Analysis and Forecast of Volatility of Producer Price Index in Agriculture

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Abstract

The work is devoted to the methodology for predicting the variability of price conditions that determine producer operation in agriculture. There were investigated the series of producer price indices by crop and livestock industries. Additionally, the dynamics of the food price index volatility was examined. The main objective of the study was to form, according to available data, models of generalized autoregressive conditional heteroscedasticity - GARCH. The analysis was based on the data from index growths, hyper-parameters and model specifications were selected by information criteria. A preliminary exploratory analysis of time series was carried out, an intermediate simulation of average values was made using SARIMAX algorithms. Selected models were used to formulate the forecast for the next period, including twelve months of 2020. Conclusions are drawn from the data. Difficulties in further use of predictive models and implementation of the received forecasts are indicated. They are primarily related to the growing uncertainty in the world and domestic economies.

Keywords: producer price index; consumer price index; livestock production; crop production; food products; GARCH; volatility forecast.

Introduction

According to some researchers, despite population growth, income growth, the introduction of new technologies, and globalization, until recently it was difficult to capture clear global trends in food price levels or their degree of variability (Larson, 2018). However, food prices have been rising since 2010, making it less accessible to the population and signaling that agricultural productivity growth is slowing. At the country level, terms of trade are unstable, and at the farm level, these processes hinder investment and technology adoption in the long term.

Inflation factors play a significant role in the process of business activity, and taking into account the prolonged problem of price disparity in agriculture and falling consumption levels, they greatly strengthen their importance for agricultural business. The new concept of food security (Decree on food security, 2020, January 20) emphasized the special importance of the products' affordability for population. This, among other things, is closely related to the general problem of the formation of aggregate demand in the domestic economy, including for food products.

The calculation of inflation at macro- and mesoeconomic levels occurs by fixing changes in price indices from both consumption and production. Therefore, a special aspect in the study of price factors is the analysis of their volatility - the degree and nature of their variability over time.

The main objective of this study is to analyze and forecast the volatility of price indices, for which it is necessary to solve a number of intermediate tasks. An important note on the term "volatility" in the work is: depending on the stage of the study, the term was applied to the variance and standard deviation for the main models, and as a standard data error for the exploratory (primary) analysis.

Methods

Autoregressive conditional heteroscedasticity (the term is taken from English - ARCH, Autoregressive Conditional Heteroscedasticity) is a model used in econometrics to analyze time series in which the variance of conditional on past values of the series depends on the past values of the series themselves, past values of these variances and other factors. These models are intended to interpret the clustering of volatility in various markets (primarily in financial ones), when periods of high volatility last for some time, followed by periods of low volatility, and the average, or in other words long-term, unconditional volatility can be considered relatively stable.

ARCH models were first proposed in 1982. A few years later, a generalization of these models appeared (Generalized ARCH, GARCH). After that various scientists proposed other versions of models of a similar type, taking into account certain data features. The ARCH model assumes that the conditional variance depends only on the squared errors of past values of the time series. This

model can be generalized assuming that the conditional variance also depends on past values of the conditional variance itself (Sheppard, 2019). In this case, the model is GARCH (p, q), where p is the order of the GARCH members, q is the order of the ARCH members. The model is described as follows:

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

The unconditional variance of the stationary GARCH (p, q)-process will be constant and equal.

There are a large number of derived models, for example, Exponential GARCH (EGARCH), which was used in the current work.

Results

Figure 1 shows the dynamic series of monthly producer price indices (PPIs) of crop production, livestock and consumer price indices (CPI) of food products from 2000 to 2019.

Source: formed by the authors according to the Federal State Statistics Service of the Russian Federation

Figure 1. Price indices of producers of crop and livestock production, and consumers of food products (Rosstat, 2020)

Indices in the source data are monthly percentage changes (growth) in prices. For further study, they were rescaled into monthly increments (value minus 100). Visually expressed seasonal character for each indicator with a period of 12 months. Thus, for the producer price index in livestock farming, the maximum was observed in the winter months, and at least the end of summer - the beginning of autumn. For the crop production index, respectively, the maximum was at the beginning of autumn and the minimum at the end of spring. Interestingly, the decomposition of a number of crop production shows another more complex seasonality with a period of 36 months. For the consumer index, seasonal fluctuations were more frequent with peaks in autumn and a decline towards the end of summer.

Table 1 summarizes the main statistics for preliminary analysis (EDA, Exploratory Data Analysis), which includes basic statistics for time data.

