Consumer prices forecasting based on ARIMA models

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Abstract: High consumer prices and high inflation afflicted many countries in the world recently. The cause is the Covid epidemic and Russian aggression in Ukraine, which primarily led to an increase in energy prices. In the Czech Republic, the inflation reached 17.5% in June 2022. The rapid increase of consumer prices has consequences. The number of poor people that depend on social benefits is growing. Government prepares measures and subsidies and for low income households. For policymaking and planning, a projection of the consumer prices development in the future is needed. Therefore, the aim of the paper is to project the prices of basic food: bread, butter, milk, poultry, potatoes, sugar, and eggs. The data were taken from Czech Statistical Office with monthly frequency for the period of 2010–2022 in order to have long time series. We applied Box-Jenkinson methodology – SARIMA and ARIMA models and modelled the development of the time series and forecast to the future 12 months. For bread prices forecast, an ARIMA model is preferred. In case of butter, both models forecast slight decrease of price. and we cannot clearly conclude which model is better. In case of milk projection, SARIMA is in contrast with ARIMA, but both models could be realistic as the price of milk is very volatile throughout the whole period. For price of chicken and potatoes, both forecasts are in contrary, but ARIMA is more probable. SARIMA model projects more realistic development of sugar price. In case of eggs price, both models project stabilization, so it cannot be concluded which model is preferred.However, econometric correctness and the best fit of the model is not a guarantee that projected values would meet the expectations based on the theory and practical experiences.

Keywords: ARIMA models, consumer prices, forecasting, inflation
JEL Classification: C53, E31

1 Introduction

Increase of consumer prices and high rate of inflation afflicted many countries in the world recently. The rate of inflation is expressed by the increase in the Consumer Price Index (CPI) in comparison to the base year, previous year or previous month. CPI consists of the consumer basket of products and services that are consumed by the households. The consumer basket is developing in time and currently contains around 850 items in the Czech Republic (CR). Also, the weight representation of individual items in the basket changes, but the share of food and non-alcoholic drinks is still dominant (it was 17.8% in 2022 in the CR). The rapid rise in consumer prices has negative societal consequences. The number of poor people that depend on social benefits is growing and the government must take effective measures. After years of relative stability of inflation in the CR, its development in year 2022 is not favourable. The CPI compared to the same month of the previous year reached two-digit values already in January. After years of low inflation below 3%, the inflation started to grow in 2021 due to Covid-19 pandemic. Later, the war at Ukraine and increasing prices of energies caused even more rapid price increase. The Czech Central Bank took the measures to lower the inflation (rise of interest rates) as it is targeting the inflation. However, "high impact of food prices on CPI, accompanied by food price volatility seriously hampers conduct of inflation targeting of the central bank." (Šoškić, 2015). According to Czech Statistical Office ((ČZSO), 2022), the inflation in the Czech Republic started to increase since July 2021.

Inflationary pressures can come from either the demand side or the supply side. "Food inflation may be coming from the demand side if the increase in income of households is fuelling the demand and pushes the food prices up." (Šoškić, 2015) On the other hand, shortage of certain commodities can raise their prices and cause supply driven inflation. Inflation in the Czech Republic is among the highest in the EU, after the Baltic states. Food prices are an important component of the consumer price index, which pushes inflation up. On average, they grow at the sixth fastest rate in Europe, while some goods, such as fish or soft drinks, remain more or less at pre-crisis prices. It is discussed to what extent the price increase

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is due to the price policy of supermarkets, which increase the price of food (e.g. bread, butter, milk, flour and sugar) more than the commodity prices are increasing. There is not lack of the commodities, so other factors are the cause.

