FORECASTING THE PRICE OF AGRICULTURE PRODUCTS USING THE DECOMPOSITION OF TIME SERIES

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Abstract

Becoming familiar with the price level of particular kind of decisions such as: strategic, tactical, operational should be supported by the results of forecasts with an appropriate time horizon. A short-time method of forecasting agriculture products prices employing a time series decomposition is presented in this study. This method based on the assessment of the mean level of prices resultant from long-period trends and cyclical changes, corrected by seasonal fluctuation and eliminating irregular changes during calculation. The study materials consist of monthly time series of broiler chicken prices for the years 2007-2017. A sample forecast was performed for broiler chicken prices for the time period from one to six month ahead. The level of ex-post relative (MPE) and absolute (MAPE) errors were calculated for each forecast. The presented method can be particularly useful for forecasting prices of agricultural products characterized by seasonal fluctuation.

Keywords: *price, time series, seasonal fluctuation, broiler chicken*

1. INTRODUCTION

Projection is a rational, scientific prediction of future events. This means that, in the entire research process, including the collection of data, their analysis and formulation of conclusions as well as transfer of results from the past into the future, the basis is the theory and the scientific apparatus. Projection is understood as a judgment regarding the future of the projected phenomenon. The projection should be characterized by the following features [Cieślak 2005]: (1) established with the use of scientific achievements, (2) relating to a specific future, (3) empirically verifiable, (4) uncertain, but acceptable.

The term ‘projecting’ is often replaced by the terms ‘making conclusions for the future’ or ‘prediction’, which cover all the principles and methods of making conclusions regarding the future based on the appropriate model, whereas the specific result of this projecting process is called the projection. The projection method includes the method of processing data regarding the past and the way of transition from processed data to projection [Czerwiński and Guzik 1980]. The method is characterized by the fact that, if different people apply it to the same case, they achieve the same results.

Analyzing (diagnosing) the past takes place through the construction of a formal (e.g. econometric) or mental model created in the mind of an expert [Borkowski et al. 2004]. The projection rule is a way of moving from processed data to projection. The most commonly used rules include: the basic rule, the basic rule with the amendment, the highest probability rule and the minimal loss rule.

The aim of the study is to present a short-term projection method based on the decomposition of a time series of prices and to carry out an example of a projection of prices of broiler chicken livestock in a time horizon of one to six months in advance.

2. MATERIALS AND METHODS

The research material constitutes the monthly prices of broiler chicken livestock in the period from January 2007 to December 2017. The data comes from the Integrated System of Agricultural Market Information (2018). Organized by years and months, they formed a statement referred to in the study as ‘a time series of prices of broiler chicken livestock’.

In the time series, the following components can be distinguished (Dittman 2008):

- The development tendency (tendency) (T); it is a long-term propensity for one-way changes (increase or decrease) in the price. It is considered as an effect of the influence of a fixed set of factors,
- Cyclic fluctuations (C); they are expressed in the form of long-term fluctuations in price values around the development trend, which are characteristic by repetitive and rhythmic intervals of more than a year.
- Seasonal fluctuations (S); these are fluctuations in the value of the observed variable (price) around the development tendency and are repeated within the time interval not exceeding one year.
- Random fluctuations - a random component – (I).

The difference between a cyclic component and a seasonal component lies in the fact that the latter occurs at regular (seasonal) intervals, while cyclical factors usually have a longer, sometimes changing period.

The description of a given time series depending on the functional relations of its components can be expressed by an additive or multiplicative model [Stańko 1999]. The study uses the multiplicative model, as, following preliminary calculations and statistical analyzes, it was found that it better describes the time series of broiler chicken prices. In the multiplicative model, the observed values of the variable in time (Yt) are the product of the components of the time series:

$$Y_t = T_t C_t S_t I_t \quad (1)$$

Due to the interdependence of the long-term tendency (T) and cyclic fluctuations (C) shaped by similar factors, in the study, these components of the time series of prices were treated jointly as a common tendency-cycle component (TtCt). Distinguishing cyclic changes requires, primarily, a sufficiently long time series covering several full cycles.

The decomposition of the time series was carried out in the following stages (Stańko 1999),

The long-term development tendency was estimated using a suitable centralized moving average of 12 (for monthly data).

1. The tendency-cycle component (Tt Ct) was eliminated from the empirical series by dividing the output value of the series by the moving average values calculated in the previous point,

$$\frac{Y_t}{T_t C_t} = \frac{T_t C_t S_t I_t}{T_t C_t} = S_t I_t \quad (2)$$

2. Crude seasonality indicators were calculated as geometric means for like-named time units (the same months),
3. Adjustments of seasonality indicators were made, during which all crude seasonality indicators were divided by their average, and then multiplied by 100. After this transformation, the average adjusted seasonality indicators should be 100.
4. The elimination of seasonality was done by dividing the empirical series (Yt) by pure seasonality indicators (St) specified in point 4:

$$\frac{Y_t}{S_t} = \frac{T_t C_t S_t I_t}{S_t} = T_t C_t I_t \quad (3)$$

5. Random fluctuations (It) were separated by dividing the time series cleared of seasonal fluctuations by an appropriate mean (SR = TtCt), called the ‘Henderson curve’:

$$\frac{T_t C_t I_t}{T_t C_t} = I_t \quad (4)$$

The length of the Henderson moving average is selected depending on the value of the quotient of irregular to cyclical fluctuations (I/C). For the analyzed I/C series, it was 0.93; therefore, a 9-word moving average was used.

