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Research Article

The Long-Term Volatility Spillovers Between Egg and Feed Wheat Prices During the COVID-19 Pandemic in Turkey

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Abstract

Having spread all over the world and become effective in a very short period, COVID-19 has brought about negative effects on food supply and demand by breaking all supply chains. This study aims to determine the long-term volatility spillovers between egg and feed wheat markets in Turkey by using an exchange rate and COVID-19 as exogenous variables as well as to investigate whether these spillovers are asymmetric. The daily market data between 2010:01 and 2022:03 and the Asymmetric BEKK-GARCH (1, 1) model were used for the study . We determined that the conditional variances of egg and feed wheat return series are positively affected by both their shocks in the short run and their uncertainties in the long run. The conditional variances of egg and feed wheat return series were observed to have been positively affected by the uncertainties arising from the exchange rate in the long run, while they were negatively affected by the volatility caused by COVID-19. The depreciation of the Turkish Lira caused a reciprocating increase in the price levels of imported products, such as oil and derivatives, and of feed products which constitute a very important part of egg production costs. The increase in egg production costs, in return, consistently triggered egg prices upwards (with positive returns), causing an increase in uncertainty in the long run. This research provides a perspective for developing policy recommendations for food security if global food supply chains are broken due to any pandemic or a similar crisis (such as the Russia-Ukraine war).

Key words: Egg and feed wheat prices, COVID-19, exchange rate, volatility spillovers, BEKK – GARCH (1, 1) model

Türkiye'de COVID-19 Pandemi Sürecinde Yumurta ve Yemlik Buğday Fiyatları Arasındaki Uzun Dönem Oynaklık Yayılımları

Öz

Tüm dünyaya çok kısa sürede yayılan ve etkisini gösteren COVID-19, tüm tedarik zincirlerinin bozulmasına yol açarak gıda arz ve talebinde olumsuz etkiler meydana getirmiştir. Bu çalışmanın amacı, döviz kuru ve COVID-19'un dışsal değişken olarak kabul edildiği bir durumda Türkiye'de yumurta ve yemlik buğday piyasaları arasındaki uzun dönem oynaklık yayılımlarını belirlemeyi ve bu yayılımların asimetrik olup olmadığını araştırmaktır. Bu çalışmada 2010:01 ile 2022:03 arasındaki günlük piyasa verileri ve Asimetrik BEKK-GARCH (1, 1) modeli kullanılmıştır. Yumurta ve yemlik buğday getiri serilerinin koşullu varyanslarının hem kısa dönemdeki şoklardan hem de uzun dönemdeki belirsizliklerinden olumlu yönde etkilendiği tespit edilmiştir. Yumurta ve yemlik buğday getiri serilerinin koşullu varyanslarının uzun dönemde döviz kurundan kaynaklanan belirsizliklerden olumlu, COVID-19 kaynaklı oynaklıktan olumsuz etkilendiği gözlemlenmiştir. Türk Lirasında yaşanan değer kaybı, yumurta üretim maliyetlerinin çok önemli bir bölümünü oluşturan petrol ve türevleri gibi ithal ürünler ile yem ürünlerinin

fiyat düzeylerinin karşılıklı olarak artmasına neden olmuştur. Buna karşılık yumurta üretim maliyetlerinin artması, yumurta fiyatlarını sürekli yukarı yönlü (pozitif getirilerle) hareket ettirmiş ve uzun vadede belirsizliğin artmasına neden olmuştur. Bu araştırma, herhangi bir pandemi veya benzeri (Rusya-Ukrayna savaşı gibi) bir kriz nedeniyle küresel gıda tedarik zincirlerinin bozulması durumunda gıda güvenliğine dair politika önerileri geliştirmek için bir perspektif sunmaktadır.

Anahtar kelimeler: Yumurta ve yemlik buğday fiyatları, COVID-19, döviz kuru, oynaklık yayılımları, BEKK – GARCH (1, 1) modeli

Introduction

The unanticipated breakout of the COVID-19 pandemic created a significant uncertainty affecting the production, consumption, supply chains in several sectors, and the prices of goods produced by these sectors (Chang et al., 2020). The increase in commodity prices, which triggered as a result of the breaking of the supply chain in almost all sectors and occurs as a current global problem, during the Covid-19 pandemic period, has also spread to agro-food products (Ivanov and Dolgui, 2020; Küçük, 2021). Sudden swings in meat prices, particularly the emergence of a significant gap between livestock and wholesale meat prices, have been associated with the COVID-19-related economic lockdown (Lusk et al., 2021). In respect of food security, increases in staple food prices have damaged both diet diversity and the share of food expenses in the consumption expenditures (Amolegbe et al., 2021). During this epidemic, volatilities in food prices have affected both farmers' incomes and consumers' purchasing power in underdeveloped and developing countries, where producers lost product sovereignty and led to food insecurity in consumers (Barrett, 2020; De Sousa, 2020). The marketing cost of agricultural products increased due to the logistics-related challenges associated with the pandemic (Hahn, 2020; Held, 2020; Poppick, 2020) and the growing gap between the consumer and farmers' prices (Reardon et al., 2020; Lusk, 2020; Narayan and Saha, 2020). While, in many countries, agri-food prices are already more volatile than they would normally be (Laborde et al., 2020; Reardon et al., 2020), the food insecurity is expected to increase further with the adverse effects of the COVID-19 period (Alvi and Gupta, 2020; FAO, 2020a; Schmidt, 2020; Laborde et al., 2021). For instance, the agri-food prices in many African countries and India have increased by over 15% compared to the pre-COVID-19 period (Hernandez et al., 2020).