1.1 Literature review

Projections of the inflation rates are done by central banks and many scholars. Besides, "reliable price forecasts can aid cash flow management and improve farm production decision planning: what and how much feed to grow, what time of year to produce." (Hansen, 2020) There are many various models which has been continually developed and enhance as inflation rate is one of the basic economic indicators. For example, Hassani and Silva (2018) exploited auxiliary information contained within United Kingdom inflation forecasts and modelled the inflation by Multivariate Singular Spectrum Analysis. First, they applied a variety of parametric and nonparametric models to generate univariate forecasts of inflation and chose the best univariate forecast. This is then included into the multivariate analysis together with data as an auxiliary information. They recommend this method because it is multivariate and brings the most accurate results. Bradley, Jansen and Sinclair (2015) examined whether excluding food and energy prices from the Consumer Price Index (CPI) produce a measure that better captures permanent price changes. They found out that "the permanent component of the core CPI is much more volatile than the actual core series and that the core excludes volatile permanent shocks to the overall price level". Besides, the core CPI series is not correctly characterized as having only permanent movements, and the food and energy time series are not correctly characterized as having just temporary movements.

Some researchers focused on the consumer food prices that takes significant share of CPI. García-Germán, Bardají and Garrido (2015) used error correction models to evaluate the extent at which world agricultural commodity price movements affect consumer food prices in the EU. There was found a long-run relationship between world agricultural commodity and consumer food prices in over half of the member states. Li and Zhao (2015) examined the CPI for food in China. They found that fluctuation of CPS for food is clustered, explosive, periodic, has decreasing amplitude and its fluctuation is asymmetric. "The impact of positive information was significantly larger than the equivalent negative impact, so the government's main task is controlling rising inflation of the food commodity prices." (Li and Zhao, 2015). The asymmetric fluctuation of CPI for food is explained by inflation inertia and the public's expectation effect. El-Ghini and El-Karimi (2020) examined the transformation of world food commodity prices to food inflation in Morocco in years 2004–2018, by using Structural Vector Autoregression (SVAR) model on monthly data.

Our paper focuses on the modelling and forecasting of the consumer prices. Particularly we focus on bread, butter, milk, poultry, potatoes, sugar, and eggs. For modelling of time series of agricultural prices Autoregressive Integrated Moving Average (ARIMA) models are often used. For example, Jadhav, Reddy and Gaddi (2017) forecasted the prices of cereals and Maize in Karnataka based on the data from period 2002–2016. Sangsefidi et al. (2015) used besides ARIMA also Autoregressive Conditional Heteroskedasticity model to predict the prices of potatoes, onion, tomato, and veal. They found out that the ARIMA models had lower relative error. Šimpach and Šimpachová Pechrová (2018) also used two models and compared their results. Besides ARIMA model applied on the time series from 02/2006 to 06/2016 of Czech producers' prices of milk, they also utilized Vector Autoregressive (VAR) model. They found out that ARIMA model showed better prediction capabilities as VAR model was probably missing some variables. Šimpach and Šimpachová Pechrová (2018) modelled prices of beef, poultry and pork meat in the CR. They found out that all timeseries were non-stationary and non-seasonal, and that depend mainly on the price one month ago. For modelling of consumer prices of sugar in period of 09/2016 to 08/2017 in the CR was the optimal model ARIMA (1, 1, 1) as found out by Pechrová and Šimpach (2017a). Pechrová and Šimpach (2017b) examined the development of consumer prices of eggs and projected them into the future. The best model was ARIMA(1, 0, 0) with constant and impulses in crisis months (03, 05, 07/2012).

2 Methodology

We focused on modelling the consumer prices of caraway bread (1 kg), fresh butter (250 g), semi-skimmed milk pasteurized (1 l), whole chicken without offal (1 kg), consumable potatoes (1 kg), sugar crystal (1 kg), and fresh chicken eggs (10 pieces). The data were taken from CZSO with monthly frequency for the period of 2010–2022 in order to have long time series that is needed for chosen methodology (at least 50 and preferably 1000 observations or more should be used (Wang and Zhao, 2009). "The input series for ARIMA needs to be stationary, i.e. it should have a constant mean, variance, and autocorrelation through time." (Novković et al., 2019)

First, Fisher F-test and Kruskal-Wallis for seasonality testing were applied on each time series. If there is significant seasonality, it has to be modelled. Then we can consider two types of models (see below). Consequently, the stationarity of the time series was tested by augmented Dickey-Fuller test (ADF test).

