

Comparative Approach of Measuring Price Risk on Romanian and International Wheat Market

Larisa N. Pop, Irina M. Ban

Abstract—This paper aims to present the main instruments used in the economic literature for measuring the price risk, pointing out on the advantages brought by the conditional variance in this respect. The theoretical approach will be exemplified by elaborating an EGARCH model for the price returns of wheat, both on Romanian and on international market. To our knowledge, no previous empirical research, either on price risk measurement for the Romanian markets or studies that use the ARIMA-EGARCH methodology, have been conducted. After estimating the corresponding models, the paper will compare the estimated conditional variance on the two markets.

Keywords—conditional variance, GARCH models, price risk, volatility

I. INTRODUCTION

WE live in an uncertain world, in which no present action has a perfectly sure future result. Normally, in the economic life, the choices that need to be made are not between risky situations and certain situations, but between different degrees of risk and different possible outcomes. Any economic activity is based on a number of unknown and uncertain factors or opportunities simply because its subject is located in the future.

Risk represents an unsure event, but perfectly possible, which has its origin into uncertainty. If the risk can be associated with danger, uncertainty may have either a negative component generated by detrimental states, or a positive one generated by unpredictable beneficial states. In this situation the negative component is associated with the risk. In the economic field in general, many experts agree that the economic activities are currently exposed at a high degree of risk, determined by the diversification of the variables generating it and the failure in forecasting them.

The price risk is one of the risks more clearly perceived by the participants at the economic activities. The key aspect of this type of risk is the variability of prices. Thus, the price risk is attributed to price movements to which are exposed the participants on a certain market. Volatility increases the risk of receiving a reduced amount of money or of paying a higher

one for a certain good, while increasing also the costs of mitigating it. Whenever the market participants are exposed to changes in prices as part of their economic activities, they are exposed to price risk. These kinds of changes in prices can have adverse impacts on the profit margins of economic agents if the increased costs cannot be passed on further into the business chain.

Efficient risk management involves identifying the risk, estimating its degree, establishing the attitude towards it, and building structures to reduce unwanted risk. Thus, an essential component of an effective risk management is the ability to measure the risk exposure with relative precision. Analytical tools are required for attaining an increased precision in measuring risk.

The price risk approach has to be made by taking into consideration its further three characteristics: the speculative nature of the price, the possibility of quick implementation of hedging methods and the high volatility of certain prices.

- the speculative nature of the price risk: price instability can cause, according to the direction of variation, both losses and gains for an economic operation; under these conditions, often in practice the economic agents prefer to assume the risks and not take any coverage measure hoping for a favorable evolution of prices;

- the possibility of quick implementation of hedging methods: some of these methods, especially those based on the use of futures contracts or options can be implemented within a very short time, allowing a fast reaction in case of unexpected changes in the evolution of prices.

Some prices, especially those formed on the markets on which speculative operations hold a significant share, are characterized by a high volatility, experiencing significant fluctuations in short intervals of time. These fluctuations are difficult to predict and can sometimes result in substantial effects, positive or negative, for the economic transactions exposed at price risks.

The possibility of realizing gains from price variation and the short time in which risks may be covered often lead to price risk-taking attitude. In this situation, however, the high volatility of prices determines the necessity of a dynamic approach of risk, based on continuous observation of the price evolution.

The present paper is structured as follows: the next section presents the main econometric methods used for measuring price risk with their advantages and disadvantages, meanwhile part III focuses on methodology description with an accent on the GARCH models. In the last section, the econometric models are applied for the analysis of two price series: the

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price series of wheat on the Romanian market and the one at international level. Further, in accordance with the obtained results, in the end of the paper it is offered a comparison between the conditional volatility on the Romanian and international markets, as estimated from the models.

II. LITERATURE REVIEW OF ECONOMETRIC METHODS USED FOR MEASURING PRICE RISK

A wide range of methods for measuring price risk can be encountered in the economic literature, evolving from rather simple (like unconditional standard deviation or the coefficient of variation) to more complex ones (like ARCH model and its extensions, Value-at-Risk, etc). Most of them are based on the assessment of historical prices volatility combined with different assumptions regarding price expectations of market participants. Approaches using implied volatilities may also be found (as for example, [1]), implemented for those commodities with efficient futures and options markets.

