Modelling of slaughter pigs' prices in the Czech Republic using stochastic models

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Abstract. Despite that the economic situation in pig meat sector improved in years 2015 and 2016, second half of 2017 was worse again due to decrease of slaughter pig price that tends to be highly volatile. Knowing the future price of slaughter pigs can minimize the risks related to the decision-making at pig farms. Hence, the aim of the paper is to find optimal model that can be used for modelling and predicting of monthly prices of slaughter pigs. Data from 01/1998 to 06/2016 are used to predict slaughter pig price for period 07/2016–06/2017. Two types of stochastic models are used. First, the development of slaughter pig meat producers' prices is modelled by Seasonal Autoregressive Integrated Moving Averages (SARIMA) model. Consequently, the relations with monthly prices of fodder plants (available only for period 02/2006–06/2016) are searched using Vector Autoregressive (VAR) model.

Keywords: SARIMA, slaughter pig price, VAR.

JEL Classification: C61, C63
AMS Classification: 62H12

1 Introduction

The sector of pork meat production has been in crisis in the Czech Republic (CR) recently. The decline of the state of sows is visible since in 1989 due to high competitiveness and cheap imports from abroad. The situation worsened after the entrance of the CR to European Union (EU). Cancelling the import tariffs lead to increased imports of live animals and pig meat. The producer's prices were low and the costs of production high [16]. The most important changes since the entrance to the EU happened in the size of the pig farms. The number of farms reduced, but their size has increased. This enabled them to adjust their production and achieve the returns to scale [10]. Also the price changes of the inputs (feed) cause distortions. For example, during 2014 there has been a high volatility in feed prices resulting in high prices for both cereals and compound feeding stuffs (see [9]). The price of slaughter pigs is volatile, which affects the decision making on the farm. "Extreme price spike and volatility in agricultural commodity prices creates negative effects on macroeconomic instability, posing a threat to food security in many countries," (Bayramoğlu [2]). Like in other sectors, the price is determined based on the agreement between the seller and the buyer. However, as Jaile-Benitez, Ferrer-Comalat and Linares-Mustarós [8] noted, "this agreement rarely remains stable because it is often reached after unwanted pressures, creating situations of dissatisfaction that involve one of the two parties". Farmers' bargaining power is lower. The reasons for asymmetric price transmission in the agro-food chain was examined e.g. by Backus, Falkowski and Fertö [1] using meta-analysis of existing studies.

Modelling and prediction of prices and finding the relations between the developments of various prices had been a subject of a long-time examination by many authors. For example, Rumánková [13] used Box-Jenkins Autoregressive Integrated Moving Averages (ARIMA) modelling method to project the prices of selected agricultural commodities. She found out that mostly the time series are integrated by the order of 1. Saengwong, Jatuporn and Roan [14] also found that the prices of broilers, cattle, duck and hogs are stationary when their first differences were taken into account. Their study also modelled the cointegration of price elasticity, searched for causalities among prices and forecasted future prices of broiler, cattle, duck and hog in Taiwan by using time series analyses (the unit roots, Johansen cointegration, Granger causality and variance decomposition tests). Šimpach [15] observed prices of honey and sugar and found out that "in some years the honey prices and sugar prices have developed in a similar trend. In this case the change in sugar price had slight delay." How the agricultural commodity prices are influenced by oil prices was studied by Fowowe [7] in South Africa. However, there was no evidence of a long-run relationship. Rafiq and Bloch [12] found that there was a non-linear relationship between oil and most of 25 commodity prices they examined using linear and nonlinear ARDL models for long-run relations and asymmetric Granger causality tests for short-run causalities. Fernandez [6] examined the causalities between four US price indices and 31 commodity prices from 1957 to 2011. She found out that "agricultural raw materials

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(cotton, hides, rubber, and wool), beverages (coffee), food (maize, rice, and wheat), minerals, ores and metals (copper), and vegetable oilseeds and oils (groundnut oil and soybean oil) display bidirectional linear and non-linear feedback effects vis-à-vis price indices", (Fernandez, [6]).

