Modelling the Development of the Consumer Price of Sugar

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Abstract. Sector of sugar production and hence production of sugar beet are so far the most regulated branch of the crop production not in the European Union, and hence it is difficult to predict their development. However, knowledge of future consumer sugar prices can help the manufacturers when deciding on the amount of production and during planning. The aim of the article is to predict future development of consumer prices of sugar crystal in the Czech Republic for the period from 09/2016 to 08/2017 using ARIMA model based on the data base of the monthly consumer price of sugar in the period 09/2000–08/2016. Data were obtained from www.agris.com. On the basis of diagnostic tests ARIMA model (1, 1, 1) was selected for modelling. Medium variant forecast predicts moderate growth rates of sugar crystal from 18.40 CZK / kg to 19.12 CZK / kg. The upper variant with a 90% probability promises a significant increase to 22.98 CZK / kg. The low variant expects decline of the price to 15.26 CZK / kg in 08/2017. This is the most probable scenario taking into account the development on the sugar market.

Keywords: ARIMA model, sugar crystal, prediction, consumer price of sugar

JEL Classification: C61, C63
AMS Classification: 62H12

1 Introduction

Sector of sugar production and hence production of sugar beet are so far the most regulated branch of the crop production in the European Union (EU). The quantity produced is limited by quotas, as well as the purchase price is also a subject of adjustments. On the cultivation of sugar beets are provided "subsidies within the scheme of sensitive commodities, which amount to 450 billion CZK (approximately one-third of the original amount of subsidies for sugar beet)" [11]. On imports from third countries are imposed high import duties. Toward the end of sugar quotas and termination of regulation of its production, imports and exports in October 2017, the farmers fear a decline in purchase prices of sugar beet. Sugar factories, on the other hand, welcome that they will be able to decide about the amount of sugar produced and sold by themselves. Currently, the sugar in the Czech Republic (CR) is produced only 7 factories, while 25 years ago there were more than 50 and 150 years ago even 400. Decline of the sugar industry was caused by number of historical events, from the nationalization, the concentration of factories in large units and state intervention in the 70s, through the return to a market economy in the 90s till entrance of the CR to the EU in 2004. Those events lead to "important changes of the owner structure of the land and factories for sugar production, to their closing and consequent changes in distribution channels of the sugar, to massive decline of the sowing areas of sugar beet and strong concentration of planting of the sugar beet in suitable natural conditions, that caused consequent increase of yields of sugar beet" [5]. "Production quota for sugar Czech Republic amounting to 372 459 tons remains in the last fiscal year with quotas at the same level and is divided among five sugar farms with 7 manufacturing plants" [8]. Expected influence of the terminus of quotas on consumer prices of sugar is so-far unclear. The prices of sugar underwent through decline during last 2 years, that caused the decrease of revenues of the sugar factories.

The aim of the paper is to model consumer prices of sugar using econometric methods and predict their development one year ahead. The paper is structured as follows: Firstly, researches that are concerned with price modelling are introduced. Than is describe the Box-Jenkins methodology that is used to model the development of the sugar price. The results are presented in next section and discussed in following one. Last section concludes. Many researches are concerned with modelling of agricultural commodity prices. For modelling volatility of agricultural commodity prices are usually used Generalized Autoregressive Conditional Heteroscedasticity (GARCH) models [17]. To predict the prices is widespread a Box-Jenkins methodology. For example, [10] used ARIMA (1, 0, 0) to model consumer prices of eggs. [12] modelled several agricultural commodities' prices and argued that ARIMA is a suitable method for price modelling. [6] used econometric model to model monthly prices of eggs from March 2000 to September 2009 in China. The explanatory variables were commercial price, feed market prices and first-

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order and second order lag of monthly eggs. For the case of egg prices in Japan, [9] applied autoregressive model and modified multiple regression model on monthly and yearly wholesale egg prices between years 1986 and 1990. Alternative method for time series modelling can be artificial neural network. These models have better statistical characteristics and they can capture a significant number of turning points [4].