Table 1. EDA of monthly growth of the studied indices

Growth of indices	Average	Median	Minimum	Maximum	Drift	Average annual volatility (standard error)	Stationarity hypothesis, test KPSS, $p > 5\%$
PPI of livestock production (ΔPPI_{live})	0.7	0.7	-4.0	8.8	-1.6	0.1	accepted
PPI of crop production (ΔPPI_{crop})	0.8	0.5	-6.3	9.5	-0.8	0.2	accepted
PPI of food products (ΔCPI_{food})	0.8	0.7	-1.8	5.7	-1.5	0.1	accepted

The average growth rates are almost identical. Medians also do not differ much from the average, which indicates a slight asymmetry in the distributions. The largest minimum and maximum are observed in a number of data in crop production, which accordingly affected the higher average annual volatility (in this case, calculated similarly to the standard error). All the indices show a negative drift, which is calculated as the difference between the last and first values of the data range.

Table 2 suggests that a significant correlation in the variables is observed mainly with their previous values (autocorrelation), while the relationship between the signs is insignificant.

Table 2. The matrix of cross-correlations (linear, Pearson's) of the main features and their lags for 1 period L^1

Indices	ΔPPI_{live}	ΔPPI_{crop}	ΔCPI_{food}	$\Delta PPI_{crop} L^1$	$\Delta PPI_{live} L^1$
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PPI _{live}	0.4				
Δ CPI _{food}	0.2	0.5			
Δ PPI _{crop} L ¹	0.1	0.7	0.5		
Δ PPI _{live} L ¹	0.7	0.4	0.4	0.4	
Δ CPI _{food} L ¹	0.0	0.4	0.7	0.5	0.2

Thus, the producer price index in livestock has a high correlation (0.7) with its values of the previous year. The remaining indicators show similar behavior: the producer price index in crop production and the consumer price index for food.

A deeper analysis also revealed the absence of significant nonlinear relationships. As a result, the use of exogenous variables is not required in a subsequent SARIMAX analysis.

Discussion

Before starting the analysis of volatility, we construct models of the series' average levels. To do this, we use seasonal auto regression and moving average algorithms with the ability to add an exogenous variable (SARIMAX). Using specialized libraries of the Python software environment (Sheppard, 2019; Pmdarima, 2020) based on the BIC information criterion, appropriate specifications and hyper-parameters were selected for the desired models.

Table 3. SARIMAX modeling based on the BIC information criterion

Row	Specification and hyper-parameters
Δ PPI _{live}	SARIMAX (1, 0, 1) (0, 1, 1) ₁₂ Without inclusion of exogenous variables, without a constant
Δ PPI _{crop}	SARIMAX (1, 0, 1) (0, 1, 1) ₁₂ Without inclusion of exogenous variables, without a constant
Δ CPI _{food}	SARIMAX (1, 0, 1) (0, 1, 1) ₁₂ Without inclusion of exogenous variables, without a constant

It is interesting that the selected hyper-parameters for the models are identical. The presence of first-order autoregression confirms the data presented in the cross-correlation matrix. There were also confirmed stable seasonality with annual periodicity.

To simulate volatility, the first step was to remove the seasonal component from the data (seasonal adjustment). Similarly, based on the BIC information criterion, there were selected the appropriate specification and hyper-parameters (Table 4).

Table 4. GARCH modeling based on the BIC information criterion

Row	Specification and hyper-parameters
Δ PPI _{live}	E-GARCH (2,1) Распределение t-Сьюдента
Δ PPI _{crop}	E-GARCH (1,1) Распределение t-Сьюдента
Δ CPI _{food}	E-GARCH (1,1) Распределение t-Сьюдента (асимметричное)

According to Table 4, the most appropriate specifications are exponential GARCH (EGARCH) for all traits studied. Hyper-parameters for a number of livestock productions (2, 1) with distribution of Student, for a number of crop productions (1, 1) also with a similar distribution. The food distribution adds asymmetry to the model, but has hyper-parameters similar to the previous ones (1, 1).

As mentioned above, the model returns the volatility in the form of dispersion, which can be converted into standard deviations for greater clarity. Figure 2 shows the forecast of changes in the volatility (standard deviation) of the indices in 2020, excluding the seasonal component.

