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DETERMINING THE SHORT AND LONG TERM VOLATILITY SPILLOVERS BETWEEN WHEAT, COTTON AND CORN PRICES IN TURKEY USING THE ASYMMETRIC BEKK-GARCH-MEAN EQUATION MODEL

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Abstract

In the study, the price volatility relationship between wheat, cotton and corn markets was investigated and daily data for the period 02.04.2005-11.03.2020 were used. The VAR-Asymmetric BEKK-GARCH model, which analyzes the markets simultaneously in a single system, was chosen. Persistent long-term uncertainty in the wheat market affects the market positively. Long-term uncertainty in the cotton market creates uncertainty both in its own market and in the corn market. Persistent long-term uncertainty in the corn market creates permanent uncertainties both in its own market and in other markets, and these effects are statistically significant. Markets were more affected by long-term shocks.

Key words: *wheat, cotton, corn, price fluctuations, VAR-Asymmetric BEKK-GARCH-mean equation model, conditional variance*

INTRODUCTION

Agricultural commodity markets are of great importance in international trade. Wheat, cotton and corn markets lead the agricultural commodity markets. These markets have an important effect on the world production. Today, wheat is a product of indispensable importance for people, from the west of Europe to the north of India, from Scandinavian and Russia to Egypt, and Turkey. Corn, the most renowned agricultural product of the modern world, has economic value with every bit of it and takes part in production of 4,000 different products, directly or indirectly [15]. The fact that cotton, which has key importance in commodity markets, is both the means of livelihood of a large producer mass and the feedstock of national weaving industry, and hence the foreign currency inflow through the Turkish textile sector is realized mainly on account of cotton and cotton-based products lays bare the importance of cotton.

These markets are of great importance in production and yield. According to 2020 data, wheat production in the world is over 750 million tons and Turkey ranks eleventh in the world (with 20 million tons of wheat production) whereas it is among the top five countries in yield (2,000 kg/ha). As for the corn market, Turkey ranks twenty-first in the world and produces 6 million tons corn a year with a production yield of 9,000 kg/ha [2, 3]. In terms of yield, Turkey ranks third after the USA and Canada. Leading countries in cotton production are India (6,000 tons/ha), China (5,800 tons/ha), USA (4,378 tons/ha), Brazil (2,755 tons/ha), Pakistan (1,350 tons/ha) and Turkey (815 tons/ha) (ICAC 2020).

When the regions where cotton is produced in Turkey is examined, production is concentrated in the Aegean, Mediterranean and Southeastern Anatolia regions in general (Gençer et al. 2005) [11].

In cotton production, Turkey ranks 6th in the world, whereas in terms of yield in production, it ranks third in the world (with 1,567 kg/ha) after China (1,758 kg/ha) and Brazil (1,658 kg/ha) [13].

For three product markets, Turkey has foreign dependency in production, which is a factor that triggers price fluctuations, one of the biggest problems in the agricultural sector. Excessive price volatility poses a threat to the political stability of the relevant markets. In this regard, problems related to policies comes first among the problems encountered in production. Apart from political problems, high production costs in agriculture, problems related to production technique, and training problems related to production and processing techniques hinder the production to a large extent [11]. There are many studies on this matter in the literature. A study by [6], similar to this one, stresses that the impact of oil prices on food prices is inevitable, and underlines that analyzing agricultural product prices separately would yield more efficient results for a better understanding of the change in food prices. In similar studies conducted in the following years, [10] found that there was an interaction between the volatility of corn, wheat and crude oil markets. In another study it was reported, considering 24 agricultural product markets between 1980-2010, that oil prices have taken ahold of the agricultural commodity prices [14]. The study that is closest to this study and supports its findings was conducted by [6], in which they examined the volatility spillover among various agricultural futures markets from a new perspective, as single futures markets are deemed inappropriate due to the increasing interdependence of global markets. Having taken the data of corn, cotton and wheat markets, they showed, using generalized autoregressive conditional heteroskedasticity (GARCH VAR) model, that the impact of the volatility of corn futures returns on cotton and wheat futures returns is statistically significant, showing that volatility spillover can be observed in agricultural futures markets in the short run. They also revealed that the effects of speculation on one market may be contagious for other markets, and therefore they argued that the increase in volatility in agricultural prices in recent years is inevitable. In a study examining the level of interdependence among agricultural commodities (corn, wheat, soybeans and soybean oil) in 2017 with a focus on commodity financialization, it has been determined that there is greater spillover in the corn and wheat market, in contrast to, especially, soybean and soybean oil markets, and that surprising economic news have a strong impact on the volatility of agricultural commodities [12]. Among the studies conducted in the recent years, this topic still preserves its actuality. In a study conducted in China in 2018, stressing that the agricultural commodities are among the fastest growing futures market in the world, by means of Generalized Autoregressive Conditional Heteroskedasticity (GARCH VAR) model, they investigated whether there was speculative activity in the Chinese futures markets and found out that the speculation rate had a positive effect on contingent volatility for most commodities, also suggesting that the results were insufficient to hedge potential risk [7]. In a study conducted in 2020, researchers investigated the effect of positive and negative shocks between agricultural products, energy market and industrial materials. They showed that volatility in price changes can be positively or negatively related to demand shocks, depending on demand and supply elasticities. By using Asymmetric Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model, they argue that a positive return shock creates higher volatility in prices, and they stated that there is only a leverage effect in crude oil. In addition, researchers emphasized that volatility is the main determinant of many financial decisions, and attested, in this respect, that their research was important in terms of shedding light on academic researchers and policy makers [8].