The outbreak of the COVID-19 pandemic has shaken the commodity futures markets through three channels: supply, demand, and increased volatility (Baldwin and di Mauro, 2020; Hunter et al., 2020; Vijlder, 2020). Therefore, the pandemic has knock-on effects on commodity prices as well as on financial state that may have consequences on economic growth (Vijlder, 2020; CRISIL, 2020). The uncertainties brought about by the COVID-19 pandemic had different effects on commodities (World Bank, 2020). For example, while there has always been a strong relationship between oil and sugar, this relationship was emphasized to have become stronger during the COVID-19 pandemic (Wang et al., 2020). During the COVID-19 pandemic, the wheat market was expected to spillovers more than other markets, particularly soybeans and corn (Cao and Cheng, 2021). On the other hand, while uncertainties in food prices affect the economic conditions in developed countries, it may negatively affect food security in underdeveloped and developing countries where food expenditures constitute the most important part of the monthly total expenditure of households (Assefa et al., 2015; Sidhoum and Serra, 2016). The supply of safe food is an important factor for public health as the consumption of safe and nutritious foods strengthens the immunity of the human body and protects it against infections (Uddin et al., 2020). Protein-rich foods such as meat, dairy products, and eggs are important for boosting the immune system and hence the body's health. Today, as the effect of the pandemic continues, certain foods that can improve our immune system, e.g., fish, meat, eggs, and milk, which are foods of animal origin, should be consumed to combat COVID-19 (Aman and Masood, 2020; WHO-EMRO, 2022).

Although egg is an important nutritional source for humans, it is also an important sector in respect of being the livelihood of millions of breeders. Turkey is one of the leading countries in world egg production and export. Based on The Observatory of Economic Complexity (OEC)'s ranking of the world's total egg exports in 2020, Turkey ranks fifth with $253 million whereas the Netherlands is in the lead with approximately $804 million (OEC, 2021). Production costs are one of the most important factors affecting poultry farming and egg production and export in Turkey. The most weighted item included in the breakdown of the production costs is feed cost, which accounts for more than 60% of the total production costs in the sector (Lawrence et al., 2008). Although price dynamics of various commodities such as energy,

agriculture, livestock, and metals have been investigated recently (Zaremba et al., 2019; Umar et al., 2021), studies that address the impact of the COVID-19 pandemic on the agricultural sector have not yet taken place in the relevant literature. In the current study, the direction and effects of the spillover processes of market return and uncertainty levels between egg and feed wheat markets, together with the asymmetric relationship, were eclectic and empirically estimated for the first time using a bivariate Generalized Autoregressive Conditional Variability (GARCH) model in the context of two exogenous variables (e.g., COVID-19 and exchange rate) in Turkey. In addition, by controlling the COVID-19 and exchange rate variables in the time-varying conditional variance equations of the egg and feed wheat markets, the effect of the unilateral volatility that occurs either in the dollar exchange rate or due to the COVID-19 pandemic on the egg and feed wheat markets was elicited. Knowing such uncertainties, which increasingly become widespread in the markets, can provide insights to both policymakers and stakeholders in the markets, as uncertainty causes producers to lose product sovereignty and consumers' food security.

Material and Methods

Material

The chicken egg prices used in the study were obtained from the database of Başmakçı Poultry Cooperative. The size of the reference chicken egg was Large (63 -73 g), also known as double, which is the most sold size. Feed wheat prices were obtained from the database of the Union of Chambers and Commodity Exchanges of Turkey, as the daily stock market value. The macroeconomic variables, exchange rate, and COVID-19 were also included in the study. The real dollar exchange rate series was obtained from the Central Bank of the Republic of Turkey Electronic Data Distribution System. Egg and feed wheat prices were deflated using the food price index. Furthermore, the effect of the COVID-19 period on the egg and feed wheat markets was investigated in comparison to the pre-pandemic period. Daily data covering the period 2010:01-2022:03 were used to obtain the volatility in the respective markets. A total of 253 observations throughout the period were used in the analyses. Although Hwang and Valls Pereira (2006) stated that there should be a minimum of 250 observations for the ARCH model and 500 observations for the GARCH model, Rezitis and Ahammad (2016) conducted an analysis using the Baba, Engle, Kraft and Kroner (BEKK)-GARCH model with just 50 observations. In this study, similar to the study of Rezitis and Ahammad (2016), the standard deviations obtained from the BEKK-GARCH model were obtained using the robust method*.

Econometric Method

Mean return equations are generally based on lag values. In the vector autoregressive (VAR) framework, we decided how many lag values to work with for the two explored returns using information criteria such as Akaike, Schwartz, and Hanna-Quinn. These three statistical tests confirmed each other and indicated that the current return equations are independent of lag and will only be defined as a function of exogenous series such as the exchange rate and COVID-19. Therefore, the current mean return equations are as follows:

$$R_t = \mu_0 + \mu_1 E + \mu_2 S + \varepsilon_t \quad (1)$$

Where R_t represents the return vector of each market ($R_{eggs,t}$ and $R_{feed\ wheat,\ t}$) in the sector and is calculated as $R_t = 100 * \ln(P_t / P_{t-1})$, where P_t, P_{t-1} are the real current price and the price in the previous period in the respective market and ln denotes natural logarithm. E shows the exchange rate, while S represents the dummy variable, taking the value 1 for the days in the COVID-19 pandemic period and 0 for the other days. μ_0 represents the constant parameter of the relevant market return, while μ_1 and μ_2 parameters, on the other hand, are a measure of the effect of the exchange rate and COVID-19 variables on the explored markets in question, respectively. Finally, ε_t represents the short-term shocks of the respective market.