Figure 2. Forecast of changes in the index volatility for 2020 without seasonality

It is seen that the variability of production indices is much greater than that of the consumer index. This generally reflects the variability of the source data, where production is more prone to fluctuations. According to the data obtained, it is especially possible to single out the crop industry, which is characterized by increased volatility. On the one hand, this is due to the specifics of production itself (seasonality), on the other hand, the nature of interaction with other industries and agribusiness sectors, and the characteristics of consumer activity for these products. So, for example, when analyzing the interaction of price production indices and agricultural production indices themselves, a special influence of the livestock industry was revealed (Shestakov et al., 2020). Suggestively, the institutional transformation and the tendencies toward the monopolization of agricultural production determine the industry as a vanguard, and this, in turn, affects price dynamics. Volatility, among other aspects, may decline with a consistent increase in prices. Perhaps that is there are observed a tendency to curtail the dynamics of production price indices and consumption index. The gradual convergence of deviations during the year is apparently

indirectly influenced by the ongoing process of “disparity” of prices in the agro-industrial complex and the imbalance of inter-industry relations.

As for the Russian agro-industrial complex, foreign economic relations are of great importance regarding the export of agricultural products and the import of capital goods and high-tech goods. And here the problems of the value of the national currency are already coming into play. In our economic conditions, strongly influencing inflationary processes.

Price factors are only one of many systemic elements that help in forecasting production volumes, crops and other aspects of business activity in agribusiness (Shestakov et al., 2020), and they can often serve as leading indicators for future changes in the state of the industry, price balance in different areas of the business. Moreover, in the opposite direction, it is necessary to take into account regional and climatic (seasonal) conditions, state support, and the general state of the economy at the macro level. All this, to one degree or another, will put pressure on prices.

In general, the work showed that the use of such methods of studying volatility is possible not only from the point of view of analyzing market returns, for example, in the exchange trade in agricultural goods, but also in terms of studying the price factors of business activity (Rahmawati et al., 2019; Bhardwaj et al., 2014). Using these methods, it can be additionally calculated the confidence intervals of the forecast, as well as the risks of accelerating or slowing down inflation. This can be used in agribusiness forcing, planning and decision making at different levels.

An interesting direction for further research would be to study the impact on price indices of digital transformation in agriculture. The digital transformation is fairly moderate and unevenly in some sectors of the national economy. In the new market economy, domestic agribusiness is a driving force for improving efficiency. Quite significant progress has been made in improving the competitiveness of agricultural producers and increasing the return on resource use. In recent years, agricultural production has shown one of the best dynamics in terms of labor productivity. The downside of these processes was the negative impact on employment, and as a result on the growth of rural depopulation (Lerman, Uzun, 2017). The digital vector can also help with social problems. Thus, for modern agribusiness, the scientific and innovative component is critically important, especially in view of the sanctions conditions and the priority of effective import substitution.

Experts also confirm the close relationship between energy prices and prices for agricultural products, which is important for the Russian economy, where the role of the raw material component is quite large. Prices in agriculture respond directly to any shock in the resource markets. Here you can enable and the problems of mixed domestic pricing of petroleum products

and electricity (Taghizadeh-Hesary et al., 2020). In the long term, fluctuations in resource prices affect food security, which requires diversifying energy consumption and increasing energy efficiency in agribusiness.

It should be noted that the forecast was made for 2020 according to the available data of the past. However, it is clear without any doubt that the new period was marked by the arrival of the so-called "black swans" in the world and domestic economies. This may include the coronavirus pandemic, the general drop in global economic activity, and also, which is especially significant for the Russian economy, the fall in prices for basic natural resources. Further development of the situation is characterized by a high degree of uncertainty, with a predominance of negative scenarios. Apparently, there will be two multidirectional trends. On the one hand, increasing uncertainty will act as a driver of price fluctuations, on the other hand, weakening economic activity will reduce their amplitude. Such complex interactions will require further observation and analysis.

Conclusion

The article presents the analysis and forecast of the volatility of the dynamic series of producer and consumer price indices of agricultural products. As the main tool, the GARCH family of models was used. Preliminary analysis included calculating basic statistics and modeling averages using SARIMAX. The forecast showed the dynamics of volatility for production indices in comparison with the consumption index for 12 months of 2020. As far as one can judge by the results obtained, there are differences in the dynamics of volatility between production and consumer price indices. At the same time, there is a slight tendency for convergence of the variability dynamics. This may indicate negative processes in the economy associated with institutional features of agribusiness and macroeconomic conditions. As a development of the topic, a foresight study seems to be interesting taking into account the growing instability and crisis phenomena in the economy since 2020.

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