In line with the above cited studies, among the agricultural commodity markets, wheat, corn and cotton markets, which are of great importance in international trade, were preferred in this study. As daily price changes in the stock market are important for the study, the data used in the study, therefore, consisted daily market data for the period of 11.02.2005-06.03.2020, obtained from the Union of Chambers and Commodity Exchanges of Turkey (TOBB), İzmir Commodity Exchange, Şanlıurfa Commodity

Exchange, Adana Commodity Exchange and Çorum Commodity Exchange. Aimed in this study is to examine the volatility relationship between wheat, corn and cotton markets by using Baba-engle-kraft-kroner generalized self-coupled conditional multivariate VAR (1) – Asymmetric BEKK – GARCH (1,1) mean equation model in order to understand the wheat, corn and cotton price changes in the stock market. It is extremely important to examine the volatility pass-through between agricultural markets, and for the investor to make current and future investment decisions, it is crucial to know how an uncertainty activity in a market affects that market, as well as other substitute product markets, in the short and long term. Therefore, on account of snapping the uncertainty, being aware of the mobility of the receptors in the market can, at least, relieve the investor and can provide clearer information to the decision makers by revealing, for example, which market carries more risk and what the direction and severity of the spillover uncertainty in the pass-through from one market to another market is. In addition, quantitatively revealing how negative news in a market affects that market and other competing markets through receptors in a different aspect than positive news offers more robust and dynamic information for the investor to make investment decisions. Within the framework of all this information, this study presents information about how the spillover uncertainty, including the spillover effects of negative news, taking place in short and long term affects a market and how big a pass-through to competing markets it induces. At the same time, the results to be obtained from the study are very important in that, it can provide a foresight to the producer to make more pertinent production decisions and to enable the corn, wheat and cotton markets which constitute an important percentage in foreign trade and in the country's economy, to compete strongly with other producer countries.

MATERIALS AND METHODS

Data Set

In this research, among the agricultural commodity markets, wheat, corn and cotton markets, which are of great importance in international trade, were preferred. The daily values of relevant exchanges were followed as the data set. Since it is important to have daily market data in the stock market, daily data were obtained for these three markets. The daily data for the wheat and corn markets were obtained from the Union of Chambers and Commodity Exchanges of Turkey (TOBB), whereas the daily data for the cotton market were obtained from İzmir Commodity Exchange, Şanlıurfa Commodity Exchange, Adana Commodity Exchange and Çorum Commodity Exchange. The study covers the daily data of the markets for the period of 11.02.2005-06.03.2020. Three different data sets were obtained for the three markets in this period, and as a result of the pairing the data, a total of 176 observations were studied. In all models, returns, rather than price levels, were estimated as the dependent variable. The returns of the series are obtained using the formula 1:

$$R_{i,t} = \Delta log(P_{t,i}) = \log(\frac{P_{t,i}}{P_{t-1,i}}) \times 100 \qquad (1)$$

where:
i being 1, 2, and 3 (signifying wheat, cotton and corn), P_t is the current real price of the relevant market, $P_{t-1,i}$ is the price of $P_{t,i}$ in the previous period.

Econometric Method

VAR (1) – Asymmetric BEKK – GARCH (1, 1) mean equation method was used for the analysis of the data set. The asymmetric multivariate GARCH model evaluates potential price volatility spillovers and the model known as the Asymmetric BEKK-GARCH model (Engle and Kroner 1995; Grier et al. 2004) is applied. In this study, since the price volatility between the wheat, cotton and corn markets in question was investigated, the VAR (1) – Asymmetric BEKK – GARCH (1, 1) method, which consists two equations, was preferred as a method. One of the two equations consisted in the method is the average return equation, and the second one contains the return variances. The general representation of the average return equation discussed first is expressed as in equation (2):

$$R_{j,t} = \alpha_j + \sum_{i=1}^{p} \Gamma_i R_{j,t-i} + \varepsilon_t, \quad \varepsilon_t \sim (0, H_t)$$

$$H = \begin{pmatrix} h_{11} & \cdots & h_{1n,t} \\ \vdots & \ddots & \vdots \\ h_{1m,t} & \cdots & h_{mn,t} \end{pmatrix} \quad (2)$$

Here, j denotes wheat, cotton, corn markets, and i denotes the lag level determined by the AIC, BIC or HQ criteria. Here m=n=3 (representing three product markets).

The general expansion of the vector and parameter matrices in the return averages is as given in equation (3).

$$R_{j,t} = \begin{bmatrix} R_{1,t} \\ R_{2,t} \\ R_{3,t} \end{bmatrix}; \alpha = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{bmatrix}; \Gamma_i = \begin{pmatrix} \Gamma_{11}^{(i)} & \cdots & \Gamma_{1n}^{(i)} \\ \vdots & \ddots & \vdots \\ \Gamma_{m1}^{(i)} & \cdots & \Gamma_{mn}^{(i)} \end{pmatrix}; \varepsilon_{j,t} = \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \end{bmatrix} \quad (3)$$

In Equation (3), $R_{j,t}$ denotes yield vector of products, $R_{1,t}$, $R_{2,t}$, $R_{3,t}$ the parameter matrix of previous returns for wheat, cotton and corn, α_j fixed term parameter of each return, and Γi the parameter vector of the lag lengths determined by the AIC, BIC or HQ criteria for each return equation. Since the VAR equation supports only one lag, i.e., the relationship of a lag in, say, wheat, cotton or corn yields with the yield in wheat market can be determined, only one relationship was determined in this study. The same was applied to the return levels of the other two markets. On the other hand ε_t represents the error terms vector, which enables the short-term and asymmetrical relationship in the conditional variance equation be determined.

Considering the lag length, the algebraic representation of the variance equation that constitutes the second part of the VAR (1) – Asymmetric BEKK – GARCH (1, 1) model is:

$$H_t = C^{'}C + B^{'}H_{t-1}B + A^{'}\varepsilon_{t-1}\varepsilon^{'}_{t-1}A + D^{'}\xi_{t-1}\xi^{'}_{t-1}D \quad (4)$$

The equation consists of $3x3$ matrices of H, C, A, B and D. The lower diagonal matrix C contains the constant coefficients of the variance equations. A and B matrices represent short-term shocks and long-term volatility in the markets, respectively. The parameters in the D matrix show the asymmetric effect. The matrix structure in Equation 4 is shown below.

$$H_t = CC' + \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \varepsilon_{t-1}\varepsilon'_{t-1} \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} + \begin{pmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{n1} & \cdots & b_{nn} \end{pmatrix} H_{t-1} \begin{pmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{n1} & \cdots & b_{nn} \end{pmatrix}$$
$$\begin{pmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{n1} & \cdots & d_{nn} \end{pmatrix} \xi_{t-1}\xi'_{t-1} \begin{pmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{n1} & \cdots & d_{nn} \end{pmatrix} \quad (5)$$

where:
m and n = 1, 2, 3.