Grier et al. (2004) expressed the conditional variance equation they developed for the asymmetric BEKK - GARCH model as Equation 2:

$$H_t = \Upsilon\Upsilon' + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B + D'\xi_{t-1}\xi'_{t-1}D \quad (2)$$

The H matrix in Equation 2 consists of two separate parts: the constants (C, E, and S) and the variables (the ε_{t-k} short-term shocks; the H_{t-j} long-term volatility; and the ξ_{t-1}, asymmetric effect). The first part can be expressed as $Y = \left(C + \Psi E + \Phi S\right)$ whereas the second part can be represented as $\sum_{k=1}^{g} A'_k \varepsilon_{t-k}\varepsilon'_{t-k}A_j + \sum_{j=1}^{f} B'_j H_{t-j}B_j + \mathrm{D}'\xi_{t-1}\xi'_{t-1}D$, where,

* All estimates were performed under RATS 10. Possible biased standard errors have been corrected using the ROBUSTERRORS option of RATS 10.

C, Ψ , Φ , A, B, and D are 2x2 matrices. In addition, C, Ψ ve Φ are 2x2 lower diagonal matrices and represent, in respective order, the constant coefficients of the variance equations, the exchange rate, and the spread of COVID-19 on the transmission of the uncertainty in the relevant market. A, B, and D matrices, on the other hand, are the parameters that represent the short-term shocks, long-term uncertainties, and asymmetric effects, respectively. To detect the existence of an asymmetric effect in volatility transmission in product markets, in the conditional variance equation in Equation 2, the asymmetry that distinguishes the negative residual effect from the positive residual effect is enabled by coding it as 1 when the residuals are negative and 0 otherwise.

Results and Discussion

The descriptive statistics and unit root test values of the model are given in detail in Table 1. The returns of the egg and feed wheat series are 1.343 and 1.229, respectively.

Table 1. Descriptive statistics and Unit Root Test results

Statistics	**Returns**	
	$R_{egg,\ t}$	**$R_{feed\ wheat,\ t}$**
Mean	1.343	1.229
Std. Dev.	16.853	5.241
t-statistics (mean=0)	1.265 (0.207)	3.722 *** (0.000)
Skewnees	-0.042 (0.786)	0.326 *** (0.036)
Kurtosis	2.238 *** (0.000)	3.015 *** (0.000)
Jarque-Bera	52.683 *** (0.000)	99.897 *** (0.000)
Correlations for Price Levels		
$Pr_{egg,\ t}$		0.989
$Pr_{feed\ wheat,\ t}$		
Correlations for Returns		
$R_{egg,\ t}$		0.166
$R_{feed\ wheat,\ t}$		
Correlations among Squared Returns		
$R^2_{egg,\ t}$		0.222
$R^2_{feed\ wheat,\ t}$		
Testing Autocorrelations in Price Levels or Closing Levels		
LB-Q (6)	24.752 *** (0.000)	7.524 *** (0.000)
McLeod-Li (6)	27.662 *** (0.000)	33.036 *** (0.000)
HM-Q (6)	43.833 *** (0.008)	
Testing ARCH in Price Levels or Closing Levels		
ARCH-LM (6)	3.768 *** (0.001)	4.824 *** (0.000)
MARCH-LM (6)	92.610 *** (0.001)	
HM-Q^2(6)	64.887 *** (0.000)	
Unit Root Test for Returns Series		
ADF	-15.411 *** (lags=1)	-11.543 *** (lags=1)
KPSS	0.026 (lags=1)	0.079 (lags=1)

Note: The critical values vary with lags selected. In parenthesis are associative p-values. *, ** and *** are statistically significant at 10%, 5% and 1% respectively.

When examining the unconditional standard deviations obtained from the standard deviations of the egg and feed wheat price returns, we determined that the volatility, i.e. standard deviation, of the egg price (16.853) is approximately 3.5 times higher than that of the feed wheat price (5.241). The higher return and volatility of egg compared to feed wheat during the analyzed period may be attributed to either that the egg has a higher profit margin or lower production cost or that it has higher transaction volume. The kurtosis coefficients of the related series show that the return series have a fat-tailed and leptokurtic (thin belled) distribution. The leptokurtic distribution of the return series is an important indicator of the ARCH effect in the series. It was determined that all return series of the test statistics in Table1 do not have a normal distribution at the 1% significance level. The correlation values between egg and feed wheat price and return series were 0.989 and 0.166, respectively, these two series were found to affect each other in terms of the spread of transmission.

This can be explained by the fact that feed wheat is one of the important input items in egg production. The ARCH-LM (6) test indicates that there is a time-varying variance in the egg and feed wheat returns series, and therefore the volatility of the return series changes over time. Similarly, examining the return series simultaneously, an ARCH effect on the residuals of the return series was observed and the return series have a simultaneous ARCH effect indicating the suitability of performing the analyzes with the bivariate GARCH model. According to the Ljung-Box (LB) test statistic, which shows whether there is autocorrelation (cascade dependency) in the price and returns series, the return series includes autocorrelation. Lastly, the Augmented Dickey-Fuller (ADF) unit root test developed by Dickey and Fuller (1979) shows that the return series are stationary at the I(0) level at a 1% significance level. Results similar to that of the ADF unit root test were also obtained from the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. The variation of egg and feed wheat daily return series over time is presented in Figure 1.

