FOOD AVAILABILITY AND THE DEVELOPMENT OF THE CONSUMER PRICES OF MEAT

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Annotation: The share of households' expenditures on food and beverages in the Czech Republic is on acceptable level, but it is still important to observe consumer prices, because this share depends also on the type of the household (especially unemployed and retired people can experience some constrains). The structure of the consumption has not changed much, but beef meat (BM) consumption decreased. Consumers started to prefer poultry meat (DM) due to health reasons and high increase of BM price. Knowledge about future consumer' prices is desirable to ensure that meat is available also to low-income households.

The aim of the paper is to model consumer prices of BM, PM and DM and predict them from 03/2018 to 02/2019. Methodological objective is to find suitable method for modelling of consumers price of meat: Box-Jenkins methodology (ARIMA) or VAR model. Monthly data were taken from Czech Statistical Office for 01/2006–02/2018.

First, the time series were explored in terms of their stationarity and seasonality. Time series were non-stationary and only PM price was seasonal, but insignificantly. The consumer prices depended mainly only on the lag of price one month ago: BM – ARIMA(1,1,0)c, PM – ARIMA(1,1,0) with unit impulse in 06/2008, DM – ARIMA(1,1,0) with unit impulse in 07/2008. However, the projections of price were unsatisfying. VAR(2) model showed weak relations between consumers' prices. Only BM statistically significantly depends on PM two months ago, PM on its second lag and DM on its first and second lag. According to the projections, the prices might increase next year. This may cause certain problem to low-income households that might not be able to afford enough meat for balanced nutrition.

However, our projection has limitation as the final prices are influenced also by the politics of the retail and it is difficult to construct regression model with more explanatory variables.

Key words: ARIMA, consumer price, meat, VAR

JEL classification: E64, C22, E27

1. Introduction

Despite that the share of expenditures on food and beverages of the households in the Czech Republic is on acceptable level (decreased on 20% level in 2015 after slightly increasing trend in years 2010–2014) and in spite of low share of expenditures only on food (18.3%), it is still important to observe consumer prices, because the share of expenditures on food depends also on the type of the household. Households where the main person is unemployed spend almost 22.7% of their income on food, beverages and tobacco and in households of retired people even 23.9%. Those types of households can experience some budgetary constraints.

While the structure of the consumption has not changed much in general, significant changes happen especially in the structure of consumed meat. Particularly, beef meat (BM) consumption steeply decreased and consumers started to prefer (for healthy and price reasons) poultry meat (DM) which consumption doubled. This change was also caused by the increase of price of BM from average 167 CZK/kg in 2006 to 218 CZK/kg in 2017 (by 31%), while the price of PM increased from 105 to 118 CZK/kg – i.e. by 24% only. Increase of DM price was the highest (by 43%) from 48 to 68 CZK/kg, but it remains the cheapest type of meat in absolute terms. Besides, consumers started to prefer poultry meat (DM) due to health reasons. "Health conscious consumers have driven upwards

the demand for low fat and low cholesterol meat, in turn sparking a new interest in suitable alternatives to traditionally sourced farm meat products," (Tomasevica et al., 2018) Besides, there is certain saturation level, or more precisely intervals, where the meat consumption is moving between 80 to 110 kg. (Ingr, 2004) The scope of decrease of consumption is proportional to the price elasticity of particular meat. "Price elasticity is generally negative; when a brand's price increases, sales decrease, and vice versa" (Huang et al., 2017), but with different intensity that depends on lifestyle of the consumer. "The average consumption frequency of different types of meat was examined for example by Escriba Perez et al. (2015) in Spain according to two methodologies: consumer segmentation using the food-related lifestyle (FRL) framework, giving rise to 4 segments, and analysis of socio-demographic profiles.

Consumer prices are not modelled that often as agricultural producers' prices, despite that knowing the probable future development of them is also desirable to ensure that meat will be available despite budget restrictions of households. The prices for which consumers buy food are the highest in the whole commodity vertical due to the highest added value. Price transmission in pork agri-food chain concerned for example Čechura and Šobrová (2008). They found out that this chain is demand-driven. "The type of market structure implies that the agricultural support is in this case shared within the vertically related markets and thus is less efficient", (Čechura and Šobrová, 2008). Špička, Náglová and Gürtler (2017) evaluated the effects of investment subsidies in the Czech meat processing industry and found out that "subsidies from the national program increased the profitability of family-owned and medium-sized companies and changed the capital structure of the supported companies which used more bank loans for upgrading the technology", (Špička, Náglová and Gürtler, 2017).