There are three types of ADF test for stationarity: with constant and trend, with constant only, and without constant and trend. The largest model – ADF with constant and trend – is calculated according the equation (1).

$$\Delta Y_t = c + \gamma t + \beta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t , \quad (1)$$

where ΔY_t is the first difference of the explained variable, Y_{t-1} is lags of explained variable and α and β are their parameters, c represents the constant, t is trend variable and γ is its parameter, m is the maximum length of the lagged dependent variable, and ε_t is pure white noise error term. All three types of models are compared, and the best is chosen based on the statistical significance of the parameters and of the model or based on information criteria (e.g. Akaike information criterion). The null hypothesis is non-stationarity (parameter is equal to zero). Alternative hypothesis states that the parameter is less than 0 (stationarity).

Each time series was modelled by Box and Jenkins (1970) methodology that works with autoregressive (AR) and moving average (MA) processes. When only autoregressive and moving average part is present, then we talk about ARMA model that can be used only when the time series is stationary. If the time series is not stationary, its difference of d^{th} order must be done. Than the model is ARIMA(p, d, q), where p is the order of AR term, d is the number of non-seasonal differences and q is the order of MA term.

Diagnostic of the type of the model was done by Autocorrelation function (ACF) and Partial Autocorrelation function (PACF) that were plotted in order to determine the order p of AR process and order q of MA process. Correlograms of ACF and PACF are simply the plots of ACF and PACF against the lag length (Wang and Zhao, 2009). ARIMA(p, d, q) model is then written as (2).

$$Y_t = c + \sum_{i=1}^{p} \phi_i Y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} , \quad (2)$$

where φ and θ are parameters. When there is a seasonal component, a model is in a form of SARIMA(p, d, q)(P, D, Q)$_S$, where P is the order of SAR model, D is order of seasonally differencing, Q is the order of SMA model, and S means the periodicity. Model is then written as (3).

$$Y_t = c + \sum_{i=1}^{p} \phi_i Y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \sum_{i=1}^{P} \Phi_i Y_{t-S} + \sum_{j=1}^{Q} \Theta_j \varepsilon_{t-S} \quad (3)$$

Currently, consumer food prices are difficult to predict because they are subject to many economic shocks. But statistical software nowadays allows to choose an appropriate model. There are algorithms that can calculate all shapes / types of ARIMA and SARIMA models in a relatively short time. It can also perform their diagnostics and evaluation statistics. Based on the selected information criteria, it can then recommend a suitable model. In our paper, we chose Akaike's information criterion. The resulting model was tested whether there was autocorrelation (Breusch-Godfrey serial autocorrelation LM test), homoscedasticity (Autoregressive Conditional heteroscedasticity (ARCH) test) and normality (Jarque-Bera test) of the residues. It is desirable that null hypothesis H_0 (no serial autocorrelation, no heteroscedasticity, normality) are not rejected.

The seasonality of each time series was indicated and examined by Census X12-ARIMA algorithm. If there is a seasonality present, an algorithm tries to seasonally adjust the time series. All our time series contained certain type of seasonality, so we elaborated both models – SARIMA and ARIMA. They were applied on original time series of chicken, potatoes, and eggs and then on non-seasonally differenced time series in case of bread, butter, milk and sugar. The predictions were done for next 12 months. We used software Eviews 10 for the calculations.

3 Results and Discussion

Consumer prices of agricultural commodities usually depends on the industrial producers' prices and agricultural producers' prices. Our chosen method takes into account only previous prices of particular food (commodity) and hence, the projection of the final price for consumer is difficult and the results must be taken with caution. Each type of time series had different ideal model. Results of the timeseries diagnostic are given in Table 1. In case of high data volatility, it is recommended to use their logarithmic transformation. We had to do it in almost all cases with exception of SARIMA and ARIMA models for milk, and ARIMA models for potatoes and eggs.

All analysed time series show some form of seasonality. Fisher or Kruskal-Wallis tests confirmed it in majority of time series. Only the chicken price was clearly non-seasonal time series. Similarly moving seasonality was identified in all prices' development with exception of potatoes.