The parameters in the matrices were calculated using maximum probability methods and marginal effects needed to be calculated due to nonlinear parameter combinations. In this regard, the standard deviations of the marginal effects were calculated using the delta method.

RESULTS AND DISCUSSIONS

In the study, after converting the series to real, the analyzes were made by obtaining the series of returns. The changes in the return and return squares for the series over the years are given in Figs. 1 and 2, and the change in the conditional correlation and variance between the returns over time is given in Figures 3 and 4.

When Figures 1 and 2 are examined in detail, a significant level of price volatility is observed in the returns of wheat, cotton and corn in a period of approximately 7-8 years, between 2008/09 and 2015. The highest price volatility is in the cotton market, followed by wheat and corn markets, respectively. One of the main reason for price volatility can be said to be the world food crisis occurred in 2008/09. In the return squares graph, again, cotton is seen to have the highest frequency range and corn, and wheat follow. The lowest price volatility is in the wheat market. In this regards, the uncertainty, showing up generally in the cotton market, affects the cotton producer and makes them sway to the wheat market, which has a more stable trend compared to cotton and corn.

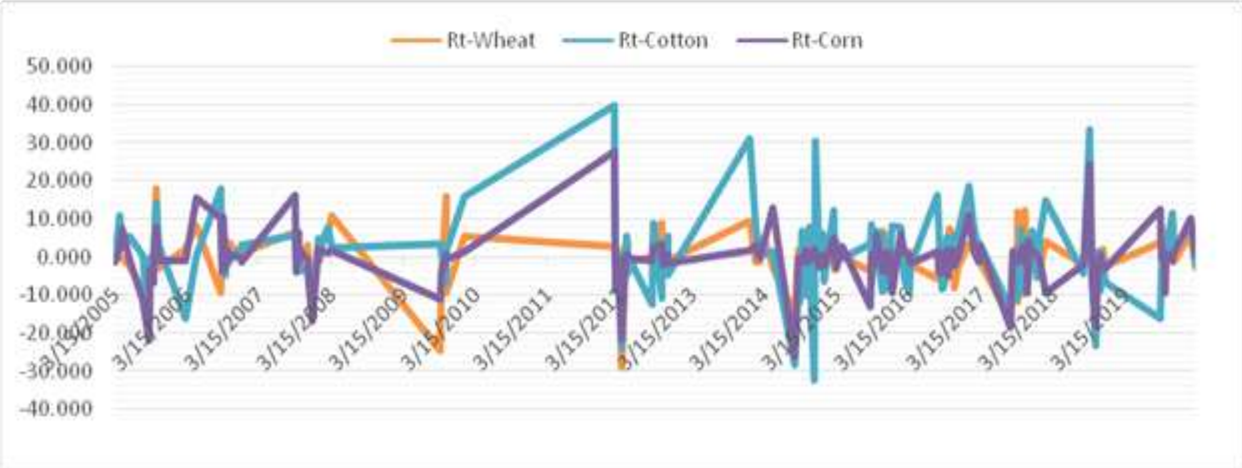

Fig.1. Changes in returns over the years
Source: Authors' own design and calculations.

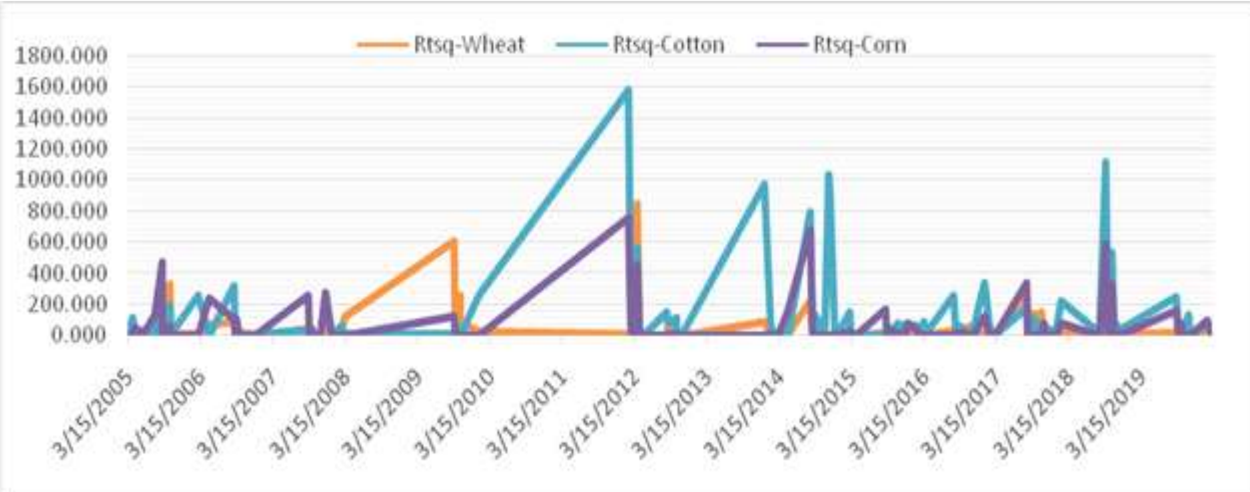

Fig. 2. Changes in return squares over the years
Source: Authors' own design and results.