The investigation of the literature showed that it cannot be chosen a singular method as being the best one for measuring price risk, as the results depend on the characteristics of the analyzed product, the available data series, the position of the assessor in the trading process, or the assumptions regarding price expectations of the market participants [2]-[4].

As [4] synthesized in their paper, the price risk assessment implies a series of alternative approaches that have to be considered:

(a) *to choose between using price levels or price rates of returns (logarithmic price ratios)*. Most of the economic studies use the second approach, as it is supported by the better statistical properties incorporated in the logarithmic price ratios (e.g. [4], [5]).

(b) *to distinguish or not between positive and negative variations*. The distinction implies taking into consideration the fact that for a market participant (in accordance to his position in the act of trade – i.e. seller or buyer), at a certain point in time, only one type of variations have negative consequences, thus it should be considered either downturn or upturn in prices as potential exposure to price risk. In these cases price risk is generally computed based on semi-variance (e.g. [6], [7] and [8]).

(c) *to separate or not predictable and unpredictable components*. Not separating predictable components (like seasonality or trend) and treating all price movements as indicators of instability may overestimate the degree of risk [2]-[5].

(d) *to treat variability as time invariant or time varying*. As variability may change over time, it is not adequate to assume its time invariance without testing it; consequently, in the economic literature a series of methods for testing if the variance of a series has changed between two periods may be found, as for example, in [2] and [5]. Reference [2] also presents a list of reasons that may determine the decrease or the increase of volatility over time, among which may be

mentioned: the existence of imperfect competition, the growth of market and non-market instruments to hedge price risk, policy guaranteed price supports and decreases in macroeconomic instability (as reasons for decrease in volatility), and mismatch between demand and supply, large scale entry and exit on global markets, large scale dumping, significant changes in risk, and so on (as causes for increase in volatility).

It can also be added: (e) *the choice between historical or implied volatility*. The use of implied volatility is conditioned by the existence of efficient futures and options markets [1].

Unconditional standard deviation, the coefficient of variation or the Black-Scholes model represent the basis point in measuring price risk. Other classical approaches include: average deviation, nonparametric volatility coefficient, inter-quartile range, the average percentage change, the moving average, or the Coppock index. From the economic literature using this kind of basic approaches in measuring price risk may be mentioned: [9] used a moving variance of past prices as a risk measure, [10] utilized annual coefficients of variation in modeling the wheat market, [11] used a deviation from past price levels in a rice market model, while [12] took the research a step forward by using the variance of futures prices as a risk measure.

A range of shortcomings may be identified in the mentioned classical approaches, determining an exaggeration of uncertainty and related price risk while computed. These aspects are due to the fact that the unconditional standard deviation and the coefficient of variation do not distinguish between the predictable and unpredictable components of price series, intrinsically assuming that market participants behave in a naive way, not having the ability to detect regular features of the price process. A certain approach is not founded on realistic considerations as it appears unrealistic to suppose that market participants do not have the experience of predicting seasonal behaviors, long-time tendency or cyclical components in the prices of the commodities with which they operate [4]. Further, the Black-Scholes model assumes a constant or deterministic variance of price over time, being unable to account for periods of changing volatility [3].

Researches by [13] and [14], albeit chronologically placed before the previously mentioned studies ([9]-[12]), offer a more suitable approach, assessing risk as a function of past absolute, respectively squared, deviations from expectations [1]. The research of [5], followed more recently by [4], offered different connotations in assessing risk by suggesting a model based on logarithmic returns of monthly prices, with deterministic elements for trend, seasonality, and with autoregressive component, in which the risk is basically associated with the sum of the unpredictable elements of the price process.

A widespread employed approach is represented by the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model [15], which has the merit of accounting for both the predictable and unpredictable components in the price process, while considering time varying conditional

variances, and consequently considering only the stochastic or unpredictable component when assessing price risk [3]. Applications of the GARCH approaches are widespread in situations where the volatility of returns is a central issue [16]. Studies using ARCH model and its extensions are commonly encountered for measuring stock market price risk. With regard to commodity price risks the following can be mentioned: [17] applied the GARCH method to modeling meat production; [18] analyzed the role of price risk in sow farrowings by using bivariate ARCH-M and GARCH-M models and a nonparametric kernel estimator. Also realizing an incursion into the semi-variance approach, [19] built separate ARCH type conditional variance models using separately positive and negative daily returns. Reference [2] used GARCH to determine the volatility of commodity prices in international markets. More recently, [3] measured and compared the conditional volatilities in the prices of some crops traded on the South African Futures Exchange using the ARCH or GARCH approach, depending on which of the two approaches was relevant statistically, while, [4] tested for conditional volatility analyzing monthly wheat procurement prices in Poland.