Seasonality is greater for commodities that have a statistically significant order of P or Q (order of SAR or SMA model). The prices in particular month of bread, milk, and sugar depend on their own prices in the same month last year and the

year before (order of SAR is 2). The prices of butter, chicken, potatoes and eggs depend on the prices in the same month only from last year (order of SAR is 1). The price of bread depends on the price of bread in the previous month according to the SARIMA model. ARIMA model assumes that it depends on the price in the previous 3 months because seasonality is removed in this model. The price of eggs depends on the price of the previous two months according to SARIMA model, while ARIMA states that it is 3 months back. The price of butter, chicken, potatoes and sugar has a longer "memory", it depends on the price in the previous 3 periods according to SARIMA model. ARIMA model states that in case of butter and sugar, the price is dependent only on prices 2 months ago. Chicken price is dependent according to ARIMA on the previous 4-month prices and potatoes price on last 3 prices. The price of milk is dependent even 4 periods back by both models.

Table 1 Optimal models for consumer prices

	Seasonality		**Moving seasonality**	**Optimal model**	
	Fisher test	**Kruskal-Wallis test**		**Seasonal**	**After seasonal adjustment**
caraway bread	Yes	Yes	Yes	SARIMA(1,1,1)(2,0,0)$_{12}$ in logs	ARIMA(3,1,3) in logs
fresh butter	Yes	Yes	Yes	SARIMA(3,1,2)(1,0,1)$_{12}$ in logs	ARIMA(2,1,2) in logs
semi-skimmed milk	No	Yes	Yes	SARIMA(4,1,3)(2,0,0)$_{12}$ no logs	ARIMA(4,1,4) no logs
whole chicken	No	No	Yes	SARIMA(3,0,2)(1,0,0)$_{12}$ in logs	ARIMA(4,0,1) in logs
potatoes	Yes	Yes	No	SARIMA(3,0,1)(1,0,2)$_{12}$ in logs	ARIMA(3,0,4) no logs
sugar crystal	No	Yes	Yes	SARIMA(3,1,0)(2,0,1)$_{12}$ in logs	ARIMA(2,1,3) in logs
fresh chicken eggs	Yes	Yes	Yes	SARIMA(2,0,1)(1,0,0)$_{12}$ in logs	ARIMA(3,0,2) no logs

Source: own processing

The econometric software performed many models and selected the optimal ones in terms of the Akaike information criteria. In case of bread, it can be seen that SARIMA model has optimal one of the lowest projections. Unlike in ARIMA model where the highest price should reach 45 CZK in 2023 and stabilize, in SARIMA, the price should not overcome 42 CZK/kg. Due to increasing prices of wheat and energies (gas and electricity), the ARIMA scenario seems more realistic. Bread price increased significantly in 2021 and the forecast takes into account this trend. The models just differ in the magnitude of the price increase. The trend of increasing agricultural producers' prices is assumed by the Ministry of Agriculture (MoA, 2021a). "For the marketing year 2021/2022, it is assumed that despite higher cereal production, but with average quality parameters, there will be a significant increase in prices on the cereal market for most commodities, both with regard to European and world cereal production, but above all to the uncertain political situation in Ukraine and Russia and also with regard to the increase of all costs (fuel, electricity, fertilizers, spare parts, etc.)." MoA expects that the monthly average producers' prices of food wheat will reach 6200–7200 CZK which will be reflected in the consumer prices of bread and pastry. For case of Serbia, Novković et al. (2019) found that optimal model for wheat prices projections was ARIMA(1,1,1).

Increase of butter prices is projected by both models, but in case of ARIMA, it is only up to September 2022, while SARIMA shows the peak in November 2022. Nevertheless, SARIMA projection is milder – the prices of butter shall not overcome the threshold of 230 CZK per 1 kg. Surprisingly, ARIMA predicts slight decrease in December 2022. MoA (2021b) proclaimed that "butter prices will continue to decline slightly in real terms in line with most other agricultural commodities over the projection period". However, this is an old projection. As can be seen from Fig 1, the prices increased rapidly in 2021 and first half of 2022, so maybe stagnation is more realistic than such sudden decrease. Hansen (2020) suggested that world-prices of butter are fitted the best by autoregressive process. For their projection AR yielded the best forecast with a reasonable MAPE up to 8–9 months ahead. After 9 months, the SETAR (self-exciting threshold