2 Methodology

Box-Jenkins methodology was chosen for the purpose of modelling of the time series of the consumer price of sugar. It requires long time series of data. Future development is predicted based on the knowledge of stochastic trend. The model was elaborated in several steps. Firstly, the stationarity of the time series was tested using unit root test. All 3 types of Augmented Dickey-Fuller test (ADF test) – with constant and trend, with constant only, and without constant and trend – were elaborated and was chosen the most appropriate. (In this paper, we have non-seasonal monthly published data, for other cases see e.g. study [14], [15] or [16]). ADF test with constant and trend is calculated as (1).

$$\Delta Y_t = \beta_1 + \beta_2 t + \beta_3 Y_{t-1} + \sum_{i=1}^{m} \alpha_i Y_{t-i} + \varepsilon_t , \tag{1}$$

where ΔY_t is the first difference of the examined time series, t is trend variable, ε_t is pure white noise error term, m is the maximum length of the lagged dependent variable, and α, β are parameters (β_1 represents the constant). Methodology by [1] was used to elaborate a model with autoregressive (AR) and moving average (MA) processes. Diagnostic of the type of the model is done by Autocorrelation function (ACF) and Partial Autocorrelation function (PACF) that were plotted to determine, what process generated the time series and what is the order p of AR process and order q of MA process. When the time series is not stationary, its difference of d^{th} order must be done. If the time series include all processes it is an ARIMA (p, d, q) model (2).

$$Y_t = \beta + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=1}^{q} \delta_j \varepsilon_{t-j} , \tag{2}$$

where α and δ are parameters and β is the constant. When there is a seasonal term, the models are formulated as SARIMA (P, D, Q) (p, d, q). The adjustment was done by algorithm elaborated by Census X13-ARIMA. Verification of the model for autocorrelation was done for by Breusch-Godfrey serial correlation LM test [3]. Null hypothesis states that there is no serial correlation. If the calculated value of the test exceeds the tabled test criterion from Fisher and χ^2 distribution the null hypothesis is rejected and there is autocorrelation. Heteroscedastity was tested by Autoregressive Conditional heteroscedasticity (ARCH) test [3]. Null hypothesis is again that the variance of the stochastic term is constant and finite. The test is also using Fisher and χ^2 critical values and rejects the null hypothesis when the calculated value of the test exceeds the table values. Finally, the normality was tested using Jarque-Bera test [3] with null hypothesis that the residues are normally distributed. Calculated value of the test is compared to critical value of J-B distribution. If the value exceeds the table one, null hypothesis is rejected. Based on the ARIMA model, the predictions are done for next 12 months and 90% confidence intervals are introduced. We used software EViews 8 for the calculations.

3 Data

A total of 192 observations were analysed from 09/2000 up to 08/2016. Data were obtained from the Czech Statistical Office (CZSO) and are available besides others from www.agris.cz. Time series of weekly consumer prices of sugar until 2011 was by calculating the arithmetic mean converted to monthly frequency to match the frequency of data collected from 2011 onwards. Data for 01 and 05/2015 were calculated as the average of previous and following values in the time series.

The average annual sugar prices are given in the Table 1. At the end of 2000 and beginning of 2001, the price was around 22 CZK / kg, but in the second quarter it fell below this level and continued to fall. It fell below 21 CZK / kg in 03/2002 and in the last month of 2002 it fell below 20 CZK / kg. The year 2003 was marked by very low prices, which reached a minimum in 08/2016 (16.76 CZK / kg). Then came slow growth, which peaked price 26.35 CZK / kg the following year. Last quarter of 2004 the price was above 25 CZK / kg. However, in the second quarter of 2005 appeared decline again. It continued in the following year too. But the price did not fall below 21 CZK / kg. The return to growth of crystal sugar consumer price was recorded in 08/2006, when it again exceeded the limit of 22 CZK / kg. In the following months occurred dramatic fluctuations. In 2007 and 2008 the price fluctuated between 20 and 22 CZK / kg. Only in the second quarter of 2009 it dropped below 20 CZK / kg and continued to decline until 01/2011. At the end of 2012 occurred rapid growth on 24.85 CZK / kg. Higher prices

were noted in the following year (on average 24.15 CZK / kg). There was a decline in prices to 19.40 CZK / kg in 12/2014. Prices continued to decline throughout the year 2015 to an absolute minimum in 11/2015. Despite the fact that prices increased this year they reached maximum of only 18.23 CZK / kg in 08/2016.

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Price	22.36*	21.84	20.56	17.74	22.31	23.27	21.73	21.90	21.00
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Price	19.81	18.23	22.45	24.27	24.15	22.03	17.75	16.20**	

Note: *Average 09-12/2000, **Average 01-08/2016; Source: own elaboration

Table 1 Average annual consumer prices of sugar crystal (in CZK / kg)

4 Results

Using ADF test without trend and constant it was found out that the time series is non-stationary at 5% significance level (*t*-statistic = -0.6105, p-value = 0.4518). It is stationary after 1st difference, i.e. that the time series is I(1). ACF and PACF analysis revealed that the best model for capturing the time series of sugar is ARIMA (1, 1, 1) without constant. In order to improve statistical characteristics of the model, a unit impulse was added. Variable IMP took value 1 in 08/2004, 02 and 04/2011, where there were shocks in prices, and value 0 otherwise. Using this model, the residues are not autocorrelated (based on the results of *Q*-statistics and Breusch-Godfrey test. The variance of the residues is according to the ARCH test constant and finite. Results of Jarque-Bera test shows that residues are also normally distributed.

