to price hikes determined by supermarkets and/or hypermarkets, and therefore, there may not be causality from consumer prices to producer prices.

In Table 2, we have questioned the existence of Granger causality of some variables (e.g., the time-varying heteroscedasticity) in the mean return equations and conditional variance equations, as well as the existence of some constraints on the parameters of the conditional variances of the models for four citrus products in question. For example, no GARCH effects, no off-diagonal effects, and no asymmetric effects in GARCH were rejected using the Wald-test for all citrus products. These test results confirmed the appropriateness of the analysis covering all possible effects in the system and the existence of transmission of shock or permanent volatility spillovers, including asymmetric spreads from the opposite market, provided evidence for the relevant market (e.g., producer versus wholesaler). It also shows that the impact of negative news in the producer and wholesaler markets will be different from that of positive news, suggesting that industry stakeholders should be cautious against negative news. This is also important for the decision-makers to make interventionist decisions in the face of negative news that speculators may create in the markets, especially in terms of preventing high price hikes that will be reflected on the consumer. These results support the findings of Natcher and Weaver (1999), Apergis and Rezitis (2003), and Ait Sidhoum and Serra (2016). In addition, $H_o : \Psi_{ij} = 0$ i, j $= 1, 2.$, for each citrus product in the mean return equations, the effects of the volatility coefficients of the producer and wholesaler markets on the

Table 3 Marginal effects of variables in the conditional variance equation in the asymmetric GARCH-BEKK model

Producer-lemon	$h_{11,t} = 217.476*** + (0.028*\varepsilon^2_{1,t-1} - 0.073\varepsilon_{2,t-1}\varepsilon_{1,t-1}) + (0.047\varepsilon^2_{2,t-1}) + (0.221***h_{11,t-1} + 0.542***h_{21,t-1}) + (0.331***h_{22,t-1}) + (0.002\xi^2_{1,t-1} - 0.053\xi_{2,t-1}\xi_{1,t-1}) + (0.356***\xi^2_{2,t-1})$
Wholesale-lemon	$h_{22,t} = 112.434** + (0.005\varepsilon^2_{1,t-1} + 0.057\varepsilon_{2,t-1}\varepsilon_{1,t-1}) + (0.145*\varepsilon^2_{2,t-1}) + (0.275***h_{11,t-1} - 0.819***h_{21,t-1}) + (0.609***h_{22,t-1}) + (0.145**\xi^2_{1,t-1} - 0.382***\xi_{2,t-1}\xi_{1,t-1}) + (0.252*\xi^2_{2,t-1})$
Producer-tangerine	$h_{11,t} = 16.705 + (0.000\varepsilon^2_{1,t-1} - 0.006\varepsilon_{2,t-1}\varepsilon_{1,t-1}) + (0.057*\varepsilon^2_{2,t-1}) + (1.046***h_{11,t-1} - 0.526**h_{21,t-1}) + (0.066h_{22,t-1}) + (0.081**\xi^2_{1,t-1} - 0.068\xi_{2,t-1}\xi_{1,t-1}) + (0.014\xi^2_{2,t-1})$
Wholesale-tangerine	$h_{22,t} = 558.278*** + (0.000\varepsilon^2_{1,t-1} + 0.013\varepsilon_{2,t-1}\varepsilon_{1,t-1}) + (0.154*\varepsilon^2_{2,t-1}) + (0.081**h_{11,t-1} + 0.237***h_{21,t-1}) + (0.174h_{22,t-1}) + (0.052\xi^2_{1,t-1} - 0.132\xi_{2,t-1}\xi_{1,t-1}) + (0.084\xi^2_{2,t-1})$
Producer-orange	$h_{11,t} = 129.049*** + (0.008*\varepsilon^2_{1,t-1} - 0.002\varepsilon_{2,t-1}\varepsilon_{1,t-1}) + (0.000\varepsilon^2_{2,t-1}) + (0.779***h_{11,t-1} + 0.217***h_{21,t-1}) + (0.015**h_{22,t-1}) + (0.004\xi^2_{1,t-1} + 0.024***\xi_{2,t-1}\xi_{1,t-1}) + (0.035**\xi^2_{2,t-1})$
Wholesale-orange	$h_{22,t} = 141.868** + (0.001\varepsilon^2_{1,t-1} - 0.017\varepsilon_{2,t-1}\varepsilon_{1,t-1}) + (0.039**\varepsilon^2_{2,t-1}) + (0.034***h_{11,t-1} - 0.353***h_{21,t-1}) + (0.920***h_{22,t-1}) + (0.002\xi^2_{1,t-1} + 0.019\xi_{2,t-1}\xi_{1,t-1}) + (0.038\xi^2_{2,t-1})$
Producer-grapefruit	$h_{11,t} = 4.538 + (0.048**\varepsilon^2_{1,t-1} - 0.062**\varepsilon_{2,t-1}\varepsilon_{1,t-1}) + (0.020*\varepsilon^2_{2,t-1}) + (0.988***h_{11,t-1} - 0.249***h_{21,t-1}) + (0.015h_{22,t-1}) + (0.090***\xi^2_{1,t-1} + 0.022\xi_{2,t-1}\xi_{1,t-1}) + (0.001\xi^2_{2,t-1})$
Wholesale-grapefruit	$h_{22,t} = 245.994*** + (0.045***\varepsilon^2_{1,t-1} - 0.013\varepsilon_{2,t-1}\varepsilon_{1,t-1}) + (0.001\varepsilon^2_{2,t-1}) + (0.012h_{11,t-1} + 0.176***h_{21,t-1}) + (0.627***h_{22,t-1}) + (0.001\xi^2_{1,t-1} - 0.013\xi_{2,t-1}\xi_{1,t-1}) + (0.023*\xi^2_{2,t-1})$