Myers et al. (2018) examined the price transmission in oil market and found important long-run relationship between oil prices, producer prices, and consumer prices using permanent-transitory decomposition method. Price transmission between world food prices and different consumer food price indices for the case study of Thailand was examined by Barahona and Chulaphan (2017). Their findings showed that all world prices were co-integrated with domestic ones, and that the speed of adjustment was similar in all models regardless of the type of consumer price used (average consumer, low-income consumer or consumers located in rural areas (Barahona and Chulaphan, 2017). The volatility of wheat and agricultural commodity prices was examined by Čermák, Malec and Maitah (2017). They recommended to use general auto-regressive conditional heteroscedasticity model GARCH(1,1) that "has the ability to capture the main characteristics of the commodity market, specifically leptokurtic distribution and volatility clustering", (Čermák, Malec and Maitah, 2017).

In our article we compare Autoregressive Integrated Moving Average (ARIMA) and Vector Autoregressive (VAR) models in terms of their ability to predict the future consumers meat prices the most accurately measured by the mean square forecast error. "A forecasting method with small forecasting error is generally accepted as good and the forecasting error is calculated based on the difference between forecast and actual values," (Ha, Seok and Ok, 2018).

2. Materials and Methods

The aim of the paper is to model consumer prices of BM, PM and DM and predict them from 03/2018 to 02/2019. Methodological side-objective is to find suitable method for consumers' meat price modelling. Box-Jenkins methodology (ARIMA) and Vector Autoregressive (VAR) models are used and compared by mean square forecast error. Monthly data prices of beef back without bone, pork roast with bone and whole chickens were taken from Czech Statistical Office for 01/2006–02/2018 (146 observations). Calculations were done in EViews 8.

First, the time series were explored by Augmented Dickey-Fuller (ADF) test, model with constant *c* for BM (1a), and without constant and without deterministic trend for PM and DM (1b) to assess whether there are 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.

$$\Delta Y_t = c + \Phi Y_{t-1} + \sum_{i=1}^{m} \alpha_i Y_{t-i} + \varepsilon_t \qquad (1a) \qquad \Delta Y_t = \Phi Y_{t-1} + \sum_{i=1}^{m} \alpha_i Y_{t-i} + \varepsilon_t \qquad (1b)$$

where ΔY_t is the first difference of the examined variable (time series Y_t), t is time, m is the maximum length of the lagged dependent variable, α, Φ are parameters, and ε_t is a pure white noise error term. Consequently, F-test for seasonality is applied on each time series. Only PM price was seasonal, but statistically insignificantly and seasonality could not be modelled.

Identification 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. The autoregressive model of order p AR(p) is defined as (2)

$$Y_t = \beta + \sum_{i=1}^{p} \Phi_i Y_{t-i} + \varepsilon_t, \qquad (2)$$

where α_i (i = 1, ..., p) are the parameters, β represents the constant, and ε_t is a pure white noise error term. Moving average model of order q is formulated as (3).

$$Y_t = \varepsilon_1 - \sum_{j=1}^{q} \delta_j \varepsilon_{t-j}, \qquad (3)$$

where δ_j (j = 1, ..., q) are the parameters and ε_t is white noise. Sample ACF is calculated as (4)

$$ACF(k) = \frac{\sum_{t=k+1}^{n} (Y_t - \bar{Y})(Y_{t-k} - \bar{Y})}{\sum_{t=1}^{n} (Y_t - \bar{Y})^2}, \qquad (4)$$

ACF and PACF can be expressed graphically in correlograms. PACF is defined for k >2 as (5).

$$\begin{aligned} PACF(1) &= cor(Y_{t+1}, Y_t) \\ PACF(k) &= cor\left(Y_{t+k} - P_{t,k}(Y_{t+k}), Y_t - P_{t,k}(Y_t)\right), \end{aligned} \qquad (5)$$

where $P_{i,k}(Y)$ denotes the projection of Y onto the space spanned by Y_{t+1}, ..., Y_{t+k-1}. In case of agricultural prices some seasonality in the prices can be expected as the supply and demand of exhibit volatility during the year (due to natural character of the agricultural production), but it was statistically insignificant. Impulses in certain years were included to catch the price shocks.