Looking at the correlation in Fig 3, it is seen that the three product markets affect each other. An uncertainty in the wheat market will show up in the cotton and corn markets. In other words, an uncertainty showing up in the cotton market will have an impact on the wheat and corn markets, similarly the uncertainties in the corn market will have an impact on the other two markets. While the correlation between the three markets was stable until 2008, it showed great volatility in and after 2008. Especially in 2008, the corn market was more volatile than the other two markets. Later in the same year, this price volatility showed up in the cotton and wheat markets, respectively. This situation can be explained by the fact that the effect of the world food crisis that occurred in 2008 was effective in all the three product markets that year and remained in effect for many years. From 2008 to 2015, the volatility in the relationship between wheat, cotton and corn markets continued and uncertainties occurred in the markets due to the price volatility that occurred. Cotton market showed fluctuations the most between these years, corn and wheat markets followed cotton. In this context, it is stated that the wheat market is less affected by the world food crisis and the uncertainties that might have occurred in the markets, or the negative news in those years, compared to the cotton and corn markets. In one study, while cotton was the product that showed the most fluctuations between these years, corn and wheat markets follow cotton. In this context, the wheat market was the least affected from the world food crisis or the uncertainties or negative news that may occur in the markets in those years, compared to the cotton and corn markets. [19] noted that the prices of all agricultural futures exhibited a very volatile behavior due to weak US dollar, rising global revenues, trade restrictions by major grain suppliers, commodity financialization, and very apparent fluctuations in the oil prices, up to the year 2014, and that the volatility in all agricultural grain markets decreased significantly from 2014 onwards.

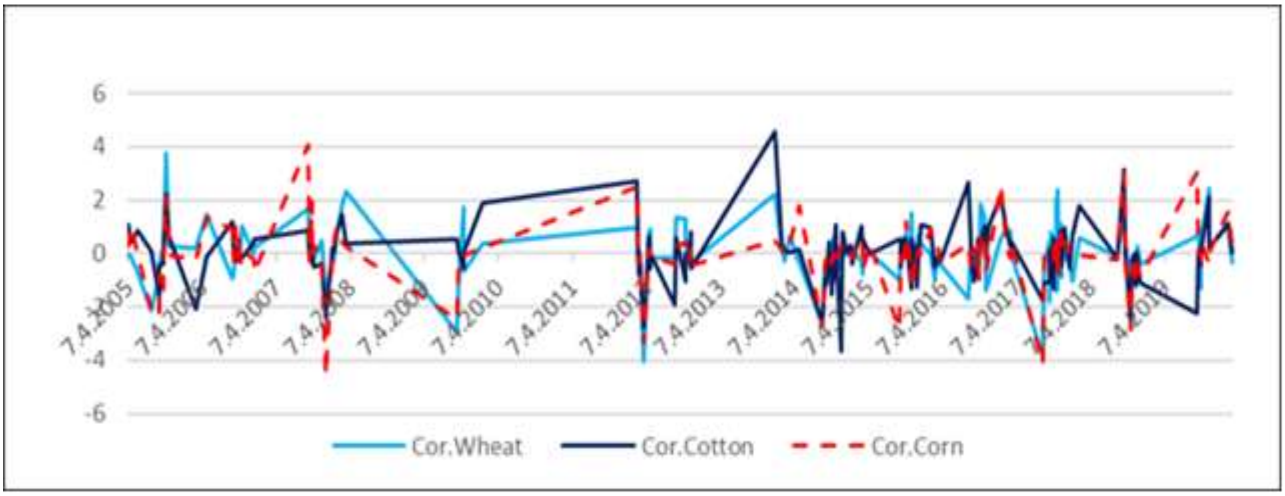

Fig. 3. Conditional correlation between returns over time
Source: Authors' own design and results.

Modeled by the conditional variance equation, conditional volatility and speculative activity measured by two ratios is shown in Fig. 4 [7]. Examining the change in the conditional variance of the wheat market over time, it is noted that wheat showed a considerable fluctuation in 2006, 2012 and 2017/18. While the conditional variance of cotton returns exhibited low volatility from 2005 to 2012, after this year, it showed a large volatility in 2013/14, a relatively less volatility in 2015 and 2017 compared to 2013/14, and the volatility is noted to have been decreasing, generally, since then to the present. The results show that the hedging ratio is not sufficient and it suggests that cotton has a negative effect on the conditional volatility [7], which supports the results obtained in the present study. The conditional variance of the corn returns is seen to have displayed a more stable structure in 2005 and increased significantly in 2007/8. After the year 2008, it exhibited a decrease and a more stable graphic until 2014, whereas from 2014 onwards it have been exhibiting a volatility of drastic increases and decreases. There is a large variation among all three conditional variances. Despite the increase in the conditional variance of corn returns in 2007 and 2008, no significant increase is there in the conditional variance of wheat and cotton returns. Compared to the increase in the conditional variance of cotton returns in 2013/14, the wheat market marked a slight increase, while corn marked a much smaller increase. In this regard, the uncertainty and high price volatility occurred in those years in the cotton market is thought to have made the cotton producer sway to wheat and corn, as an alternative, through which they can produce more profitably. In this context, the results show that the three relevant markets affect each other. A similar study reports that the corn prices increased by 43%, compared to the average of the previous 15 years, in the 2007/08 marketing year [4], hence supporting the results of the present study.

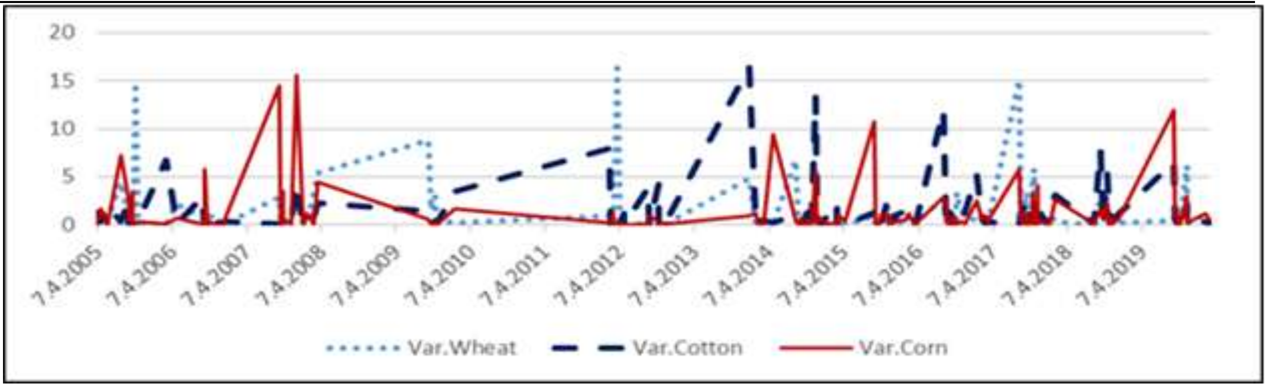

Fig. 4. Conditional variance between returns over time
Source: Authors' own design and results.