*, **, and *** are statistically significant at 10%, 5%, and 1%, respectively

relevant market (e.g., the producer or wholesaler) were tested and the null hypothesis was rejected for all citrus markets. For this reason, time-independent volatility in producer and wholesaler price returns in all markets affects both producer and wholesaler returns. These results show that the directionless price movements in the Turkish citrus markets have great effects on the returns of both producers and wholesalers or traders, which, unfortunately, are expected to harm vital issues such as food security.

Looking at the mean equation parameters obtained from the VAR (1)-GARCH-BEKK-M (1,1) model, it is noteworthy that the coefficients of the producer and wholesale return volatilities (the time-varying heteroscedasticity) added to the equations are statistically significant in the citrus market in general. For example, increases in producer price swings in the lemon market put upward pressure on wholesale price returns, while the opposite is true for producer prices. In the tangerine market, the situation is slightly different. Increases in producer price uncertainties put upward pressure on producer price returns, while the increase in wholesale price uncertainties decreases producer price returns. While increases in producer price uncertainties in the orange market increase producer and wholesale returns, increases in wholesale price uncertainties have the opposite effect on producer and wholesale price returns. Finally, although producer and wholesale price uncertainties in the grapefruit market have a positive effect on their returns, they hurt each other.

After obtaining the parameters of the maximum likelihood function in Eq. 5, the marginal effects were obtained by applying the differentiation rule to the conditional variance of the equation (Eq. 4) and the results are then presented in Table 3. In the equations in Table 3, h_{11} and h_{22} show the conditional variances of the producer and wholesale markets, respectively. First, the conditional variance of the producer price return for the lemon market is positively and significantly affected by its short-run shocks (0.028). The interaction of short-run shocks of the lemon market producer price return and short-run shocks of wholesale price return did not have a statistically significant effect on the lemon producer price return conditional variance. However, long-run volatilities have positive and persistent effects on the conditional variance of producer price returns. This result differs from the studies conducted by Ait Sidhoum and Serra (2016); Apergis and Rezitis (2003). In these studies, short-term shocks in retail prices increased the volatility in producer price returns. The first study investigated the vertical volatility transmission for the tomato market. Since tomato is not a seasonal product and suitable for greenhouse cultivation, it can be produced in any period and can also be harvested many times during its life cycle, based on its classification as a fruit, but unlike lemons. Therefore, producer prices can adapt themselves by reacting to consumer prices as to changing supply and demand conditions. Our results show that price volatility poses great risks for farmers, emphasizing that in the face of price volatility, farmers can cut off production and investment and even stop production by switching to alternative production options in the short term. Farmers reducing production in the face of price volatility will push prices upwards, in turn pushing upwards wholesale and consumer prices. In particular, farmers reducing production for the next year in the face of price fluctuations of agricultural products such as seasonally produced citrus will greatly affect wholesale and consumer prices (Assefa et al. 2015). In their study, Holt and Aradhyula (1990) argued that price uncertainties in agricultural products have a mitigating effect on production. Although their study was carried out in the broilers sector, where production can be done in a mass manner as opposed to citrus production, supply can be controlled in the face of price uncertainties in citrus production. If the citrus fruits offered by the farmers do not achieve the price demanded by the farmers in the market, the supply can be partially controlled by either keeping the fruit juice for production or storing the fruits in modern refrigeration units for later use rather than fresh use. Although it is possible to increase production in the long run, it is possible to control the price by reducing the supply of the product in the market by farmers or speculators.