Estimated parameters are displayed in Table 2. All parameters are statistically significant (p-value is lower than the level of significance $\alpha = 0.05$). Compared to the alternative models (which results are not displayed here) based on information criteria this model appeared to be the most suitable. Model fulfil all econometric requirements and can be used for predictions. Residual diagnostics are displayed in Table 3 and Figure 1.

Variable	**Coefficient**	**Standard error**	**t-value**	**Probability (p-value)**
IMP	3.2877	0.2878	11.4218	0.0000
AR(1)	0.8347	0.1612	5.1779	0.0000
MA(1)	-0.7386	0.1963	-3.7626	0.0002
R^2	0.4297	Akaike information criterion		1.4399
Adjusted R^2	0.4236	Schwarz criterion		1.4911
Durbin-Watson statistics	2.0662	Hannan-Quinn criterion		1.4606

Table 2 ARIMA(1, 1, 1) model estimates for consumer prices of sugar, Source: own elaboration

Breusch-Godfrey Serial Correlation LM Test:				**Heteroskedasticity Test: ARCH**			
F-statistic	1.1507	Prob. F(2,185)	0.3187	F-statistic	1.9048	Prob. F(1,187)	0.1692
Obs*R-squared	0.7245	Prob. Chi-Sq.(2)	0.6961	Obs*R-squared	1.9058	Prob. Chi-Sq.(1)	0.1674

Table 3 residual diagnostics of ARIMA(1, 1, 1) model, Source: own elaboration

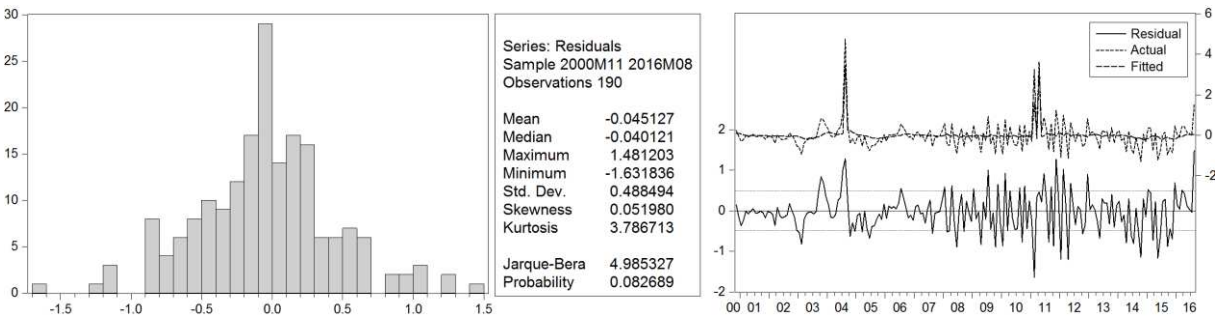

Figure 1 Normal distribution of residuals and graphical control, Source: own elaboration

Development and prediction of consumer prices of sugar, along with a 90% confidence interval is shown in Figure 2. From the graph, there are visible two significant declines in 2003 and again even deeper decline towards the end of 2015. According to the forecast the price should mildly and constantly grow from 17.57 CZK / kg in 09/2016 up to 19.12 CZK / kg at the end of the period 08/2017 without significant fluctuations. This price is relatively low and corresponds to the price, which was on the market between late 2009 and mid-2010. According to the upper variant, there is 90% probability that the growth will be much higher. Price could thus reach 20.64 CZK / kg at the end of 2016 and 22.98 CZK / kg in 08/2017. Still, it will not be reach the high prices that prevailed in the market since the second quarter of 2011 and mid-2014. The lower variant of calculation assumes that with 90% probability the prices will decline from 17.57 CZK / kg in 09/2016 until 15.26 CZK / kg. It reaches nearly a minimum price of 15.17 CZK / kg, that sugar showed at the end of 11/2015. Whereas in recent years the price of sugar has been highly volatile (except for the period from the second quarter of 2011 to mid-2014), for the period 09/2016–08/2017, no significant fluctuations in the price are expected.