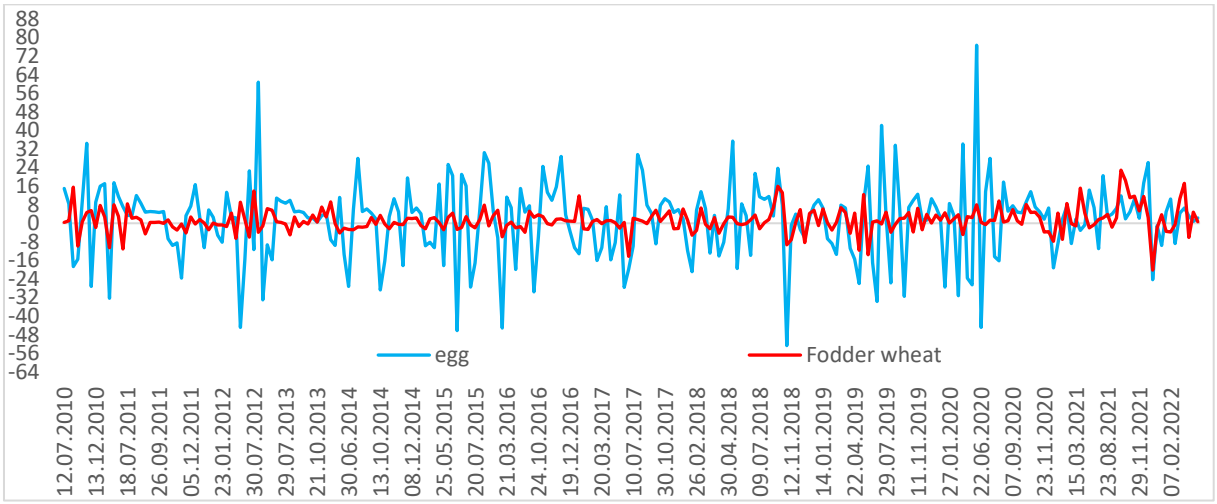

Figure 1. Variation of egg and feed wheat returns over time

The volatility of the squares of egg and feed wheat return series over time is presented in Figure 2. Considering the magnitudes in the squares of return, the frequency and magnitude of the local peak points in the egg and feed wheat series show that the said points diverge from the averages of the series, which is an important finding in respect of showing that there is an ARCH effect in the related series. These findings, therefore, indicate that the return series contain the ARCH effect simultaneously and it is appropriate to perform the analyses with the bivariate GARCH model.

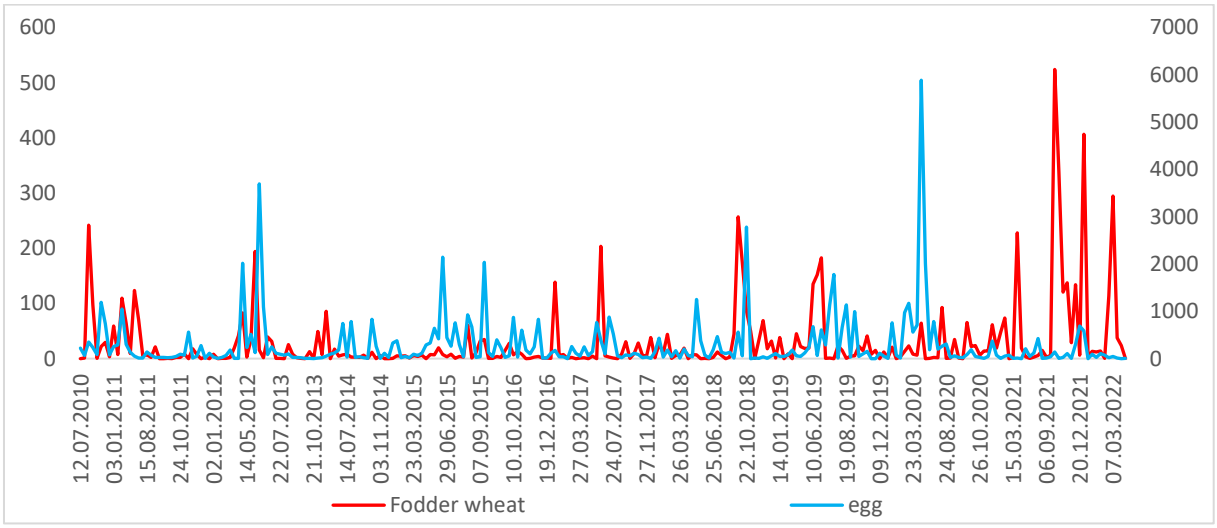

Figure 2. Squares of time-varying return series of egg and feet wheat

Given in Table 2 are the values of the mean equation and conditional variance of the return series of the Asymmetric BEKK-GARCH (1, 1) model. The close value of the return of the exchange rate in the previous period (E_{t-1} = 7.125) was found to significantly increase the return of the current price of the egg.