In order to examine the current situation and to project future development of prices of slaughter pigs in the Czech Republic, univariate and multivariate approaches to the time series analysis are used. Individual time series is scrutinized and forecasted by Box-Jenkinson methodology (SARIMA model), and the type of the relations among multiple time series is examined by VAR model. Both models are also used for predictions. The paper is structured as follows. First, methods and data are described. In the article we are concerned not only with modelling of the individual time series, but the relations between particular prices are also examined and future development is projected. Next section presents results of both forecasts and compares them. Last section concludes.

2 Methodology and Data

There are two groups of methods used for the time series analysis – univariate and multivariate. First, the Box-Jenkins [3] Seasonal Autoregressive Integrated Moving Average (SARIMA) analysis is applied on time series of individual series of price of slaughter pigs. Second, the influence of the price of the feed (short-term relationship) is examined using Vector Autoregressive (VAR) model. Both models are diagnostically tested.

First, the time series is examined by Augmented Dickey-Fuller (ADF) test whether it is stationary or non-stationary as the analysis of the relationship between time series by VAR model can be done only if they are integrated of the same order. There are three types of ADF tests elaborated by Dickey and Fuller [5]: with constant and trend, with constant only, and without constant and trend. We applied the last mentioned as (1)

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

where ΔY_t is the first difference of the examined variable, t is time, m is the maximum length of the lagged dependent variable, α, β are parameters, and ε_t is a pure white noise error term.

Diagnostic of the type of ARIMA model is done by Autocorrelation function (ACF) and Partial Autocorrelation function (PACF) that are plotted in order to determine the order p of Autoregressive (AR) process and order q of Moving Average (MA) process. Consequently, the appropriate type of the model is identified. AR model, MA model, Autoregressive Integrated Moving Average (ARIMA) model, and Seasonal ARIMA (SARIMA) model in terms of statistically significant parameters and their ability to explain the correlation structure of the process that generated the time series. In case of agricultural prices some seasonality can be expected (due to natural character of the agricultural production). Therefore, SARIMA(P, D, Q) (p, d, q) model is chosen and estimated as (2)

$$Y_t = \beta + \sum_{i=1}^{P} \mathrm{A}_i Y_{t-is} + \sum_{j=1}^{Q} \mathrm{B}_j \varepsilon_{t-js} + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=1}^{q} \delta_j \varepsilon_{t-j} \tag{2}$$

where s marks an order of seasonality. Consequently, fitted models are used to predict the future producers' price of slaughter pig in next 12-month period. Also 95% confidence intervals are elaborated.

Possible correlation between the time series of the price of slaughter pigs and the price of the main feed of the (feed wheat, feed barley, feed oat, and feed maize) are assessed next. It is assumed that they have similar trend and are integrated of the same order. They are tested by ADF test (after and before seasonal adjustment) and consequently by Granger test for spurious regression. General VAR(p) model can be written in the form (3)

$$\mathbf{Y}_t = \boldsymbol{\beta} + \sum_{i=1}^{m} \boldsymbol{\Phi}_i \mathbf{Y}_{t-i} + \boldsymbol{\varepsilon}_t \tag{3}$$

where $\boldsymbol{\beta}$ is l x 1 dimensional vector of constants, $\boldsymbol{\Phi}_i$, i = 1, 2, …, m are l x l dimensional non-random matrices of AR parameters and $\boldsymbol{\varepsilon}_t$ is l-dimensional process of white noise. In our case, price of slaughter pigs is modelled with 5 time series (in natural logarithms). The middle projection and projection with 95% confidence intervals are done in both models for 12-month period.

The presence of autocorrelation is tested using Breusch-Godfrey serial autocorrelation LM test with H_0: There is no serial autocorrelation. If the calculated value of the test exceeds the tabled test criterion from Fisher and χ^2 distribution H_0 is rejected and there is autocorrelation. Heteroscedastity is tested by Autoregressive Conditional Heteroscedasticity (ARCH) test where is H_0: There is no heteroscedasticity present. The test is also using Fisher and χ^2 critical values. Normality is tested by Jarque-Bera test with H_0: The residues are normally distributed and value is compared to critical value of Jarque-Bera distribution. All tests are done at 0.05% level of significance.