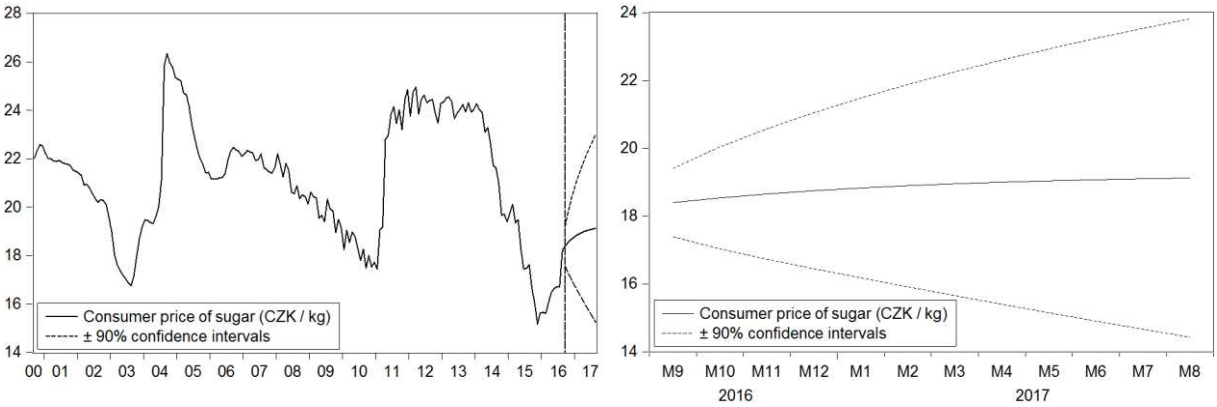

Figure 2 Last development and prediction of consumer price of sugar (CZK / kg), Source: empirical data from www.agris.cz, own elaboration

5 Discussion

Our results can be compared to those of [12]. She also found that the agricultural time series are non-stationary and stationary after first differentiation. For most time series, she analysed, there were also the best type of models ARIMA (1, 1, 1). Similarly, [7] did not find any seasonality in the prices of sugar on the Czech data from year 1993. Regarding the determinants of the price, the analysis of [13] „proved that global sugar price is independent of the level of global sugar reserves level." However, the consumer sugar prices depend on the market situation. As [2] showed the prices of agricultural producers are reflected in consumer prices of sugar.

Ongoing reform of the sugar market in 2006–2009 caused significant decrease of the guarantee price for the producers of sugar beet in EU. This decreased was reflected in real prices, when the prices of sugar producers in 2015 continued in sharp decreased on average 12.13 CZK / kg. In the first half of 2016, the prices were not decreasing any more, but fluctuated around 12.36 CZK / kg of sugar supplied from sugar factories to the market. Consumer prices reaction was fast and the sugar crystal price decreased on average 17.79 CZK / kg during year 2015 and continued to decrease in 2016 (average price for 01–06/2016 was 16.24 CZK / kg). (MoA [8]) Hence, we can expect that the most probable scenario of the price development will be the lower variant – lower bound of 90% confidence interval of our prediction. The price may decrease according to this scenario from 17.57 CZK / kg for 09/2016 to 15.26 CZK / kg in 08/2017.

6 Conclusion

Knowledge of future consumer sugar prices can help the manufacturers when deciding on the amount of production and during planning. Therefore, the article predicted the consumer price of sugar for 09/2016 to 08/2017. Used ARIMA methodology allows to conclude on future price only on the basis of past development of the time series, which is advantageous in terms of data availability. However, the disadvantage is that if it was the past development in time series is very volatile, the prediction may be biased. The aim of the contribution was not only to state what exactly will be the consumer price of sugar in the future, but also to set boundaries in which the price will move with a certain probability. These boundaries are confidence intervals that establish the minimum and maximum price of sugar, which occurs at given time with a 90% probability.

In our case, the predicted price in lower variant was only 17.57 CZK / kg for 09/2016 with a strong trend of decline, falling to 15.26 CZK / kg in 08/2017. This is the most probable scenario taking into account the development on the sugar market. Contrary to that, the upper variant envisages for the same periods growth from 19.22 CZK / kg to 22.98 CZK / kg. Finally, medium variant of forecast expects a slight increase from 18.40 CZK / kg to 19.12 CZK / kg.

Acknowledgements

The research was supported by the Czech Science Foundation project no. P402/12/G097 DYME – "Dynamic Models in Economics" and from Internal Research Grant no. 1110/2017 of Institute of Agricultural Economics and Information.

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