While the time-varying conditional variance of wholesale returns in the lemon market is positively and significantly affected by its short-run shocks, the producer price return and short-run shocks did not have a statistically significant effect on such a conditional variance directly or indirectly. Likewise, the time-varying conditional variance of the wholesale price return in the lemon market is positively and significantly affected by the long-run volatility of its own and its producer price returns. Being an indispensable complementary product of traditional Turkish cuisines such as tea, soup, and salad in the country, lemon has the feature of being available in all seasons compared to other citrus products, making price uncertainties the focus of attention. Similar to these results, Natcher and Weaver (1999) and Buguk et al. (2003) claimed that there is a mutual pass-through between producer and retail price uncertainties in their studies for agricultural products.

The time-varying conditional co-variance of producer and wholesale price returns affects the conditional variance of wholesale price returns negatively. Ait Sidhoum and Serra (2016) reached similar results for the tomato market. Table 3 illustrates that there are asymmetrical pass-throughs between producer and wholesale price uncertainties in the lemon market. In addition, the findings obtained for the orange market are similar to those of the lemon market. While the conditional variance of the tangerine producer price return is positively affected by its long-run volatility as well as its short-run shocks, it has been determined that the conditional co-variance between producer and wholesale prices is negatively and significantly affected. Similarly, the conditional variance of the wholesale price return is positively and significantly affected by its short-run shocks and the lagged volatility of the producer price return, and the conditional co-variance between producer and wholesale prices. In the grapefruit market, the uncertainty pass-throughs between producer and wholesale prices show differences compared to lemon, orange, and tangerine. The conditional variance of the producer price return in the grapefruit market is affected positively by its short-run shocks and shocks of the wholesale price return, and it is negatively by the product of the two. The conditional variance of producer price returns in the grapefruit market, similar to that in the tangerine market, is persistently affected by its historical volatility and the co-variance between producer and wholesale prices. The conditional variance of the wholesale price return is positively affected by the co-variance between producer and wholesale prices and its historical volatility.

Conclusions

When the related literature is examined, it is seen that there are many studies on the producer, wholesale, and retail price (vertical price) volatility pass-throughs in agricultural products. In the present study, the uncertainty pass-throughs between producer and wholesale prices for products in the Turkish citrus market were examined. Vertical price pass-throughs, and general producer and consumer price levels, especially in meat and dairy products, have been examined with empirical findings in both domestic and international literature. To the best of our knowledge, there are no studies examining vertical price pass-through on the citrus market using first and/or second-moment analysis. In this context, the present study closes a significant gap in the literature.