Before VAR model construction, the time series are tested by ADF test (after and before seasonal adjustment) and consequently by Granger test for spurious regression. Possible correlation between the time series of the consumer price of three types of meat is examined by VAR(2) model for three time series (in natural logarithms) (6).

$$\mathbf{Y}_t = \mathbf{\Phi_1 Y_{t-1}} + \mathbf{\Phi}_2 \mathbf{Y_{t-2}} + \boldsymbol{\varepsilon}_t, \qquad (6)$$

where $\mathbf{\Phi}_i$, 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. The middle projection and projection with 95% confidence intervals are done for 12-month period.

Models were verified in terms of autocorrelation, heteroscedasticity and normality of residues. The autocorrelation is tested using Breusch-Godfrey serial autocorrelation LM test with H_0: There is no serial autocorrelation. If the calculated value 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 with H_0: There is no heteroscedasticity. The test uses Fisher and χ^2 critical values. Normality is tested by Jarque-Bera test with H_0: The residues are normally distributed and calculated value is compared to critical value of Jarque-Bera distribution. Tests are done at 0.05% significance level.

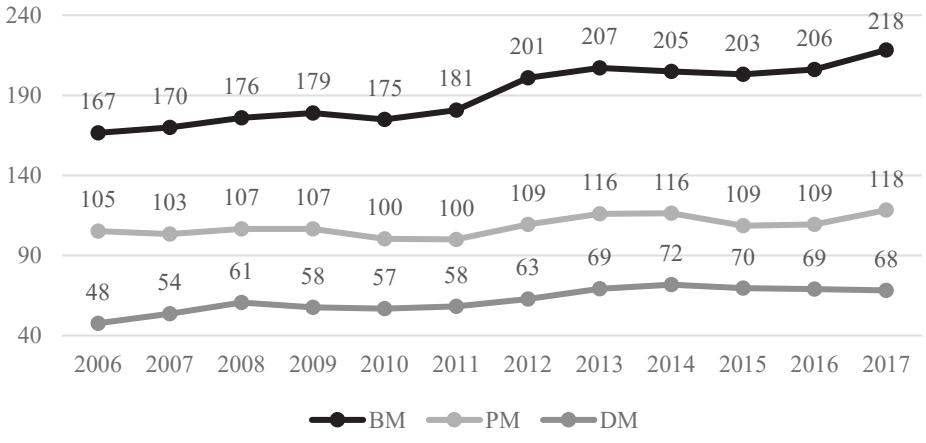
The most typical measures of accuracy of forecasting methods are Mean Absolute Deviation (MAD), Mean Square Error (MSE), Mean Absolute Percent Error (MAPE), Cumulated Forecast Error (CFE), Number of Shortages (NOS), and Period in Stock (PIS). (Ha, Seok and Ok, 2018). We used MSE that is squared differences between predicted $\hat{Y}$ and real Y value divided by the number of observations n (7).

$$MSE = \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 / n \tag{7}$$

3. Results and Discussion

As it can be seen from Figure 1, average year prices of the meat have been increasing since 2006 and were the highest in 2017 with exception of DM which average price was the highest in 2014. While BM was approximately 3.5 times more expensive than DM and 1.6 times more expensive than PM in 2006, it was only 3.2 times more expensive than DM in 2017, but the gap between BM and PM deepened slightly to 1.7. BM price increased from 167 CZK/kg in 2006 to 218 CZK/kg in 2017 that is 1.3 times more. The average growth rate was 31% with the highest between years 2011 and 2012. Average growth rage of PM was milder, only 12% with the biggest change between years 2016 and 2017. The price is almost the same, in 2017 it is only 1.1% times higher than it was in 2006 that indicates relative stability. The highest average growth rate was in case of DM, 43%. Between 2006 and 2007 and 2007 and 2008 the average growth rate accounted to 13%. The price is 1.4 times higher in 2017 than it was in 2006.