Table 2. Parameter estimates for both mean returns and conditional variances

Parameters	**Returns**	
	$R_{egg,\,t}$	**$R_{feed\ wheat,\,t}$**
Mean return estimates		
Constant	**-6.634**** (0.012)	-0.154 (0.943)
E_{t-1}	**7.125***** (0.009)	0.774 (0.696)
S_{t-1}	1.445 (0.206)	**1.696***** (0.002)
Conditional Variance Estimates		
c_{1i}	**-5.740***** (0.003)	-
c_{2i}	**-2.764***** (0.806)	**-1.111***** (0.005)
a_{1i}	**0.277***** (0.000)	0.002 (0.831)
a_{2i}	-0.132 (0.166)	**0.319***** (0.000)
b_{1i}	**0.793***** (0.000)	-0.006 (0.608)
b_{2i}	-0.030 (0.549)	**0.870***** (0.000)
d_{1i}	**0.543***** (0.000)	0.035 (0.148)
d_{2i}	**-1.185***** (0.000)	-0.005 (0.955)
$E_{1i,t-1}$	**13.915***** (0.000)	-
$E_{2i,t-1}$	**3.245***** (0.000)	**2.673***** (0.000)
$S_{1i,t-1}$	**-9.783***** (0.000)	-
$S_{2i,t-1}$	1.291 (0.147)	**-2.738**** (0.023)

Note: The critical values vary with lags selected. In parenthesis are associative p-values. *, ** and *** are statistically significant at 10%, 5% and 1% respectively.

The variation of the conditional variances of egg and feed wheat return series over time is presented in Figure The conditional variance of the return series of the egg was calculated to be (16.50) approximately 3.3 times higher than that of feed wheat return series (4.93).

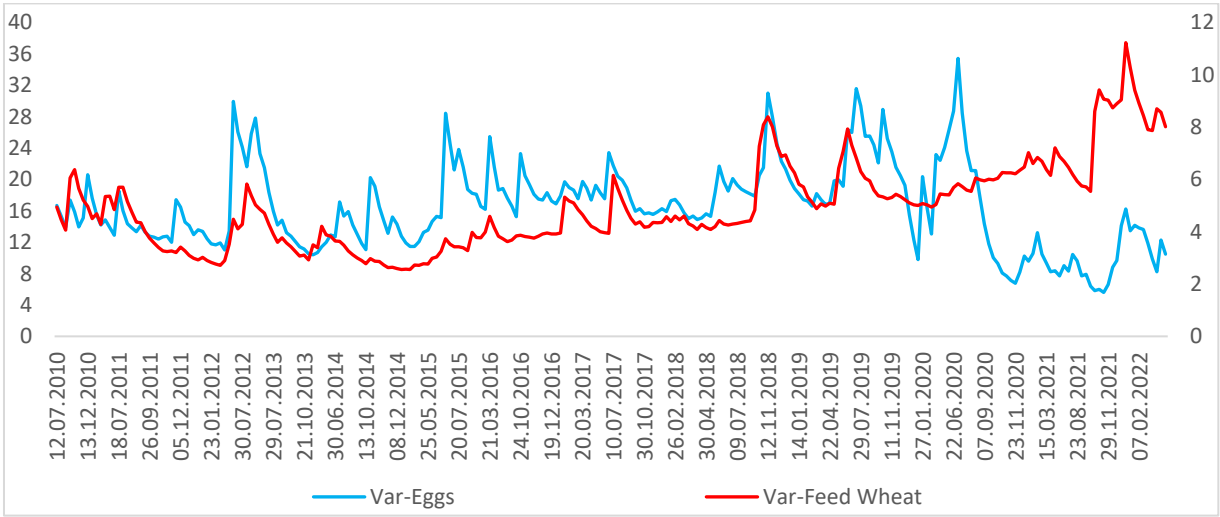

Figure 3. Covariation of conditional variances of egg and feed wheat over time

The variation of the conditional correlation between egg and feed wheat return series over time was presented in Figure 4. The correlation of conditional variances of egg and feed wheat was calculated to be 0.14 on average in the pre-COVID-19 period and 0.26 during the COVID-19 period, which suggests that egg and feed wheat triggered each other, in terms of volatility, more in the COVID-19 period compared to the pre-COVID-19 period.