To reveal the uncertainty pass-throughs between producer and wholesale prices of lemon, orange, tangerine, and grapefruit products in the citrus market, daily data for the period between January 2009 and May 2020 were analyzed using the VAR (1)-GARCH-BEKK-M (1,1) method. Due to the econometric method used, the present study employed both the first moment and the second-moment analyses, enriching the results. According to the findings obtained from the analysis results, uncertainty pass-throughs between producer and wholesale prices in the citrus market are evident. Price uncertainties in both the producer and wholesale or trader sides create negativities in terms of producer and consumer prices. While price uncertainties cause a decrease in production for the producer, raising raise concerns about food insecurity for future production in the country, considering that a large part of consumer income in developing countries such as Turkey is allocated to food expenditures, the increase in product prices negates the purchasing power of the consumer, making it difficult to reach balanced and healthy food in the daily diet. Thus, problems occur in terms of production, food safety, and affordability for both producers and consumers. Also, in the face of continued and widespread uncertainty, it creates the forced migration of producers from rural areas to urban areas, placing an additional financial burden on the state with increasing unemployment and even high crime rates.

As such, policymakers should employ agricultural policies that will reduce producer price uncertainties. It is of great importance for future studies to examine the uncertainty pass-throughs between producer, wholesale, and consumer prices for the citrus market because vertical price uncertainty pass-throughs are a determining factor here in the context of both the formation of food inflation, food safety, and consumer affordability.

Conflict of interest G. Bozma, F. Urak, and A. Bilgiç declare that they have no competing interests.

References

Abdallah MB, Farkas MF, Lakner Z (2020) Analysis of dairy product price transmission in Hungary: a nonlinear ARDL model. Agriculture 10(6):1–14. https://doi.org/10.3390/agriculture10060217

Abdelradi F, Serra T (2016) Asymmetric price volatility transmission between food and energy markets: the case of Spain. Agric Econ 46(4):503–513

Aguiar DR, Santana JA (2002) Asymmetry in farm to retail price transmission: evidence from Brazil. Agribus Int J 18(1):37–48

Ahmed O (2018) Vertical price transmission in the Egyptian tomato sector after the Arab Spring. Appl Econ 50(47):5094–5109

Ait Sidhoum A, Serra T (2016) Volatility spillovers in the Spanish food marketing chain: the case of tomato. Agribusiness 32(1):45–63

Alexandri C (2011) Analysis of price transmission along the agri-food chains in Romania. Agric Econ Rural Dev 8(2):171–189

Apergis N, Rezitis A (2003) Agricultural price volatility spillover effects: the case of Greece. Eur Rev Agric Econ 30(3):389–406

Arouri EHM, Jouini J, Nguyen DK (2011) Volatility spillovers between oil prices and stock sector returns: Implications for portfolio management. J Int Money Finance 30(7):1387–1405. https://doi.org/10.1016/j.jimonfin.2011.07.008

Arouri EHM, Jouini J, Nguyen DK (2012) On the impacts of oil price fluctuations on European equity markets: Volatility spillover and hedging effectiveness. Energy Econ 34(2):611–617. https://doi.org/10.1016/j.eneco.2011.08.009

Assefa TT, Meuwissen MPM, Lansink OAGJM (2015) Price volatility transmission in food supply chains: a literature review. Agribusiness 31(1):3–13. https://doi.org/10.1002/agr.21380

Bakucs LZ, Ferto I, Szabó GG (2007) Price transmission in the Hungarian vegetable sector. Stud Agric Econ 106:23–39

BBC (2017) Russia lifts sanctions on Turkish food in diplomatic thaw. https://www.bbc.com/news/world-europe-40134701. Accessed: 19 Aug 2022

Ben-Kaabia M, Gil JM (2007) Asymmetric price transmission in the Spanish lamb sector. Eur Rev Agric Econ 34(1):53–80

Benson BL, Faminow MD (1985) An alternative view of pricing in retail food markets. Am J Agr Eco 67(2):296–306

Buguk C, Hudson D, Hanson T (2003) Price volatility spillover in agricultural markets: an examination of US catfish markets. J Agric Resour Econ. http://www.jstor.org/stable/40987174

Chadwick MG, Bastan EM (2017) Beef price volatility in Turkey: Can import policy affect the price and its uncertainty?