Data were taken from database at http://www.agris.cz. Originally, the frequency of slaughter pigs' prices was weekly, but as the prices of feed were available only on the monthly bases, they were transformed on monthly data by calculating the monthly average. There were 222 observations in period from 01/1998 to 06/2016 for slaughter pig price used for SARIMA model. The prices of fodder wheat, fodder barley, fodder oats, and fodder maize were available from 02/2006 to 06/2016 and therefore the VAR model worked with 125 observations only. The projections are compared with real price development from 07/2016 to 07/2017. Calculations were done in EViews 8.

From Figure 1 and Table 1 can be seen that the highest price was around 07/2001 (47.75 CZK/kg). Year 2001 was almost the only one when the prices were higher than 40 CZK/kg. Average price in this year was also the highest from the whole observed period. The prices were fluctuating around 32.33 CZK/kg (arithmetic mean). Over half time, the price was higher than 32.10 CZK/kg, but in 25% of cases lower than 29.32 CZK/kg or higher than 35.07 CZK/kg. On the other hand, the lowest price (23.42 CZK/kg) was noted in 03/1999, but on average the lowest prices were so far noted during the first six months of year 2016. Almost similar situation was in year 2010. The prices usually decrease on the turn of the New Year (only exceptions are 1998/1999, 2002/2003, 2010/2011). "At the beginning of each year, price of pork usually decreases as many households save after the Christmas. Part of consumers is also trying to fulfil New Year's resolutions about loss of weight and healthy lifestyle and the consumption and the prices are decreasing." (Brož, [4])

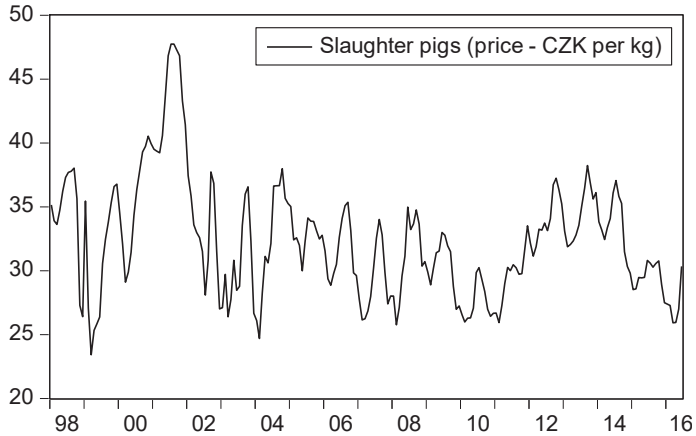

Figure 1 Development of slaughter pigs price [CZK/kg] (01/1998–*06/2017); Source: own elaboration

Year	Price	Year	Price	Year	Price	Year	Price
1998	34.48	**2003**	30.34	**2008**	31.08	**2013**	34.51
1999	30.75	**2004**	32.65	**2009**	30.34	**2014**	33.57
2000	35.43	**2005**	32.87	**2010**	27.51	**2015**	29.58
2001	43.62	**2006**	31.65	**2011**	29.55	**2016**	30.31
2002	33.00	**2007**	29.16	**2012**	34.01	**2017***	33.48

Table 1 Development of slaughter pigs price [CZK/kg] (01/1998–*06/2017); Source: own elaboration

Regarding the prices of fodder wheat, barley, oats and maize, they developed almost equally during the observed period. They were increasing since 2006 until 2008, when due to the financial crisis experienced steep decrease. The highest average prices were in year 2013. In the first half of 2016 they stabilized on higher level than a decade ago. The trend of the development of average prices is almost similar to the development trend of slaughter pigs price, hence, there might be correlation and certain type of short-term relationship.

3 Results and Discussion

First, the prices of slaughter pigs were modelled individually by Box-Jenkinson methodology – SARIMA model and further used for prediction. Second, VAR model was estimated and used for price prediction.

The price of slaughter pigs was modelled individually by Box-Jenkins methodology after the diagnostics by ACF and PACF functions. The results of the model together with verification tests are displayed in Table 2. F-test revealed that the time series is seasonal. After testing, it was found that the most suitable model is SARIMA(1,0,1)(0,0,1)c. The time series is stationary and with autoregressive term AR of the degree of 1. The price depends on the price one month ago. MA is of the first order in non-seasonal version of the model and of the first order in seasonal version. Autocorrelation of residues was also rejected by Durbin-Watson and Breusch-Godfrey tests, but the residues were not normally distributed and constant and finite, hence, the HAC errors were used.