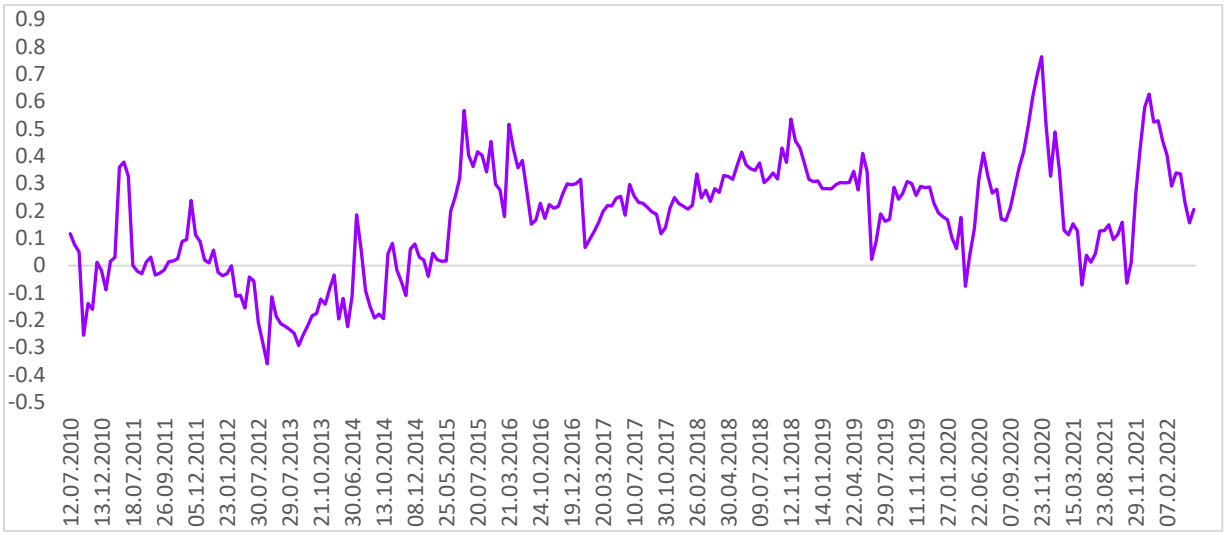

Figure 4. Time-varying conditional correlation between egg and feed wheat

The diagnostic test and Granger causality test statistics of the Asymmetric BEKK-GARCH (1, 1) model are presented in Table 3. Whether the error terms and squares of the error terms have autocorrelation was determined using Ljung-Box Q (LB-Q) and Hosking Multivariate-Q (HM-Q) test statistics. According to the results obtained from the test statistics, the error terms of the egg return series have autocorrelation, while the squares of both the error terms and the squares of error terms of the feed wheat return series were found to have no autocorrelation.

Table 3. Parameter estimates for conditional variances in VAR (1)-Asymmetric BEKK GARCH (1, 1)

		$R_{egg,t}$	$R_{feed\ wheat,t}$
Panel A: Residual Diagnostic Tests			
H_0: No serial correlation			
Ljung-Box Q (6)		14.451** (0.025)	9.463 (0.149)
McLeod-Li (6)		8.114 (0.230)	2.506 (0.868)
HM-Q (6)		43.849*** (0.008)	
H_0: No ARCH effect			
ARCH-LM (6)		1.306 (0.255)	0.312 (0.930)
MARCH-LM (6)		98.120 (0.262)	
Panel B: Model Specification Tests			
Granger Causality Tests			
H_0: Exchange rate and COVID-19 do not granger cause egg.			0.606 (0.546)
H_0: Exchange rate and COVID-19 do not granger cause feed wheat.			0.290 (0.748)
No GARCH	H_0: $a_{ij} = b_{ij} = d_{ij} = 0$ for all i, j =1,2,3		21890.312*** (0.000)
Diagonal GARCH	H_0: All off-diagonal elements of A, B, and D are jointly zero		65.137*** (0.000)
No Asymmetry	H_0: $d_{ij} = 0$ for all i, j =1,2,3		132.142*** (0.000)
H_0: Off-diagonal exchange rate estimates in the conditional variance equations are jointly zero.			4950.878*** (0.000)
H_0: Off-diagonal COVID-19 estimates in the conditional variance equations are jointly zero.			22.784*** (0.000)

Note: The critical values vary with lags selected. In parenthesis are associative p-values. *, ** and *** are statistically significant at 10%, 5% and 1% respectively.

It was concluded based on these results that the Asymmetric BEKK-GARCH (1, 1) model is sufficient in explaining the volatility of each return variable used in the model. The ARCH effect of error terms was investigated using individual McLeod-Li and Multivariate Lagrange Multiplier (MLM) tests under the H_0 hypothesis. As these tests indicated, the error terms obtained from the volatilities of the egg and feed wheat return series were determined to have no ARCH effect. In addition, as a result of the multivariate ARCH-LM test statistics, it was determined that there was no ARCH effect in the Asymmetric BEKK-GARCH (1, 1) model at lags six. As a result of all the test statistics applied above, we observed that the mean of the error terms was equal to 0 and the variance was equal to 1. A, B, and D outer diagonal elements of the H_0 hypothesis established for the diagonal GARCH test of the model are zero, indicating that the estimators are simultaneously nonzero and the volatility in one market affects the volatility in other markets. The effects of one-period lags of the exchange rate and COVID-19 on the returns of egg and feed wheat markets were tested using the Wald test statistic, and the hypothesis to accept states that their individual and simultaneous effects were zero was rejected at a significant level. Accordingly, the volatility in the egg and feed wheat markets can be said to be significantly affected by the uncertainties in the counterfactual markets. The probabilities of the Wald hypothesis tests, which state that the diagonal and the off-diagonal elements of the exchange rate and COVID-19 parameters used in the second moment (variance) model were equal to zero, were found to be 4950.878 ($p<0.000$) and 22.784 ($p<0.000$), respectively. Based on these test statistics, we concluded that the dominant long-term volatility in the exchange rate and COVID-19 were transferred to other markets by the respective buyers in those markets.