Chen S-T, Kuo H-I, Chen C-C (2010) Modeling the relationship between the oil price and global food prices. Appl Energy 87(8):2517–2525. https://doi.org/10.1016/j.apenergy.2010.02.020

COMTRADE (2022) United nations commodity trade statistics database. https://comtrade.un.org/. Accessed: 19 Aug 2022

Dickey DA, Fuller WA (1979) Distribution of the estimators for Autoregressive time series with A unit root. J Am Stat Assoc 74(366):427–431 (http://www.jstor.org/stable/pdfplus/2286348.pdf?acceptTC=true)

Dong X, Brown C, Waldron S, Zhang J (2018) Asymmetric price transmission in the Chinese pork and pig market. BFJ 120(1):120–132. https://doi.org/10.1108/BFJ-02-2017-0056

Engle RF, Kroner KF (1995) Multivariate simultaneous generalized arch. Econ Theory 11(1):122–150 (http://www.jstor.org/stable/3532933)

FAO (2018) Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/?#data/. Accessed: 19 Aug 2022

Ferrer-Pérez H, Gracia-de-Rentería P (2020) Asymmetric price volatility transmission in the Spanish fresh wild fish supply chain. Mar Resour Econ 35(1):65–81

Gardebroek C, Hernandez MA (2013) Do energy prices stimulate food price volatility? Examining volatility transmission between US oil, ethanol and corn markets. Energy Econ 40:119–129. https://doi.org/10.1016/j.eneco.2013.06.013

Gervais J-P (2011) Disentangling nonlinearities in the long-and short-run price relationships: an application to the US hog/pork supply chain. Appl Econ 43(12):1497–1510

Girapunthong N, VanSickle JJ, Renwick AW (2003) Price asymmetry in the United States fresh tomato market. J Food Distrib Res 34:51–59

Goetz L, Grethe H (2009) The EU entry price system for fresh fruits and vegetables—paper tiger or powerful market barrier? Food Policy 34(1):81–93. https://doi.org/10.1016/j.foodpol.2008.06.005

Goodwin BK, Harper DC (2000) Price transmission, threshold behavior, and asymmetric adjustment in the US pork sector. J Agric Appl Econ 32:543–553

Götz L, Von Cramon-Taubadel S, Kachel Y (2014) Vertical price transmission in the international fresh fruit and vegetable supply chain: Israeli grapefruit exports to the EU after export liberalisation. Q J Int Agric 53(2):99–120 (https://www.scopus.com/inward/record.uri?eid=2-s2.0-84902180279&partnerID=40&md5=ced08d28ff851929ce97d5b4e8e8e7ef)

Hasanov AS, Do HX, Shaiban MS (2016) Fossil fuel price uncertainty and feedstock edible oil prices: evidence from MGARCH-M and VIRF analysis. Energy Econ 57:16–27. https://doi.org/10.1016/j.eneco.2016.04.015

Hassan D, Simioni M (2004) Price transmission in the French fresh vegetables channel: an application of threshold cointegration tests

Headey D, Fan S (2008) Anatomy of a crisis: the causes and consequences of surging food prices. Agric Econ 39:375–391

Holt MT, Aradhyula SV (1990) Price risk in supply equations: an application of GARCH time-series models to the US broiler market. South Econ J 57:230–242

Hwang S, Pereira VPL (2006) Small sample properties of GARCH estimates and persistence. Eur J Finance 12(6–7):473–494. https://doi.org/10.1080/13518470500039436

Jurkėnaitė N, Paparas D (2019) Towards better understanding of vegetable market functioning: the Lithuanian cases of fresh tomatoes and cucumbers. Outlook Agric. https://doi.org/10.1177/0030727019866208