As seen in Table 1, the wheat market has higher returns than the cotton and corn markets. Compared to the other two markets, this situation can be explained by the limited supply of wheat, in respect of its position in the current market, and the high price it faces. When the unconditional variance obtained from the standard deviations of the returns of wheat, cotton and corn is examined, it is seen that cotton has higher volatility (standard deviation) than corn and wheat, which has the lowest standard deviation. In this context, cotton market is more volatile, while wheat and corn are relatively stable. Other important statistical value for the return series are the skewness and kurtosis values.

When the skewness coefficients of the return series are examined, it is observed that the return series have an asymmetric distribution. The kurtosis coefficient, on the other hand, indicates that the leptokurtic (fat-tail) values of the return series have a value greater than three and indicates a flat distribution. The presence of leptokurtic distribution in the series indicates that there may be an ARCH effect, that is, it suggests that the markets in question can react asymmetrically to negative and positive shocks in the short term [17]. Another important statistical value in return series is the Jarque-Bera statistic showing that the return series do not have a normal distribution.

Based on to the correlation values for the return series, there is a strong positive relationship between the series. While wheat market has a strong relationship with cotton and corn markets, cotton market has a strong relationship only with corn market. Studies show that the pass-through of volatility between markets is more intense during periods of increased market turbulence that occur due to the increasing financialization of commodity markets in the last two decades [1, 9].

Additionally, Ljung-Box statistic, an important value that shows whether price and return series have autocorrelation, of price levels and closing values were tested and the statistical results showed presence of autocorrelation in the returns of wheat (29.318***) and corn (20.708**), except cotton (13.371).

In order to test the ARCH effect on the return series, the ARCH-LM test introduced by Engle (1982) was applied. According to the results obtained, ARCH effect was observed only in wheat return series, no ARCH effect was observed in cotton and corn returns. However, when viewed simultaneously (MARCH–LM), ARCH effect is observed in the residues of the series, and in this regard, the series is said to have ARCH effect simultaneously, therefore the series need to be analyzed with the multivariate GARCH model. In the literature, the results of the LM tests support the use of the GARCH model, and therefore the volatility of the returns of the variables studied is represented by the conditional variances estimated by the GARCH model [7].

Augmented Dickey–Fuller (ADF) unit root test, proposed by Dickey and Fuller (1979), was applied to determine whether there is stationarity in the return series and the results are presented hereafter. As a result of the unit root test, return series were found to be stationary at the 5% significance level. KPSS test results confirmed the ADF unit root test results.

Table 1. Descriptive statistics

Statistics	Returns		
	$\Delta logPr_{wheat,t}$	$\Delta logPr_{cotton,t}$	$\Delta logPr_{corn,t}$
Mean	0.042	0.281	-0.060
Std. Deviation	5.711	9.052	6.086
t-statistics (mean = 0)	0.097 (0.922)	0.410 (0.682)	-0.130 (0.896)
Skewness	-1.051*** (0.000)	0.530*** (0.004)	-0.166 (0.374)
Kurtosis	5.883*** (0.000)	4.806*** (0.000)	7.563*** (0.000)
Jarque-Bera	282.989*** (0.000)	175,667*** (0.000)	415,596*** (0.000)
Correlation for Price Levels or Closing Values			
$\Delta logPr_{cotton,t}$	0.968		
$\Delta logPr_{corn,t}$	0.995	0.967	
Correlations for Return Series			
$\Delta logPr_{cotton,t}$	0.325		
$\Delta logPr_{corn,t}$	0.512	0.581	
Correlation Between Return Squares Series			
$\Delta logPr_{cotton,t}$	0.308		
$\Delta logPr_{corn,t}$	0.451	0.713	
Testing of Price Levels or Closing Values			
Ljung-Box Q (10)	29,318*** (0.001)	13,371 (0.203)	20.708** (0.023)
Ljung-Box Q2 (10)	19.678 ** (0.032)	7.342 (0.692)	5.122 (0.882)
HM-Q (10)	123.6048 **		(0.010)
Testing of ARCH or Closing Values at Price Levels			
ARCH-LM (10)	1.978** (0.039)	0.721 (0.704)	0.558 (0.845)
MARCH-LM (10)	1009.13*** (0.000)		
Stationarity Unit Root Test for Return Series			
ADF	-11,231** (lags=1)	-9,680** (lags=1)	-10.020** (lags=1)
KPSS	0.035 (lags=1)	0.016 (lags=1)	0.025 (lags=1)

Note: ARCH-LM and MARCH-LM refer to Lagrange and multivariate Lagrange tests, respectively, for ARCH effects.
Ljung-Box Q and Ljung-Box Q2 apply sequential dependency tests on residue and residue squares, respectively.
HM-Q refers to Hosking's sequential dependency test on multivariate residues.
The null hypothesis under the MARCH-LM test assumes a constant common variance and that the mean of the return series is zero.
ADF refers to the Augmented Dick-Fuller test, considering constants and trend variables. KPSS refers to the Kwiatkowski-Phillips-Schmidt-Shin test, which is used to test a null hypothesis that an observable time series is constant around a deterministic trend. Lag selections are based on AIC, BIC and HQ values. Critical values change with selected delays. Values in parentheses reflect p-values. *, ** and *** indicate the significance levels of the parameters at 10%, 5% and 1% levels, respectively.
Source: Authors' own results.