The Census II/X11 method was used to determine the seasonality indicators (Kudrycka and Nilsson 1993). In order to arrive at the final assessment of the tendency and seasonal fluctuations, this method applies a series of subsequent adjustments to the estimators, due to (extreme) outliers. Another advantage of the Census II/X11 method is the ability to estimate seasonal fluctuations for each year separately, which allows the analysis of potential changes in seasonality patterns in longer periods of time. The calculations were made using the time series analysis package and projection included in the Statistica 12.0 software (Kot and others 2011).

3. RESULTS

The results of the decomposition of a part of the time series of the monthly prices of broiler chicken livestock in the period from September 2015 to December 2016 are presented in Table 1.

Year	Month	Real prices TCSI [PLN]	Seasonality indicators S [%]	Prices cleared of seasonal fluctuations TCI [PLN]	Irregular fluctuations I [%]	Prices cleared of irregular and seasonal fluctuations TC [PLN]
2015	9	3,62	103,95	3,48	100,21	3,48
2015	10	3,48	98,26	3,54	101,45	3,49
2015	11	3,34	96,22	3,47	100,71	3,45
2015	12	3,17	94,45	3,36	98,87	3,39
2016	1	3,19	94,36	3,38	99,61	3,39
2016	2	3,24	97,11	3,34	99,37	3,36
2016	3	3,37	100,07	3,37	100,18	3,36
2016	4	3,28	98,11	3,34	100,06	3,34
2016	5	3,43	100,33	3,42	103,55	3,30
2016	6	3,43	103,73	3,31	99,93	3,31
2016	7	3,52	106,13	3,32	100,56	3,30
2016	8	3,53	107,38	3,29	100,05	3,29
2016	9	3,38	103,95	3,25	100,03	3,25
2016	10	3,19	98,26	3,25	99,08	3,28
2016	11	3,12	96,22	3,24	99,35	3,26
2016	12	3,08	94,45	3,26	100,47	3,25

Table 1. Components of the time series of monthly prices of broiler chicken livestock

Explanations of symbols as in Formula 1

Source: own calculations based on (Integrated... 2018).

Based on the numerical data contained in Table 1, livestock price projection for the period from January 2016 to June 2017 was developed (Table 2). The predicted price in January 2016 (PLN 3,26 zł · kg^{-1}) was obtained as a product of the average value of prices from September to December 2015, cleared of irregular and seasonal fluctuations (PLN 3.45 · kg^{-1}) and the seasonal changes index in January 2016 (94.4%). Based on the same average price value (PLN 3.45· kg^{-1}), adjusted to include the seasonality indicator for February (97.1%), the projection for February 2013 was prepared - PLN 3.35 · kg (a two-month horizon of the projection). The projections were prepared in the same way in the horizon of three to six months, that is from March to June 2017, taking into consideration seasonality indicators appropriate for these months. The projection horizon of one month means that the projection was based on the data available a month earlier. Similarly, the six-month projection horizon means that the projection was prepared on the basis of data available six months before the projected period, respectively.

Year	Month	Development tendency TC(śr4)*	Seasonality indicators [%]	Projected price [PLN] Projection horizon/months					
				1	2	3	4	5	6
2016	1	3.45	94.4	3.26	–	–		–	
2016	2	3.43	97.1	3.33	3.35	–		–	
2016	3	3.40	100.1	3.40	3.43	3.45		–	
2016	4	3.38	98.1	3.31	3.33	3.37	3.39	–	
2016	5	3.36	100.3	3.37	3.39	3.41	3.44	3.46	
2016	6	3.34	103.7	3.47	3.49	3.50	3.53	3.56	3.58
2016	7	3.33	106.1	3.53	3.55	3.57	3.58	3.61	3.64
2016	8	3.31	107.4	3.56	3.57	3.59	3.61	3.63	3.65
2016	9	3.30	103.9	3.43	3.44	3.46	3.47	3.50	3.51
2016	10	3.29	98.3	3.23	3.24	3.25	3.27	3.28	3.30
2016	11	3.28	96.2	3.15	3.16	3.17	3.19	3.20	3.21
2016	12	3.27	94.4	3.09	3.10	3.10	3.12	3.13	3.14
2017	1	3.26	94.4	3.07	3.08	3.09	3.10	3.11	3.13
2017	2	–	97.1	–	3.16	3.17	3.18	3.19	3.20
2017	3	–	100.1	–	–	3.26	3.27	3.28	3.29
2017	4	–	98.1	–	–	–	3.20	3.21	3.22
2017	5	–	100.3	–	–	–	–	3.27	3.28
2017	6	–	103.7	–	–	–	–	–	3.38

Table 2. Price projection for broiler chicken livestock by decomposition of a time series with a horizon of one to six months

Source: own calculations based on (Integrated... 2018).