Figure 1. Development of BM, PM and DM prices in period 01/2006–12/2017



Source: own elaboration, 2018

The time series were tested for their stationarity (Augmented Dickey-Fuller test and seasonality (F-test). They were not stationary (had unit root) and were integrated of order 1. Only PM price time series was seasonal, but this seasonality was statistically insignificant at 5% significance level and could not be modelled. Also, the process that generated the time series was weak – the consumer prices depend mainly only on the lag of price one month ago. ARIMA(1,1,0)c was optimal for BM price, ARIMA(1,1,0) with unit impulse in 06/2008 (IMP1) for PM price and ARIMA(1,1,0) with unit

impulse in 07/2008 (IMP2) for DM. The residues were normally distributed and uncorrelated. Their variance was constant and finite. However, the projections were unsatisfying (linear function close to the average value of the price in time series).

Hence, VAR model was also constructed to examine linear inter-dependencies of 3 time series. First, Granger test revealed that there is not spurious regression, because residues of this static regression are stationary at 5% significance level. Stationarity was proved by Augmented Dickey-Fuller test statistic (model with constant and deterministic trend) with p-value 0.04. Optimal type of model – VAR(2) was used for prediction of consumer prices. There was no serial correlation. The residuals were homoscedastic (constant and finite variance in time) and normally distributed.

The results (see Table 1) show that relations between consumers' prices are weak. BM statistically significantly depends (α level = 0.05) on itself one and two months ago (BM_{t-1}, BM_{t-2}), and PM two months ago (PM_{t-2}). PM (seasonally adjusted) depends on its first and second lag (PM_{t-1}, PM_{t-2}) and DM on its first (DM_{t-1}) and second lag (DM_{t-2}). Nevertheless, VAR show only short time interdependences between 2 or more time series. Granger causality shows long-term relations. If 1 time series affects the other in Granger sense, than the final prediction of both time series is more quality in terms of lower mean square forecast error.

Table 1. VAR(2) model estimates

	BM (-1)	**BM (-2)**	**PM D11(-1)**	**PM D11(-2)**	**DM (-1)**	**DM (-2)**	**IMP1**	**IMP2**	**Model character.**
BM	*0.6090*	*0.3939*	*0.2716*	*-0.2675*	-0.1747	0.1680	0.1958	-2.2944	R^2 = 0.9800
	(0.0775)	(0.080)	(0.1166)	(0.1140)	(0.1214)	(0.1206)	(2.5653)	(2.5454)	$\underline{R}^2$ = 0.9790
	[7.8599]	[4.9306]	[2.3292]	[-2.3475]	[-1.4387]	[1.3928]	[0.0763]	[-0.9014]	F = 951.4611
PM D11	0.0632	-0.0116	*0.7068*	*0.21775*	0.0256	-0.0523	*4.3746*	*6.4852*	R^2 =0.9310
	(0.0517)	(0.0533)	(0.0778)	(0.0760)	(0.0810)	(0.0805)	(1.7118)	(1.6985)	$\underline{R}^2$ =0.9275
	[1.2223]	[-0.2178]	[9.0829]	[2.8635]	[0.3164]	[-0.6500]	[2.5555]	[3.8181]	F = 262.2329
DM	-0.0493	0.1013	0.0758	-0.1055	*0.6754*	*0.2189*	*5.0893*	0.1230	R^2 =0.9523
	(0.0526)	(0.0543)	(0.0792)	(0.0774)	(0.0825)	(0.0819)	(1.7423)	(1.7287)	$\underline{R}^2$ =0.9499
	[-0.9361]	[1.8678]	[0.9568]	[-1.3635]	[8.1905]	[2.6730]	[2.9211]	[0.0711]	F = 388.2461