Kwiatkowski D, Phillips PC, Schmidt P, Shin Y (1992) Testing the null hypothesis of stationarity against the alternative of a unit root. J Econom 54(1–3):159–178

Lass DA (2005) Asymmetric response of retail milk prices in the northeast revisited. Agribus Int J 21(4):493–508

Ling S, McAleer M (2003) Asymptotic theory for a vector ARMA-GARCH model. Econ Theory 19(02):280–310

López Cabrera B, Schulz F (2016) Volatility linkages between energy and agricultural commodity prices. Energy Econ 54:190–203. https://doi.org/10.1016/j.eneco.2015.11.018

Mai TC, Shakur S, Cassells S (2018) Testing vertical price transmission for Vietnam's Robusta coffee. Aust J Agric Resour Econ 62(4):563–575. https://doi.org/10.1111/1467-8489.12260

Mensi W, Beljid M, Boubaker A, Managi S (2013) Correlations and volatility spillovers across commodity and stock markets: linking energies, food, and gold. Econ Model 32:15–22. https://doi.org/10.1016/j.econmod.2013.01.023

Mensi W, Hammoudeh S, Nguyen DK, Yoon S-M (2014) Dynamic spillovers among major energy and cereal commodity prices. Energy Econ 43:225–243. https://doi.org/10.1016/j.eneco.2014.03.004

Munyeka W (2014) Price mediation in tomato commerce of limpopo province of the Republic of South Africa. Mediterr J Soc Sci 5(20):778

Naseer MAUR, Mehdi M, Ashfaq M, Hassan S, Abid M (2019) Effect of marketing channel choice on the profitability of citrus farmers: Evidence form Punjab-Pakistan. Pak J Agric Sci 56(4):1003–1011. https://doi.org/10.21162/PAKJAS/19.8671

Natcher WC, Weaver RD (1999) The transmission of price volatility in the beef markets

Pala A (2013) Structural breaks, cointegration, and causality by VECM analysis of crude oil and food price. Int J Energy Econ Policy 3(3):238–246

Pozo VF, Bachmeier LJ, Schroeder TC (2020) Are there price asymmetries in the U.S. beef market? J Commod Mark. https://doi.org/10.1016/j.jcomm.2020.100127

Reziti I, Panagopoulos Y (2006) The price transmission mechanism in the Greek agri-food sector: an empirical approach. Citeseer

Rezitis AN (2019) Investigating price transmission in the Finnish dairy sector: an asymmetric NARDL approach. Empir Econ 57(3):861–900. https://doi.org/10.1007/s00181-018-1482-z

Rezitis AN, Stavropoulos KS (2011) Price transmission and volatility in the greek broiler sector: a threshold cointegration analysis. J Agric Food Ind Organ 9(1):1–35

Serra T, Goodwin BK (2003) Price transmission and asymmetric adjustment in the Spanish dairy sector. Appl Econ 35(18):1889–1899

TUIK (2018) Foreign trade statistics. www.tuik.gov.tr. Accessed: 19 Aug 2022

TUIK (2020) Consumer price statistics. www.tuik.gov.tr. Accessed: 19 Aug 2022

TUIK (2022a) Consumer price statistics. www.tuik.gov.tr. Accessed: 19 Aug 2022

TUIK (2022b) Crop products balance sheets. www.tuik.gov.tr. Accessed: 19 Aug 2022

TUIK (2022c) Producer price index of agricultural products. www.tuik.gov.tr. Accessed: 19 Aug 2022

USDA (2022) Fruit and tree nuts data. https://www.ers.usda.gov/. Accessed: 19 Aug 2022

Uysal O, Polatöz S (2017) Dünyada ve Türkiye'de turunçgil üretimi ve dış ticareti. Türk Tohumc Bir Derg 6(22):4–9

Ward RW (1982) Asymmetry in retail, wholesale, and shipping point pricing for fresh vegetables. Am J Agric Econ 64(2):205–212