In the panel A section of Table 2, the mean equation and variance equations were examined amount the parameter estimations. According to the average equation values in the table, any positive or negative progress in the wheat market reduces the return (Γ_{11} = -0.247) in the wheat market and is statistically significant. While, a lagged return from cotton market (Γ_{21} = - 0.016) and corn market return (Γ_{31} =0.054) affected the wheat market in a negative and positive way, their degree of influence was found to be statistically insignificant. In a similar study, it was determined that there was more spillover in the corn and wheat markets, apart from other commodity markets, and that economic news surprises had a strong effect on the volatility of agricultural commodities (Hamadi et al. 2017)[12]. The cotton market was negatively but insignificantly affected by its own lagged return (Γ_{22} = -0.073), and effect of the lagged returns from the other two competing markets was positive (wheat) and negative (corn). A similar situation applies to the return level of the corn market. The corn market return is negatively (Γ_{33} = - 0.094) affected by the lagged return of its own market, while it is positively (Γ_{13} = 0.131) affected by the lagged return of the wheat market and negatively (Γ_{23} = -0.02) affected by the lagged return of the cotton market. Result suggest that the markets are differently affected by the cross-markets while they are negatively affected by their own lagged returns. Although increasing return encourages the producer to produce more of the same product, the price level decreases with the excess supply and conforms with the spider web theory.

As the second step of Panel A, the coefficients of the equation of variance are given. In line with the results obtained, it is seen that the long-term uncertainty in wheat market positively affects both its short-term uncertainty (a_{11} = 0.463) and the corn market (a_{13} = 0.107), but while its positive effect on the corn market is not statistically significant, its positive effect on its own the market was found to be statistically significant. In a study conducted in this regard, they argued that a positive return shock induces higher volatility in prices [8]. Short-term uncertainties in the wheat market negatively affects the short-term uncertainty (a_{12} = -0.158) of the cotton market, but is not statistically significant.

Long-term uncertainty in the cotton market, according to the results obtained, is positively affected by both the short-term uncertainty in its own market (a_{22} = 0.896) and the short-term uncertainty in the corn market (a_{23} = 0.652), and it is statistically significant at 1% significance level. Beckmann and Czudaj (2014) [6] determined that the volatility of corn futures returns on cotton and wheat futures returns is statistically significant, showing that a spillover of uncertainty can be observed in agricultural futures markets in the short term, and the results support the results of our study. The short-run volatility spillover between cotton and corn markets supports the situation in the unconditional correlation relationship. The tight relationship between the cotton and corn production patterns constitutes a justification for the price uncertainty pass-through.

Being negatively affected by both its own short-term uncertainty (a_{31} = -0.317) and the short-term uncertainties in the wheat (a_{23} = 0.663) and cotton (a_{23} = 0.659) markets, the long-term uncertainty in the corn market was found to be statistically significant at 1% significance level. Consequently, the spillover of uncertainty, initially showing up in the corn market, will be adversely affected by the short-term uncertainties occurring both in its own market and in the other two competing product markets. In this context, short-term fluctuations in the markets are likely to adversely affect the corn market. [6] showed that the effects of speculation on one market can be contagious for other markets, and therefore, propounded that the increase in volatility in agricultural prices in the recent years was inevitable. Their results is in line with the results we obtained from the present study.

Having combined all the information above, it can be concluded that every agricultural product market is affected by its own short-term internal dynamics, while short-term uncertainties initially showed up in the wheat and cotton markets trigger long-term uncertainties in these markets to become more evident, whereas in the corn market, short-term uncertainty limits the long-term uncertainty of its own market. This situation depends on the transaction volume of selected agricultural products in the markets, and since the wheat and cotton markets constitute huge amounts in terms of transaction volumes, their short-term uncertainties in their markets create a permanent and increasing effect on the long-term uncertainties. In this context, long-term uncertainties of these markets can be limited by avoiding speculations and other short-term shocks that will cause short-term uncertainty in these markets. Interestingly, while the short-term uncertainties initially showing up in the wheat market and the long-term uncertainties of the other two competing markets induce an increasing persistence in the corn market, the short-term uncertainties in the cotton market limit the long-term uncertainties in the corn market, and the short-term uncertainties in the corn market, likewise, limits the spillover of long-term volatility in the cotton market.

In the long run, the uncertainty that may occur in the wheat market is negatively affected by the long-term uncertainty of both its own market and of the other two markets, but it is not statistically significant. The long-term uncertainty in the cotton market, the second product considered, is affected by the long-term uncertainty in the wheat market (b_{21} =-0.449) and is statistically significant. It is positively affected by long-term uncertainty particularly in its own market, and in the corn market, but is not statistically significant. In the light of all this information; the long-term uncertainties in the cotton market are affected by the long-term uncertainty initially showing up in the cotton market, and in a way, the long-term uncertainties in the cotton market eliminate the long-term persistence in the wheat market.

Lastly, the long-term uncertainties in the corn market are affected in a positive way by the long-term volatility that occurs in both its own market (b_{33} = 0.699) and in the other two competing markets (b_{31} = 0.994 for wheat and b_{32} = 0.641 for cotton) at a level that is statistically significant. In a similar study supporting the results obtained in the present study, the effect of volatility in the returns of corn futures on the returns of cotton and wheat futures was reported to be statistically significant, noting that there may be differences for both markets [6]. In the light of this information, the most fragile market can be said to be the corn market, which is affected by its own long-term uncertainty and by the long-term volatility showing up especially in the wheat and cotton markets, thus becoming a market with persistent and high-intensity long-term uncertainty. On the other hand, long-term uncertainties in the wheat market limit the long-term persistence in the cotton market, while increasing the long-term persistence in the corn market. Long-term uncertainties showing up in the cotton market only increase the spillover of long-term uncertainty in the corn market.