New connotations of risk measurement were offered by the introduction of Value-at-Risk (VaR), as a measure of price risk. Even though commonly used for assessing financial assets in the context of portfolio diversification, VaR has been implemented also on the commodity market, as for example by [20] who assessed the measurement and analysis of fruit market price risk on the Chinese market. With the introduction of VaR, a new role for ARCH models emerged. A variety of studies analyzed the effectiveness of volatility models in computing VaR and comparing these methods with it, GARCH methods proving to be successful if errors were not assumed to be Gaussian [16].

III. METHODOLOGY

When analyzing time series with a relatively high volatility, there are two main problems that must be overcome: autocorrelation of the residuals and heteroscedasticity. Heteroscedasticity refers to a situation in which the variances (σ_t^2) do not have a constant evolution in time, being conditioned, on one hand, by its own lagged values (σ_{t-i}^2) and revealed by the GARCH-terms and, on the other hand on the lagged values of standardized errors with the aid of so-called ARCH-term $\left(\frac{\varepsilon_{t-i}}{\sigma_{t-i}}\right)$.

The GARCH (*generalized autoregressive conditionally heteroscedasticity*) models are meant to resolve both the autocorrelation and the heteroscedasticity problem, especially when analyzing time series with a high volatility like price returns [15]. Generally speaking, a GARCH(p,q) model includes two equations: one for the conditional mean (1) and the other for the conditional variance (2).

$$X_t = \mu + \varepsilon_t \quad (1)$$

$$\sigma_t^2 = \omega + \sum_{i=1}^p \alpha_i \cdot \varepsilon_{t-i}^2 + \sum_{j=1}^q \beta_j \cdot \sigma_{t-j}^2 \quad (2)$$

The coefficients of ARCH-terms (α_i) reveal the volatility of previous periods of time and this volatility is measured with the aid of squared residuals from the equation of mean. The coefficients of GARCH-terms (β_j) show the persistence of passed shocks on the volatility. In order to have a stationary system, the sum of the two coefficient must be smaller than unity: $\sum_{i=1}^p \alpha_i + \sum_{j=1}^q \beta_j < 1$.

For some time series, the conditional mean (μ) cannot be expressed through a constant, but through an autoregressive moving average process (ARMA). This is due to the fact that in the case of financial data a higher risk is normally associated with a higher expected return. In order to include in the model also this aspect, [21] proposed an extension of the GARCH models, in which the conditional variance generates a risk prime to be included in the expected return [22]. This extension is called GARCH-in-Mean (GARCH-M). The most common measures used to approximate the conditional volatility are: standard deviation (σ_t), dispersion (σ_t^2) or the logarithm of dispersion ($\log \sigma_t^2$). Introducing one of these elements in the model, we obtain a transformed mean equation:

$$X_t = \mu + b \cdot \log \sigma_t^2 + \varepsilon_t \quad (3)$$

When b is positive and statistically significant, we can conclude that a higher risk will generate a higher return.

In our empirical analysis, we started from the model described above, but during our research we concluded that for the price returns the asymmetrical GARCH models perform better compared to the symmetrical ones. The symmetrical models assume that both the positive and negative innovations have a similar impact on volatility. In reality, it was demonstrated that for certain financial series, their volatility is significantly higher after negative shocks ($\varepsilon_t > 0$) compared to its level after positive ones ($\varepsilon_t < 0$), behavior known in the economic literature as the leverage effect [23]. This effect is included in the so-called EGARCH model, with the aid of an asymmetric coefficient, γ_i . Furthermore, in this case there are no more restrictions concerning the coefficients from the conditional variance equation.