Source: own elaboration, 2018

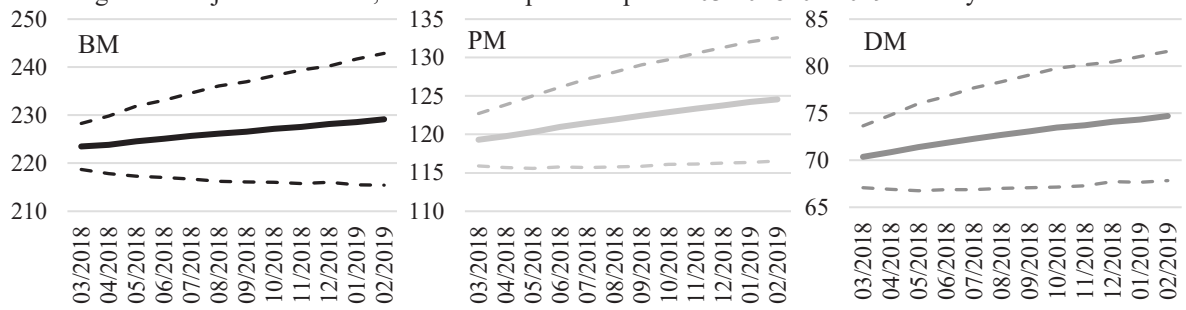
Note: parameter (standard error) [t-statistic], PMD11 – pig meat price seasonally adjusted; significant coefficients at 5% level of significance marked in italics

The results of projections are displayed at Figure 2. Average projected price of BM will be 226 CZK/kg, 122 CZK/kg for PM and 73 CZK/kg in case of DM for 03/2018–02/2019. Slight increase of prices is expected in case of all prices of meat. Average growth rate is expected the lowest in case of BM (only 3% between 02/2018 and 02/2019), the highest in case of DM (7%), then PM can increase only by 5% on average). This may cause certain problem to low-income households that might not be able to afford enough meat for balanced nutrition. It can be seen that the 95% confidence interval in absolute terms is the widest in case of BM. Nevertheless, the relation between prices shall not change much, DM still will be the cheapest.

Regarding the quality of the projection, as ARIMA model did not provide any reasonable results, VAR model and its methodology can be recommended to be used to predict prices of agricultural

commodities. MSE was the lowest in case of DM price, only 13.8, then in case of PM price (28.2) and the highest for BM (39.4). While in financial sphere, the time series exhibit generally certain "well-known statistical features such as heavy tails and volatility clustering" (Chavez-Demoulin, Embrechts and Sardy, 2014), time series of prices of agricultural commodities are less examined and predictable. While Rumánková (2016) uses different types of ARIMA models to predict agricultural producers prices, and also Pechrová and Šimpach (2017a) recommended for consumer prices of sugar using ARIMA(1,1,1) model and Pechrová and Šimpach (2017b) use ARIMA(1,0,0) for projection of eggs prices, our suggestion is to rather use VAR model for projection of consumer prices of meat.

Figure 2. Projections of BM, PM and DM prices in period 03/2018–02/2019 done by VAR model



Source: own elaboration, 2018

4. Conclusion

The aim of the paper was to model consumer prices of beef, pork and poultry meat and to predict them for nest 12 months. Monthly data of prices of beef back without bone, pork roast with bone and whole chickens were taken from Czech Statistical Office for 01/2006–02/2018. Projections with 95% confidence interval were done for period 03/2018–02/2019. Methodological objective was to find suitable method for modelling of consumers price of meat – either Box-Jenkins methodology (ARIMA) or VAR model.

Optimal model for BM was ARIMA(1,1,0)c, for PM an ARIMA(1,1,0) with unit impulse in 06/2008 and for DM an ARIMA(1,1,0) with unit impulse in 07/2008. However, the projections to the future were not feasible. Hence, VAR model was constructed. Despite that it shows only weak linear interdependencies between consumers' prices, but the projections were relatively feasible. The prices of all types of meat might slightly increase in the future. We may expect that average price of BM will be 226 CZK/kg, 122 CZK/kg for PM and 73 CZK/kg in case of DM for 03/2018–02/2019. MSE was used to assess the quality of prediction which was the best in case of DM. BM prices were projected with high MSE and also 95% confidence intervals were the highest. Possible increase of price may cause certain problem to low-income households that might not be able to afford enough meat for balanced nutrition. On the other hand, it might be positive for farmers if it agricultural producers' prices also increase.

We can also conclude that the most suitable way how to predict consumer prices of meat is VAR model. However, our projection has also limitation. The final prices that are paid by the consumer are influenced also by the politics of the store chains. The decision of the retail part of the agri-food chain is hard to be modelled, hence, it is difficult to construct regression model with more explanatory variables. This remains a challenge for future research.

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