When the intermarket asymmetrical relationship is examined, the long-term uncertainties in the cotton market is negatively affected by the negative news from wheat (d_{21} =-0.211) and corn (d_{23}=-0.396**) markets and it is found to be statistically significant. Asymmetric spillover in other markets were found to be statistically insignificant. In this regards, short-term speculative news, especially in the wheat and corn markets, means, in a sense, good news for long-term uncertainties in the cotton market, and limits the spillover of uncertainty. Negative news, initially showing up in the wheat market, primarily triggers the long-term persistence in its own market, while at the same time increasing the long-term uncertainty in the corn market. Negative news, initially showing up in the cotton market, triggers long-term uncertainty in the wheat market and has a negative effect on the corn market.

Among the Panel B diagnostic statistics, Ljung-Box Q and Hosking Ljung-Box (MLBQ) tests were used and these tests show whether there is autocorrelation between the error terms and squares of the error terms obtained from each variance equation. The results showed that there is no autocorrelation between error terms and squares. In this regards, VAR (1) – Asymmetric BEKK – GARCH (1, 1) model is concluded to be valid in explaining the volatility (variance) of each return variable. Another important statistical value in the table is the ARCH effect. Whether the error terms has the ARCH effect or not was examined under the null hypothesis by using individual McLeod-Li and Multivariate LM tests. The results suggest that the error terms obtained from the uncertainty of the returns of respective markets do not have the ARCH effect.

In Panel C, the GARCH, asymmetric and causality relationships of the respective markets were examined by using the diagonal VAR test in the VAR-Asymmetric BEKK-GARCH (1,1) model. The Wald statistic value at 2244.975 ($p<0.000$) obtained by the hypothesis test established for the diagonal VAR test was found to be significant at 1% significance level. Since the statistical value is significant, The H_0 hypothesis (which asserts that A, B, D and all non-diagonal parameters are zero) was rejected.

In this context, it can be concluded that wheat, cotton and corn markets affect each other statistically significantly and that the uncertainties in market returns are affected by short, long and asymmetric uncertainties in other market returns. Among the results obtained in the present study is the fact that shocks that occur or may occur in other markets, or long-term uncertainty and asymmetry that is present in the market have an effect on the uncertainty of respective market [9]. On the other hand, the probability value of the Wald statistic of the hypothesis established to test the GARCH relationship between the markets under consideration was found to be statistically significant at 1% significance level, at 401.859 ($p<0.000$). With the statistical result being significant, the Ho hypothesis was rejected and it was concluded that there was a GARCH relationship between the markets under consideration. The results obtained, hereby, verify the existence of long-term volatility pass-through between the return series of the markets under consideration. It is seen that the coefficients extracted from the variance equation have asymmetric properties ($p<0.000$).

Finally, the causality relationship between the markets was examined. The established H_0 hypothesis states that there is no causal relationship between the market under consideration and the other two markets. Since the results obtained are statistically insignificant, the H_0 hypothesis was not rejected, verifying that there is no causal relationship between the returns of the markets. In this regard, the point reached as a result of all these tests is that the asymmetric BEKK-GARCH model proposed for the explanation of volatility (variance) parameter is coherent with the data [16,18].

Table 2. Parameter estimations of conditional variances, Panels A, B, C

Coefficients	$\Delta\log\mathrm{Pr}_{wheat,t}$ **(i=1)**	$\Delta\log\mathrm{Pr}_{cotton,t}$ **(i=2)**	$\Delta\log\mathrm{Pr}_{corn,t}$ **(i=3)**
Panel A: Average Return Equation and Long-Run Volatility (Variance) Equation			
Average Equation			
α_0	0.056 (0.894)	0.300 (0.665)	-0.059 (0.898)
Γ_{1i}	-0.247 *** (0.005)	0.119 (0.401)	0.131 (0.167)
Γ_{2i}	-0.016 (0.777)	-0.073 (0.435)	-0.023 (0.711)
Γ_{3i}	0.054 (0.564)	-0.029 (0.848)	-0.094 (0.360)
Variance Equation			
c_{1i}	0.898 (0.146)		
c_{2i}	5,334 (0.000)	-0.000 (0.999)	
c_{3i}	-0.937 (0.028)	-0.000 (0.999)	-0.000 (0.999)
a_{1i}	0.463 *** (0.000)	-0.158 (0.185)	0.107 (0.182)
a_{2i}	0.138 (0.062)	0.896 *** (0.000)	0.652 *** (0.000)
a_{3i}	-0.317 *** (0.000)	-0.663 *** (0.000)	-0.659 *** (0.000)
b_{1i}	-0.228 (0.081)	-0.269 (0.108)	-0.140 (0.168)
b_{2i}	-0.449 *** (0.000)	0.189 (0.063)	0.041 (0.311)
b_{3i}	0.994 *** (0.000)	0.641 *** (0.000)	0.699 *** (0.000)
d_{1i}	0.326 (0.034)	0.074 (0.747)	0.037 (0.624)
d_{2i}	-0.211 *** (0.001)	0.450 (0.090)	-0.396 ** (0.025)
d_{3i}	0.029 (0.800)	-0.257 (0.405)	0.389 (0.071)
Panel B: **Diagnostic Tests:**			
Ljung-Box Q (6)	10,432 (0.107)	2,408 (0.878)	4.805 (0.569)