The volatility of the return series over time, seen in Figure 1, exactly matches the results of the study. The highest volatility in the return series was in the second half of 2019 when the COVID-19 pandemic broke out, and in the first half of 2020, when it peaked all over the world. This can be explained by the breaking of all supply chains on the global scale, caused by the COVID-19 pandemic, and by the significant increases in prices, especially in the food sector, in parallel to the increasing precautionary motive of households to stock consumer goods (Hobbs, 2021). The decrease in the magnitude of the volatility in the return series in the later periods can be explained by the positive reflection of the decreases in energy prices (oil and derivatives), that occurred upon the global closures and curfews, on food prices. With the outbreak of the COVID-19 pandemic, a sharp increase was observed in the wholesale and retail prices of agri-food products (Narayanan and Saha, 2021). However, upon the functional restrictions imposed on restaurants, shopping malls, and supermarkets worldwide, a decline of 20 percent was observed in the prices of agricultural commodities at later periods (Nicola et al., 2020). The breaking of the supply chain was a crucial factor for short-term price instability, but later on, the effects diminished and became more stable (Cranfield, 2020). It might be expected that COVID-19 will severely impact future markets by the virtue of the fact that market uncertainty, rising distribution costs, and rush demand significantly increase short-term price volatility in agricultural commodities and that COVID-19 pandemic has a devastating impact on prices, supply chains, financial channels, and agricultural markets (Umar et al., 2021; Adewopo, 2021).

Findings seen in Table 2 can be attributed to the increase in the exchange rate as a result of the upward pressure on the exchange rate due to the increase in the domestic foreign exchange demand that Turkey imports feed and energy (oil and derivatives), which are important input items in egg production. The return of the exchange rate two periods ago was also reported to have increased the return of the current price of lamb carcass (Urak et al., 2022a). Although the return of the close of the exchange rate in the previous period increased the return of the current price of feed wheat (E_{t-1} = 0.774), it was not statistically significant. Urak et al. (2022b) pointed out that the close value of the exchange rate in the previous period increased the return or current feed wheat price in Turkey by 0.186. We observed that the one-period lagged return of the COVID-19 pandemic has increased the current return of feed wheat by S_{t-1} = 1.696. In other words, the COVID-19 pandemic had a positive effect on the return level of feed wheat price. According to Turkey Statistical Institute (TSI) (2022), egg prices in the first three months of 2020 decreased by 15% in January, 13% in February, and 13% in March, compared to the same period of the previous year. However, compared to the previous year, prices increased by approximately 5% in April 2020, when the effect of the pandemic began to be felt, 25% in May, and 43% in July. Increasing prices lower the purchasing power of the consumer and may cause problems in accessing food. In the survey conducted by the World Bank (2020), 70.8% of the respondents in Malawi stated that they had consumed less food due to the financial difficulties caused by COVID-19 whereas this figure decreased to 57.7% in 2021 when the effects of COVID-19 began to diminish. Abouzid et al. (2021) determined

in their study that the respondents in the Middle East and North African countries had consumed fewer eggs in the COVID-19 period compared to the same pre-COVID-19 period. In the USA, egg prices have increased between 141% and 182% due to COVID-19 (Malone et al., 2021). Gupta et al. (2022) emphasized that the breaking of the supply chain due to COVID-19 caused an increase in prices, which changed the consumption habits in India. For example, women were determined to consume fewer eggs in the post-COVID-19 period than in the pre-COVID-19 period. Gupta et al. (2022) regard that such an event induced food insecurity among women and that there was a problem in accessing food. On the other hand, the closure of the public markets during the COVID-19 period prevented the small producers from reaching out directly to the consumer and the egg supply could meet the demand (Hafez et al., 2021). Therefore, price increases adversely affected the purchasing power of the consumers and have created a food insecurity problem. On the other hand, the inability of small producers to reach out to the consumers caused an income loss. According to VOA (2020), poultry farmers in Pakistan suffered a lot of income loss due to the decrease in demand for eggs and chicken meat. All above-cited evaluations have determined that the returns in the considered product markets affect each other significantly. Conditional variances of the return series were found to be affected significantly by their shocks in the short run and by their volatility in the long run. We observed that the conditional variances of egg and feed wheat returns were positively affected by their short-term shocks (a_{11} = 0.277 and a_{22} = 0.319), respectively. In this case, the markets considered can be said to be affected statistically significantly by the positive and negative news in the short run. Similarly, the conditional variances of egg and feed wheat returns are offset by their long-term uncertainties by (b_{11} = 0.793 and b_{22} = 0.870), respectively. The uncertainties in the feed wheat market are primarily due to the market's long-term volatility. In addition, it has been observed that the effects of positive and negative information on the egg and feed wheat markets were not symmetrical.

Similarly, the uncertainties of egg and feed wheat and the cross-uncertainties of these markets also increase significantly as the long-term volatility in the exchange rate (E_{11} = 13.915, E_{21} = 3.245, and E_{22}= 2.623) increases. Examining the effect of the long-term uncertainty in the exchange rate on the relevant markets, it is observed that the volatility induced in the egg market is approximately 5.5 times higher than the volatility induced in the feed wheat market. This is in line with the expectations, after all, a very significant part of inputs in egg production, including feed, chemicals, and energy (oil and derivatives), are foreign currency indexed. Agricultural product prices are significantly affected by the relationship between oil prices and the exchange rate (Guellil et al., 2018). Increases in agricultural product prices, thereby, positively trigger the feed prices, which is one of the production inputs of animal products (Tejeda and Goodwin, 2011; Pozo and Schroeder, 2012; Bartoli et al., 2016). Similarly, we observed that the volatility in the bilateral cross-interactions between the egg and feed wheat markets positively affected the volatility in the egg market interestingly. Accordingly, the volatility in the two markets considered was observed to be transferred to the egg market either through the conditional variance or through the conditional covariance, creating significant permanent volatility in the egg market. This can be explained by the fact that feed wheat is an important input item of egg production. Although the appreciation of the US dollar against the Turkish Lira creates high energy costs for the investors/manufacturers in the country, it also increases the price of feed wheat exported to neighboring countries in the Turkish Lira (Urak et al., 2022b). A Granger causality relationship is present between the imported agricultural products and the exchange rate in the long run (Burakov, 2016). If the dollar exchange rate declines, the prices of agricultural products are affected positively (Nazlioglu and Soytas, 2012). The high volatility and significant depreciation of the Turkish lira against foreign currencies occurred in 2013 and decreased the correlation value between mutton and fattening feed uncertainties in the same period (Özdemir et al., 2020).