In the next paragraph we intend to describe the evolution of price return with an AR(k)-EGARCH(p,q) process, elaborated by [24], as follows:

$$X_t = \pi_0 + \sum_{i=1}^k \pi_i \cdot X_{t-i} + \varepsilon_t \quad (4)$$

$$\log(\sigma_t^2) = \omega + \sum_{i=1}^p \alpha_i \cdot \left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} - E\left(\frac{\varepsilon_{t-i}}{\sigma_{t-i}}\right) \right| + \sum_{l=1}^r \gamma_l \cdot \frac{\varepsilon_{t-i}}{\sigma_{t-i}} + \sum_{j=1}^q \beta_j \cdot \log(\sigma_{t-j}^2) \quad (5)$$

where the residuals from (4), ε_t , follow a GED or a normal distribution and the $\log(\sigma_t^2)$ is the logarithm of conditional variances, our measure for the price risk in the present paper.

IV. EMPIRICAL RESULTS

We chose to analyze the wheat market for Romania, because according to some studies [25], the wheat was and remained one of the most competitive Romanian products from the group of commodities. Moreover, we considered appropriate and useful to analyze in parallel the international wheat market in order to use it as a basis for comparison. We analyzed the evolution of selling prices for Romania, offered by the National Institute of Statistics and the corresponding ones at the international level in FOB prices, Gulf of Mexico, from the International Monetary Fund database. Our study is based on monthly data between January 2004 and December 2010, the range of observations being limited by the fact that there is no information regarding the national wheat prices before 2004. Our research began with a descriptive analysis of the wheat price return series, revealing that its volatility is not constant in time, indicating the presence of heteroscedasticity, which could make our data more appropriate for a GARCH model approach. In order to detect the serial autocorrelation, we analyzed the autocorrelation (ACF) and partial autocorrelation function (PACF) estimated for a number of lags varying from 12, 24 to 36 and the calculated Q-statistics indicated the presence of this phenomenon. In Table I, we present other descriptive statistics, which show especially that the log returns of Romanian wheat prices do not follow a Gaussian distribution.

TABLE I
 BASIC STATISTICAL MEASURES OF THE NOMINAL SELLING PRICES IN ROMANIA AND THEIR RETURNS FROM JANUARY 2004 TO DECEMBER 2010

Measure	Nominal prices	Log returns of Romanian prices	Log returns of international prices
Mean	0.511617	0.002346	0.007408
Median	0.490000	0.000000	0.001794
Maximum	0.860000	0.331357	0.243798
Minimum	0.270000	-0.329626	-0.214460
Std. Dev.	0.154656	0.094420	0.076773
Skewness	0.601804	-0.592884	0.145643
Kurtosis	2.715593	6.663262	4.164073
Jarque-Bera	5.353450	51.27163	4.979699
Probability	0.068788	0.000000	0.082922

Source: own calculations in Eviews 5.1

The series are not normally distributed because, when measuring different moments characterizing our data, we can observe that the skewness is different from zero and the kurtosis has a value larger than 3, as they should be for a Gaussian distribution. At the international level, the null hypothesis of normal distribution cannot be rejected at the level of 5% statistical significance, but the associated probability is not convincingly high.

Because, when elaborating a GARCH model, the variables must be stationary, we will test, in the next step, the non-stationarity of the time series. If the series are non-stationary and they are used in the model, there is a high probability to obtain a spurious regression and, correspondingly, a false model.

TABLE II
 TESTING THE NON-STATIONARITY OF NOMINAL SELLING PRICES IN ROMANIA AND THEIR RETURNS FROM JANUARY 2004 TO DECEMBER 2010

	t-Statistic	Prob.*
Null Hypothesis: WHEAT has a unit root	-1.868600	0.6617
Null Hypothesis: DLN_WHEAT has a unit root	-4.660808	0.0002

*MacKinnon (1996) one-sided p-values.

Source: own calculations in Eviews 5.1

In Table II we showed the results of ADF test, including constant and trend for the nominal prices and only intercept for the price returns series, at the national level. For the nominal prices the calculated value of the t-Statistic is larger than the corresponding one at the 5% level of significance and the associated probability is 0.66. This means that we cannot reject the null hypothesis that the nominal prices have a unit root, which means that this series is not stationary. On contrary, when we take into consideration the price returns, it can be noticed that the probability is smaller than 0.05 and the data for price returns fulfills the requirement of stationarity. We obtained similar results for the price returns of wheat at the international level, which demonstrate that the log returns of prices perform better from a statistically point of view and they should be further taken into consideration.

In the next step, we estimate the models for each of the two variables both for the conditional mean and conditional variance. Equations (4) and (5) will be estimated using the maximum likelihood. Based on the information criterion minimization (especially that of Schwarz) and on the residual test, we chose the appropriate number of lags.