Ljung-Box Q (10)	14.138 (0.166)	16.120 (0.096)	9,682 (0.468)
McLeod-Li (6)	0.988 (0.986)	2.939 (0.816)	4,040 (0.671)
McLeod-Li (10)	2.165 (0.994)	3,830 (0.954)	12,495 (0.253)
ARCH(6)	0.154 (0.988)	0.397 (0.879)	0.717 (0.636)
HM-Q (6)	68,171 (0.092)		
HM-Q (10)	108,514 (0.089)		
HM-Q ^{2} (6)	41,437 (0.894)		
HM-Q ^{2} (10)	67,139 (0.965)		
MARCH-LM(6)	183.20 (0.948)		
MARCH-LM(10)	440.56 (0.002)		
z_i	-0.014 (1.025)	0.020 (1.021)	-0.045 (1.049)
t-stats(z_i *=0)*	-0.192 (0.847)	0.261 (0.793)	-0.578 (0.563)
z_i^2	1.0194 (5.442)	0.983 (4.911)	0.992 (5,430)
t-stats(z_i^2 *=1)*	5.747 (0.000)	5.838 (0.000)	5.604 (0.000)
AIC	19,066		
SBC	19,886		
Hannan-Quinn	19,398		
Log likelihood value	19,078		
Panel C: Wald Test Result			
Diagonal YES	H_0: all non-diagonal elements are zero Γ_{ij}	2,244.975 (0.000)	
GARCH No Relationship	H_0: all i, j = 1,2,3 $a_{ij} = b_{ij} = d_{ij} = 0$	401.859 (0.000)	
No Asymmetrical Relationship	H_0: all i,j=1,2,3, $d_{ij} = 0$	28.874 (0.000)	
Wheat has no causal relationship on the returns of corn and cotton.	H_0: $\Gamma_{31} = \Gamma_{41} = 0$	1.728 (0.421)	
Cotton has no causal relationship on wheat and corn.	H_0: $\Gamma_{32} = \Gamma_{42} = 0$	0.795 (0.671)	
Corn has no causal relationship on cotton and wheat	H_0: $\Gamma_{33} = \Gamma_{43} = 0$	0.0336 (0.983)	

Source: Authors' own results.

CONCLUSIONS

In this study, the results of the examinations made on the aforementioned markets, which maintain their strategic importance in Turkey's economy and foreign trade, by determining the spillover processes of short and long-term risk among them were presented along with the information on how risk receptors in a market perceive the uncertainties that occur both in their own market and in the competing markets. It is very important to investigate the price volatility of the relevant markets because volatility spillover is a phenomenon that significantly affects the investment strategies and decision-making processes of investors in these three product markets. Studies indicate that good predictions on correlation and volatility are needed for risk management and hedging in such markets in this regard, whether a market shock affects the volatility in other markets and/or it spreads into those markets was investigated in this study.

The findings obtained from the analyses show that the conditional variances of returns, cross conditional variances of the variables, unit effects and many other related statistics were found to be statistically significant. It was confirmed with the results that the conditional variances of the returns of the three products under consideration have persistent effects and that there are persistent spillover between the conditional variances of their returns. In line with the results, it was concluded that cotton market has higher volatility (standard deviation) than those of wheat or corn. The product market with the lowest standard deviation is the wheat market. A leptokurtic distribution was observed in the series, and in this regard, it was found that the markets under consideration gave an asymmetric response to negative and positive shocks in the short term. Intermarket correlation results show that there is a strong relationship between the wheat market and the cotton and corn markets. This interaction is followed by wheat-corn, wheat-cotton and cotton-corn markets. When the relationship between the return series in the selected markets was considered; the highest level of relationship was found to be between the cotton market and the corn market, followed by the wheat-corn and wheat-cotton markets, respectively. Another important statistical value that was considered in the study is whether there is an ARCH effect in the series and the results obtained showed that there is only an ARCH effect in the wheat returns among the return series, whereas there is no ARCH effect in the returns of cotton or corn. However, when the simultaneous analysis of three markets in a system (MARCH–LM) was considered, ARCH effect was observed in the residues of the series, through which, it has been determined that the series have ARCH effect simultaneously.

Summarizing the results of the values of mean equation, positive or negative progresses in the wheat market reduce the return in its own market. The cotton market was negatively affected by its own lagged return and positively affected by the lagged values of the other two markets. While the yield of the corn market was negatively affected by the lagged value of its own market, it was positively affected by the lagged value of the wheat market and negatively by the lagged value of the cotton market. In this regard, while the markets were negatively affected by their own lagged values, they were also differently affected by the cross-markets.

Although increasing returns encourage the producer to produce more of the same product, the price level decreases with the excess supply and conforms with the spider web theory. Long-term uncertainties, on the other hand, are affected by the long-term uncertainty of the cotton market, and in a way, the long-term uncertainties in the cotton market eliminate the long-term persistence in the wheat market. In the light of this information, it has been determined that the most fragile market is the corn market, whereas the most robust market is the wheat market, followed by the cotton market.

It has been found that the markets are affected more by the long-term shocks than the short-term shocks and that there is a cross-interaction between the markets, which was explained above in detail in the research findings and discussion section. In line with the hypotheses established by stating how negative and positive news in the economy affect each market, the theory that negative news affects markets more than positive news was seem to conform with empirical findings. Therefore, policy makers should develop opportunities to protect the market makers from possible risk in the short term and strategies that will minimize the price volatility caused short-term shocks. In the study, it has been determined that the shocks that may occur in the long term have a significant impact on both the risks in their own markets and other relevant markets. In this case, it is recommended that policy makers make strategic plans to protect the producer in order to minimize the risks that long-term shocks, as well as short-term shocks, will create in the market. The minimization of risk in product markets in parallel to such decisions expects investors to invest in these markets. On the other hand, the results show that corn is affected more by the shocks than the other two competing markets. Therefore, it is advised that decision makers prioritize the corn market while taking decisions regarding risk minimization. In line with the information given in the study about the spillover of risk within the wheat, cotton and corn markets and between other markets, it is of great importance for the policy makers to minimize the risks that may occur in the markets.

Volatility, a key determinant of many financial decisions, and its critical role in pricing, risk management and investing in financial and physical markets is noted once again in this study. By establishing strong systematic links between the markets under consideration, information that is useful not only to the participants of wheat, cotton and corn markets, but also to national and international investors, producers and consumers, and agricultural product markets with similar characteristics was provided. Therefore, understanding the return-volatility relationship is not only a matter of academic interest, but also of important practical application. Considering that the findings presented in this study will attract the attention of academic researchers, policy makers and industry practitioners, it is necessary to take precautionary decisions in order to make the markets more profitable in the face of short and long-term shocks, speculations or negative and positive news. In line with the suggestions made in the similar studies in the literature and with the results obtained in this study, recommendations deemed to be beneficial to the respective departments and concerned parties mentioned above was made.

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