Variable	Coeff. (Std. error) Prob.		
β	32.139 (1.217) ***		
AR(1)	0.8060 (0.061)***		
MA(1)	0.3870 (0.074)***		
SMA(12)	0.4530 (0.143)***		
Model diagnostic		**Breusch-Godfrey Serial Correlation LM Test:**	
R^2	0.846	F-statistic	1.267
Adjusted R^2	0.844	Prob. F [2,215]	0.284
F-statistic	397.039***	Obs* R^2	2.572
Durbin-Watson statistic	2.049	Prob. χ^2 [2]	0.276

*** statistically significant at $\alpha = 0.01$

Table 2 Price of slaughter pigs: SARIMA(1,0,1)(0,0,1)c model Source: own elaboration

The results of projection are displayed at Figure 2. The maximum price is expected to be 32.16 CZK/kg and in 10/2016 and minimum price 30.02 CZK/kg in 03/2017. Upper bound of the 95% confidence interval follows the trend of the middle prediction. There is also a peak in 10/2016 (39.20 CZK/kg) and minimum in 03/2017 (38.02 CZK/kg). Lower bound shows deep decrease to 30.02 CZK/Kg in 03/2017, but such low price has not been achieved in at any time during the observed period and hence it is not probable.

VAR model examined short-time relationship between the development of producers' prices of slaughter pigs and their possible determinants: the price of fodder wheat, barley, oat and maize. Fisher test for seasonality found that barley is non-seasonal, wheat, oat and maize are seasonal and were seasonally adjusted. Individual ADF models with constant revealed that each time series is non-stationary and stationary of the first order. Residues of Granger spurious regression test are stationary at 0.05 level of significance. Hence, the regression among variables is not spurious. All prices of fodder plants Granger cause the price of slaughter pigs. Therefore, all are included in VAR model and we obtain VAR model of the 6th grade (lag = 6). Results of the VAR model are presented in Table 3. There is no serial autocorrelation of the residues and no heteroskedasticity, but due to length of time series, the residues are not normally distributed.

The price of slaughter pigs depends on itself at first and third lag. Then it is dependent on the price of maize with two and three lags, price of oat at first, second lag, price of wheat at first, fifth and even sixth lag, price of barley at first and third lag. All fodder prices depend on the price of fodder wheat at first lag. Wheat as it can be stored for long time can also influence the prices up to half a year later (fourth, fifth, sixth lag). Price of oat is important only up to third lag, and maize up to forth lag. The least important is price of barley that depends only on its price one month ago and influences only the price of slaughter pigs. Impulse was statistically significant in case of all fodder plants with exception of wheat. This dummy variable took value of 1 at 06/2013 when there was a significant change in price. The price of fodder oat was almost twice higher as month before (4518 CZK/t) and after (4427 CZK/t). Price of maize was lower (4292 CZK/t) in 06/2016 than in 05 (5373CZK/t) or 07 (5210 CZK/t). Price of barley decreased from 5008 CZK/t in 05 to 4766 CZK/t in 06 and continued to decrease. Similar situation was with maize that decreased from 5505 CZK/t in 05 to 5306 CZK/t in 06/2013.

Predicted values o slaughter pig price are given at Figure 2. The middle variant suggests slight increase to 30.50 CZK/kg in 08/2016, but the price will decrease again on 29.50 CZK/kg in 10/2016. Then it should slightly increase on 29.94 CZK/kg at 12/2016 and decrease again on 29.54 CZK/kg one month later. Then there is no significant change, only slight increase on 29.93 CZK/kg at the end of the projected period 06/2017. Lower bound suggests pessimistic development that the price will decrease from 28.62 CZK/kg down to 24.58 CZK/kg in 06/2017. In 10, 11/2016 the price shall be the same 26.11 CZK/kg and then increase on 26.29 CZK/kg. However, further decrease is predicted. Upper bound is an optimistic variant starting from 31.58 CZK/kg in 07/2016 and increasing up to 35.29 CZK/kg. There shall be only little stagnation of the trend between 08-10/2016. Otherwise the price should continually rice.