As we showed in the literature review section, when measuring price risk, the researchers use mostly ARIMA or GARCH model. We did in the same manner, but when comparing the in-sample forecast with the real values, we could notice that a combined model ARIMA-EGARCH with a GED distribution perform better and produce more accurate estimates.

That is why, for the case of Romania, we considered that the best model has the following form: ARIMA(2,1,13)-

EGARCH(1,1). The econometric program Eviews 5.1 estimated the coefficients (the z-Statistics are given in parenthesis):

$$\hat{r}_{Ro,t} = 0.359 \cdot r_{Ro,t-2} - 0.184 \cdot SAR(12) + 0.222 \cdot \varepsilon_{t-13} \quad (6)$$

(7.32) (-4.04) (6.24)

$$\log(\hat{\sigma}_t^2) = -6.16 + 1.149 \cdot \frac{\hat{\varepsilon}_{t-1}}{\hat{\sigma}_{t-1}} + 0.003 \cdot \log(\hat{\sigma}_{t-1}^2) \quad (7)$$

(-2.30) (2.60) (0.005)

We are mainly interested in (7), which estimates the conditional variance as an indicator for price risk. Because the coefficients are based on EGARCH model, there are no restrictions related to their values. We can remark that, at the national level, only the ARCH-terms are statistically significant and an innovation in the last month will generate an increase in the degree of volatility.

At the international level, the appropriate model is:

$$\hat{r}_{Int,t} = 0.269 \cdot r_{Ro,t-6} - 0.656 \cdot \varepsilon_{t-13} \quad (8)$$

(2.20) (-10.23)

$$\log(\hat{\sigma}_t^2) = 0.027 - 0.072 \cdot \frac{\hat{\varepsilon}_{t-1}}{\hat{\sigma}_{t-1}} + 0.987 \cdot \log(\hat{\sigma}_{t-1}^2) \quad (9)$$

(1.811) (-1.20) (184.87)

Equation (9) reveals that at the international level, the GARCH-terms are statistically significant, which means that the current volatility depends mostly on the passed volatility and not on passed innovations (shocks) in the system.

Based on (6)-(9), we generated the series of conditional volatility, in order to compare for the period 2004-2010 which market was more volatile and, correspondingly, on which market the price risk was higher.

The results are given in Fig. 1, both for the conditional volatility at the international and national level.

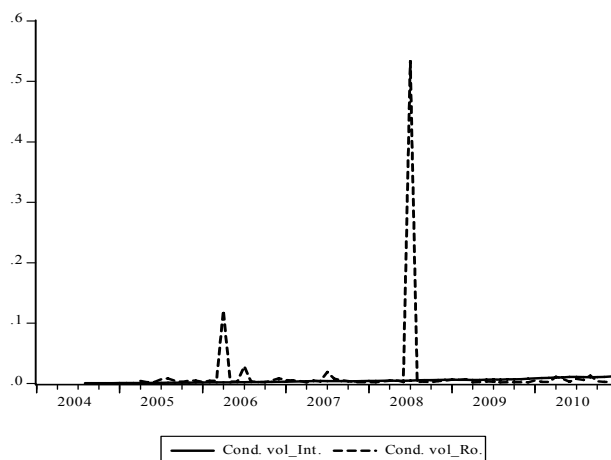


Fig. 1 Conditional volatility for the Romanian and international wheat market from January 2004 to December 2010

Source: own calculations in Eviews 5.1

As shown in Fig. 1, the estimated values of conditional volatility show an increase of the price risk between 2004 and 2010. The main difference consists in its trend in time. At the international level the price risk has smoothly increased, meanwhile at the national level there are some “peaks” generated by different events, explained in the following paragraphs.

Mostly weather-related factors (droughts) amplified the instability of the market in 2005. In 2007, Romania has become a member of European Union and trade liberalization has generated a sudden increase of price risk. But the most important volatility was registered, as the graph indicates, in 2008 and the cause was mainly the financial crisis which affected dramatically our country, generating a sudden fall of prices, after a previous steady increase generated by economic growth and EU enlargement.

Comparing the two evolutions of volatility for the two wheat markets, we can affirm that the price risk has much larger proportions at the national level, a sign of an insufficient development of its mechanisms.

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