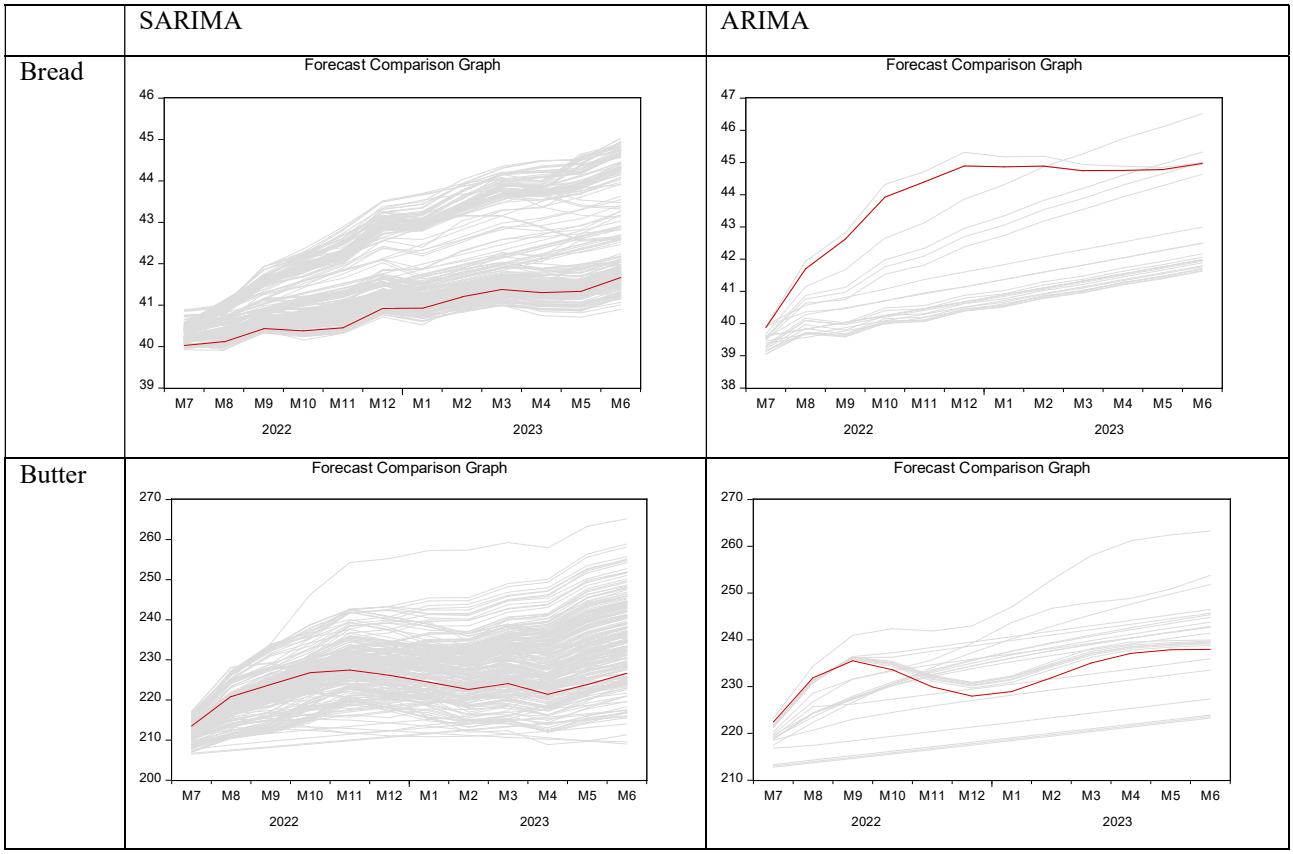
autoregressive model) and the LSTAR (logistic smooth transition autoregressive model) produce equally good forecasts. (Hansen, 2020)