Long-term uncertainties in the COVID-19 period significantly reduced the long-term volatility ($S_{11,t-1}$ = -9.783 and $S_{22,t-1}$ = -2.738) in the egg and feed wheat markets. This can be explained by the fact that COVID-19 increased the returns in egg and feed wheat markets, thus reducing the uncertainties of the said markets in the long run. With the negative impact of the COVID-19 pandemic on the supply chains (Chang et al., 2020; Ivanov and Dolgui, 2020) as well as the increased demand for food of animal origin for their immunoenhancing properties against COVID-19 (Uddin et al., 2020) significantly triggered the rise in food prices (Lusk et al., 2021; Amolegbe et al., 2021). For example, agri-food prices in many African countries and India have increased by over 15% compared to the pre-COVID-19 period (Hernandez et al., 2020). This can be explained by the fact that the rise in food prices increased the revenues of egg and feed wheat producers, and the producers in

these markets sought to reduce their risks by increasing their production. Meanwhile, the results depicted in Figure 3 can be explained by the higher demand for eggs during the examined period, especially during the COVID-19 pandemic. Foods of animal origin, such as fish, meat, eggs, and milk, which have an immunoenhancing effect, should be consumed to combat COVID-19 (Aman and Masood, 2020; WHO-EMRO, 2022). Similarly, the results shown in Figure 4 can be explained by the high demand for agricultural foods during the COVID-19 period.

Conclusion

Examining the results obtained in this study, the conditional variance of the egg return series was determined to be positively affected by the one-period lagged close value of the exchange rate, while the conditional variance of the feed wheat return series was affected in the same direction by its value in one-period before the COVID-19 pandemic. The conditional variances of egg and feed wheat return series were affected positively both by their shocks in the short run and by their uncertainties in the long run. In addition, the conditional variances of the egg and feed wheat return series were also positively affected by the uncertainties arising from the exchange rate in the long run. On the other hand, the conditional variances of the egg and feed wheat return series were negatively affected by the volatility caused by COVID-19 in the long run. One of the most important findings of the present study is that the uncertainties in the egg market in the long run caused by the exchange rate and COVID-19 were approximately 5 and 4 times higher than the uncertainties in the feed wheat market. Accordingly, the depreciation of the Turkish Lira causes a rise in the price levels of energy (oil and derivatives) and feed products, which are imported products and constitute a very important part of egg production costs. The increase in egg production costs, on the other hand, triggered egg prices constantly upward (with positive returns), causing an increase in the long-term uncertainty in the relevant market. The fact that the exchange rate is an important determinant of inflation figures in Turkey was supported by the empirical findings obtained from this study. As such, elimination of the factors that contribute positively to the uncertainty of the exchange rate in Turkey is expected to significantly reduce the uncertainties either in the macro economic indicators as a whole or in the agricultural products, in egg and feed wheat markets in particular. In addition, domestic production of feed products, an important input in egg production, is expected to reduce long-term volatility in the egg market.

Having spread all over the world and become effective in a very short period, COVID-19 has brought about negative effects on food supply and demand by breaking all supply chains. Yet, the COVID-19 pandemic has created additional risks, especially for food-insecure countries and households. Therefore, it is very important for all countries, especially countries with food security problems, to secure food supply, prevent the occurrence of food crises, and ensure the continuity of food supply chains to reduce or eliminate the negative effects of the COVID-19 pandemic or possible similar pandemics on national and global economies. As each stage of the workflow in the agricultural sector is interconnected, the smallest mistake or delay in the agricultural supply chain can lead to large losses in agricultural production by causing a “butterfly effect” (FAO, 2020b; Ivanov and Dolgui, 2020). Therefore, considering the possibility of the breaking of global food supply chains due to a pandemic or a similar crisis (such as the Ukraine-Russia war), policymakers in Turkey are, hereby, advised to adopt or develop policies for supporting the domestic production of imported agricultural products and their inputs, especially feed wheat. Likewise, Hafez et al., (2021) stated that a feed supply problem was experienced in the poultry farming sector due to the trade restrictions imposed during the COVID-19 pandemic process. In addition, the development of communication networks and transportation facilities that will reduce uncertainties in egg and feed wheat prices as well as food supply chain system and policies that will keep access active to markets in Turkey will positively affect the price stability of the products under consideration. With a holistic consideration of the above-cited findings and conclusions, the policy makers develop policies that will reduce the uncertainties in agricultural production emerges as a must.

Although this study provides new information about returns of egg and feeds wheat prices, exchange rate, and COVID-19, there also are some limitations mainly related to the data and econometric model. One of the limitations of this study is that it considers only egg and feed wheat markets. Therefore, more product markets can be analyzed in future studies. The lack of a sufficient number of observations in energy (gasoline or diesel) data can be counted as another limitation of the study.

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