Middle variants predicted by SARIMA and VAR model suggest slight increase and then slight decrease of the price of slaughter pigs to the minimum. The prices finally rise at the end of the period. In case of SARIMA model, the price might raise to 32.16 CZK/kg in 10/2016 and 32.00 CZK/kg in 06/2017. VAR model predicts the highest price 30.50 CZK/kg in 08/2016. It is a general rule that if in the VAR model, the variables are Granger caused by each other, the confidence intervals are smaller. The confidence intervals in VAR models are almost two times narrower than in the case of SARIMA model. While the difference between prices projected by SARIMA is between 7.08 and 16.02 CZK/kg, VAR model predicts the difference only between 2.96 and 10.71 CZK/kg. Hence, the theoretical expectations were confirmed.

Prices of	pigs	maize	oat	wheat	barley
Variable	**Coeff. (SE) Prob.**	**Coeff. (SE) Prob.**	**Coeff. (SE) Prob.**	**Coeff. (SE) Prob.**	**Coeff. (SE) Prob.**
pigs (-1)	1.000 (0.108)***	31.055 (38.941)	-12.052 (30.589)	33.208 (29.789)	-15.811 (29.681)
pigs (-3)	-0.324 (0.149)**	66.890 (53.579)	-24.511 (42.087)	31.396 (40.987)	19.488 (40.839)
maize (-1)	-0.001 (0.000)	0.321 (0.113)***	-0.031 (0.089)	-0.002 (0.087)	-0.133 (0.086)*
maize (-2)	-0.001 (0.000)**	0.262 (0.111)***	0.085 (0.087)	0.527 (0.085)***	0.056 (0.084)
maize (-3)	0.001 (0.000)**	0.006 (0.136)	-0.037 (0.106)	-0.493 (0.104)***	-0.090 (0.103)
maize (-4)	-0.000 (0.000)	-0.066 (0.143)	0.253 (0.112)**	0.160 (0.109)*	-0.084 (0.109)
oat (-1)	0.001 (0.000)***	0.369 (0.122)***	0.530 (0.096)***	0.079 (0.093)	0.185 (0.093)**
oat (-2)	0.001 (0.000)***	0.149 (0.113)*	0.248 (0.089)***	0.292 (0.086)***	0.026 (0.086)
oat (-3)	-0.000 (0.000)	-0.323 (0.124)***	-0.182 (0.097)**	-0.336 (0.095)***	-0.091 (0.094)
wheat (-1)	-0.001 (0.000)***	0.484 (0.142)***	0.386 (0.112)***	0.998 (0.109)***	0.264 (0.108)***
wheat (-4)	0.000 (0.001)	0.007 (0.191)	-0.040 (0.150)	-0.143 (0.146)	0.519 (0.145)***
wheat (-5)	-0.001 (0.001)*	-0.010 (0.241)	-0.610 (0.190)***	0.051 (0.185)	-0.639 (0.184)***
wheat (-6)	0.002 (0.001)***	0.154 (0.230)	0.485 (0.165)***	0.097 (0.161)	0.218 (0.160)*
barley (-1)	-0.001 (0.000)*	0.009 (0.153)	0.106 (0.120)	0.130 (0.117)	0.501 (0.116)***
barley (-3)	0.001 (0.001)***	-0.041 (0.164)	0.128 (0.129)	0.069 (0.125)	-0.047 (0.125)
IMP (dummy)	-3.806 (1.534)***	-1068.603 (551.874)**	1505.897 (433.504)***	176.288 (422.170)	-648.559 (420.642)*
Model diagnostic					
R^2	0.934	0.925	0.928	0.958	0.957
Adj. R^2	0.912	0.899	0.903	0.944	0.942
F-statistic	41.568	35.995	37.723	67.084	64.657

Table 3 Price of slaughter pigs: VAR model; Source: own elaboration

Lower bound of SARIMA prediction suggests pessimistic development that the price will decrease even on 22.02 CZK/kg in 03/2017, but it has never been so low before. VAR model minimum is 24.58 that is more realistic. Upper bound of SARIMA model supposes the increase from 34.77 CZK/kg in 07/2016 up to 40.01 CZK/kg eleven months later while VAR model projects the highest price of 35.29 CZK/kg. Both models are realistic, as the maximum price achieved was 47.75 CZK/kg, despite that it was already in year 2001. The difference between projected and real values was the lowest in case of upper bound of VAR model confidence interval. The second-best projection measured by the variance was middle SARIMA projection.