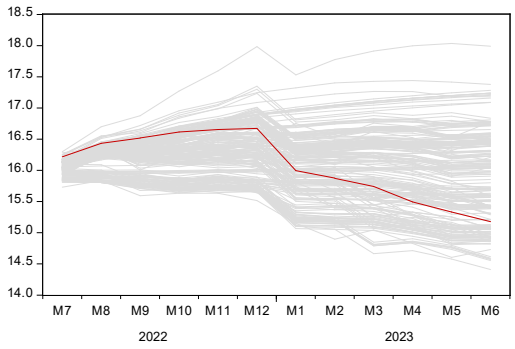
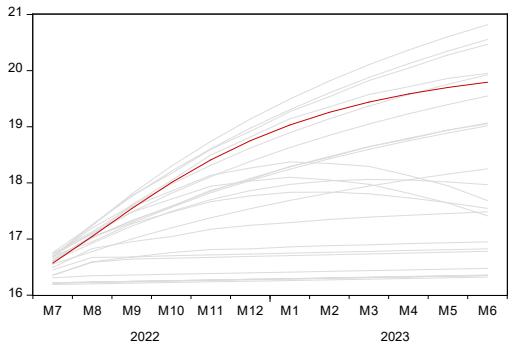
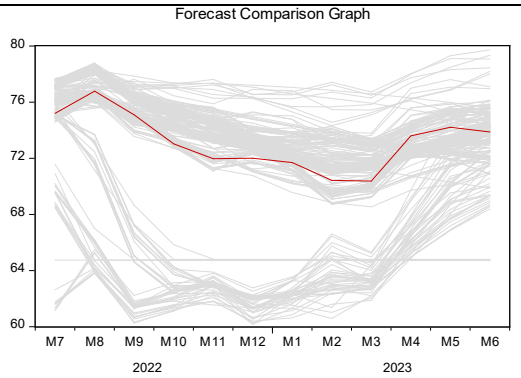
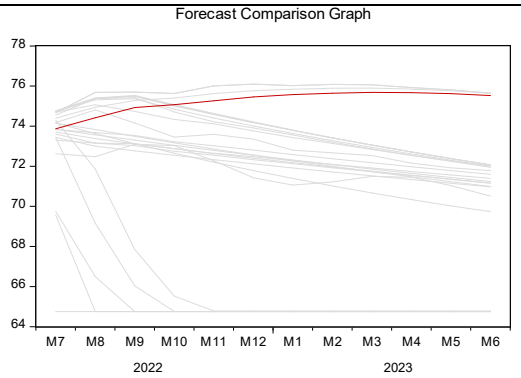
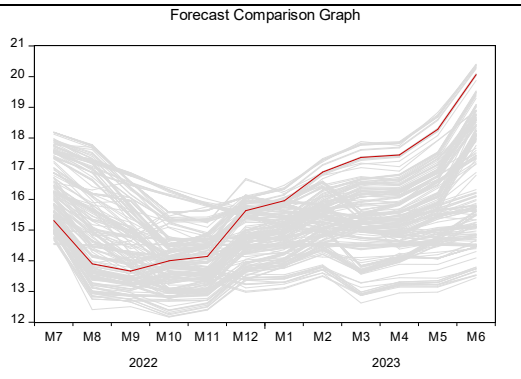
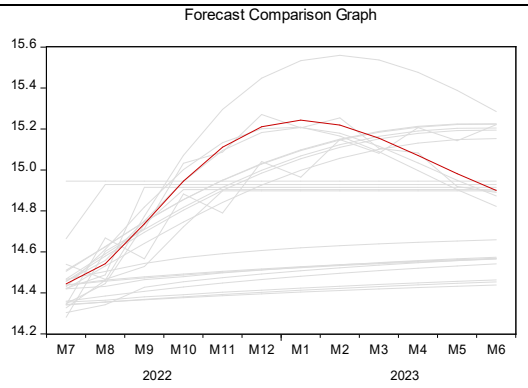
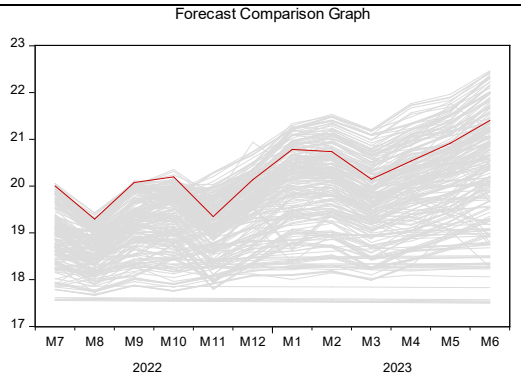
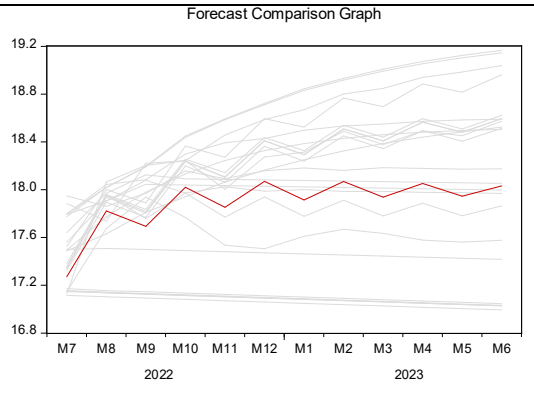
In case of milk, the algorithm chose SARIMA model that predicts decrease of the price in 2023. It might be realistic, because the price was very volatile during the observed period, regardless that the price started to increase rapidly in 2021 (it was the lowest then) and keeps the trend since that. Also, agricultural producers' price has been increasing since 2016. ARIMA model showed high increase of milk price – up to 20 CZK/l in 2023, so the results of both models are in contrast. MoA (2020) expected stabilization of price of skimmed milk powder on the international markets, that would imply that also consumer price could stabilize. Šimpach and Šimpachová Pechrová (2018) projected very low producers' prices in 2018. "ARIMA model suggests prices of milk from 5.97 to 7.06 CZK/l that is more realistic prediction than in case of VAR model that predicts lower prices (5.86–6.38 CZK/l)." (Šimpach and Šimpachová Pechrová, 2018). According to Hansen (2020), for the world price of for skimmed milk powder, whole milk powder, and whey powder the nonlinear methods are the most accurate.