For the period covered by the projection, the actual prices of broiler chickens livestock were also known. Awareness of real prices allowed us to analyze the accuracy of the projections prepared. To this end, for each projection, the *ex post* relative error for the specified projection horizon and the mean absolute percentage error (MAPE) were calculated (Table 3).

The projected price of broiler chicken livestock in January 2016 at the level of PLN 3.26 PLN / kg (Table 2) was higher by PLN 0.07 than the actual price (PLN 3.19· kg^{-1}), and the relative error of the projection was 2.11 % (Table 3). In the horizon of one month, the mean error (MAPE) of the price projection for 2016 was 1.21%, with the biggest error (2.86%) in the projection for February. At the two-month projection horizon, the mean error was at the level of 1.43%, while the maximum error (projections for February) was 3.479%.

			Relative error (%)					
			Projection horizon (months)					
Year	Month	Real price PLN · kg^{-1}	1	2	3	4	5	6
2016	1	3.19	2.11	–	–	–	–	–
2016	2	3.24	2.86	3.47	–	–	–	–
2016	3	3.37	0.91	1.90	2.50	–	–	–
2016	4	3.28	1.02	1.65	2.65	3.26	–	–
2016	5	3.43	-1.61	-1.22	-0.59	0.38	0.98	–
2016	6	3.43	1.03	1.73	2.13	2.77	3.78	4,40
2017	7	3.52	0.35	0.72	1.42	1.83	2.47	3,47
2017	8	3.53	0.76	1.24	1.61	2.32	2.73	3,37
2017	9	3.38	1.44	1.87	2.36	2.73	3.45	3,86
2017	10	3.19	1.21	1.60	2.02	2.51	2.89	3,60
2017	11	3.12	1.24	1.49	1.88	2.31	2.80	3,18
2017	12	3.08	0.21	0.51	0.76	1.15	1.57	2,06
2017	1	3.11	-1.00	-0.69	-0.39	-0.15	0.24	0,66
2017	2	3.18	–	-0.51	-0.20	0.10	0.34	0,73
2017	3	3.38	–	–	-3.52	-3.22	-2.93	-2,69
2017	4	3.29	–	–	–	-2.84	-2.55	-2,25
2017	5	3.21	–	–	–	–	1.83	2,14
2017	6	3.30	–	–	–	–	–	2,41
Mean error			1.21	1.43	1.70	1.97	2.20	2.68
Maximum error			2.86	3.47	3.52	3.26	3.78	4.40

Table 3. Comparison of *ex-post* errors in livestock price projection depending on the horizon of the projection

Source: own calculations based on (Integrated... 2018).

Projections prepared in the longer horizon are burdened with respectively higher errors. In the six-month horizon, the mean error was 2.68%, while the maximum error (the price projected for June at the level of PLN 3.58 ± 0.15 PLN / kg) was 4.40%.

4. DISCUSSION

The paper presents a short-term projecting method based on the decomposition of the time series of prices. Awareness of the manner in which prices of agricultural products are formed is important when making production decisions. Individual types of decisions should be supported by the results of projections with an appropriate time horizon. In the case of strategic decisions to undertake cost-intensive production and construction of new recovery rooms, long-term projections predicting profitability of production for several decades are needed in order to ensuring the return of funds invested in the fixed capital. In the case of long-term strategic decisions, the projection of a short-term slump in favorable economic conditions does not exclude the profitability of long-term investments. The results of medium-term projections may be useful in making decisions regarding the modernization of equipment with a depreciation period close to the horizon of such a projection. Decisions regarding a single production cycle, and, in particular, its start or end date, should be supported by the results of short-term projections with a horizon covering the duration of a given cycle. The duration of the production cycle of broiler chickens is one of the shortest in agriculture in comparison with other branches of both animal (pork and beef) (Utnik-Banaś and others 2016) and vegetable production (cereals, potatoes, beets) (Figiel 2002; Wicki 2010). In agriculture, as in the entire economy, the cyclical changes in production are observed. Cyclic changes in pork production are most characteristic and relatively well described (Szymańska 2012). There are also cyclical changes in the production of chicken broiler hens, but they are not so clear and regular (Utnik-Banaś et al. 2018). This is due, among others, to greater flexibility and the ability to adjust production to the changing economic situation, resulting from the short production period and faster reproduction of the stock compared to the production of pork or beef.

The presented method may be particularly useful for projecting prices of agricultural products in a short period of time, characterized by a distinct seasonality of prices.

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