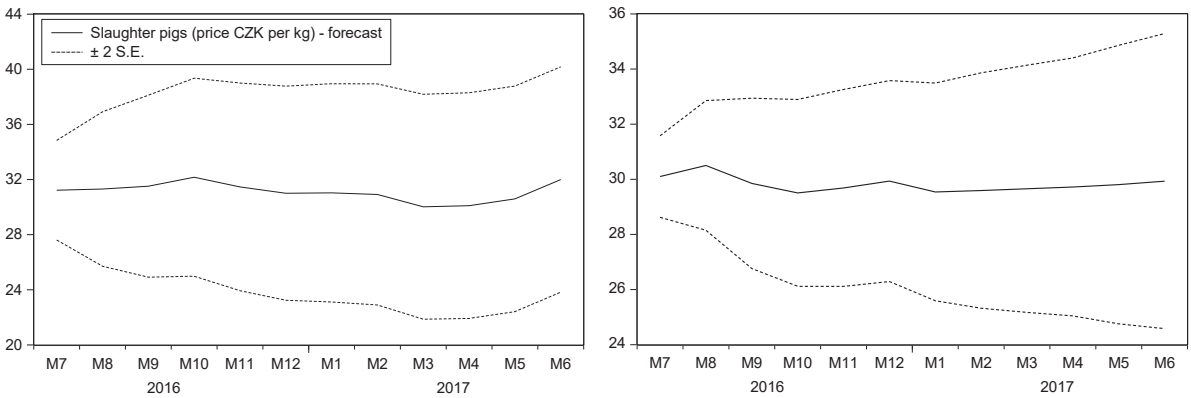

Figure 2 Predictions of producers' prices of slaughter pigs based on SARIMA model (left) and VAR model (right); Source: own elaboration

Models of Box-Jenkins methodology, ARCH or VAR models are suggested by many researchers to be used for projection of prices of agricultural commodities (see e.g. [11]). The research of Jaile-Benitez, Ferrer-Comalat and Linares-Mustarós [8] can provide comparable results to ours. The authors searched for the determinants (explanatory variables) of price of the pork and tried to quantify their weights (degree of influence) using fuzzy logic. They found that the variable influencing the price and their weights are cyclical and suffer variations in the course of events. We suggest using VAR model as it provided better results even when shorter time series was available. Besides, using more related time series enables to test the causality between variables (see e.g. study of Saengwong, Jatuporn and Roan [14]).

4 Conclusion

Analysis of the agricultural products' price volatility and trend forecasting are necessary to formulate and implement business strategies of agricultural holdings and for policy-making. Therefore, the aim of the paper was to find the optimal model for modelling and predictions of monthly prices of slaughter pigs. Producers' price was modelled by Autoregressive Integrated Moving Averages (ARIMA) models (time series from 01/1998 to 06/2016)

and by Vector Autoregressive (VAR) model in relation with prices of fodder plants (data from 02/2006 to 06/2016). Predictions are done for 12 months (until 06/2017).

The lower bound of SARIMA model of slaughter pigs' prices is too pessimistic, while according to VAR, the results are more probable. Middle and upper bound projections are again lower in case of VAR model, but feasible in both cases. SARIMA predicts the middle variant in interval 30.02 CZK/kg to 32.16 CZK/kg and VAR from 29.50 CZK/kg to 30.50 CZK/kg. Despite that the time series in the case of VAR models is eight years shorter than in case of SARIMA, the prediction in case of slaughter pigs is realistic and usable and we suggest using VAR model, where the upper bound values were the closest to the reality. Also, the variance of middle projection was not high. However, the second lowest difference between reality and projection was found in case of middle projection done by ARIMA model.

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