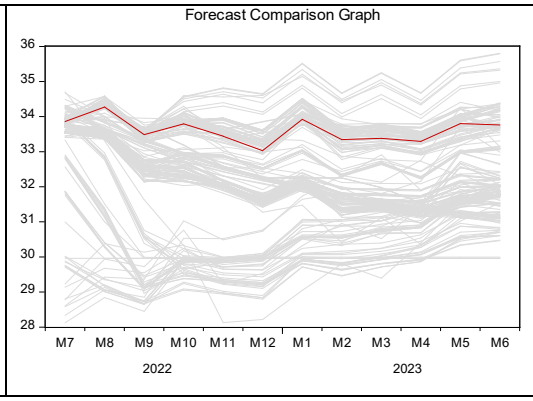
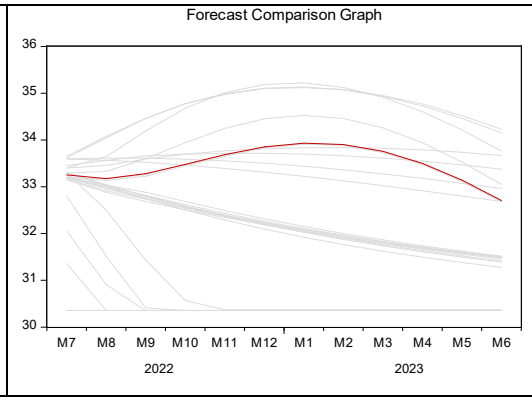
Consumer prices of chicken could move between 70 to 77 CZK/kg according to optimal SARIMA model while optimal ARIMA model expects mild increase up to 76 CZK/kg and stabilization. The stabilization can be probable scenario as the situation was already stabilized in 2020. "Overall, the situation on the poultry meat market in 2020 can be assessed as stabilized, despite the impact of the COVID-19 pandemic and the related restrictions on foreign trade." (MoA, 2021c) The economic shock came in April 2022 when the price suddenly increased from 62 CZK/kg to 75 CZK/kg. It keeps increasing, but in slower pace. Šimpach and Šimpachová Pechrová (2018) modelled the prices of poultry and found out that they depended only on the lag of price one month ago. They found out that ARIMA(1,1,0) with unit impulse in 06/2008 was optimal. In our case it was ARIMA(4,0,1), because we have different commodity – whole chicken.

Consumer price of potatoes has always been very volatile. "The development of the average consumer price of early potatoes is mainly influenced by the state of stocks of other consumer potatoes from the last harvest, the development of their price, the supply and import values of new and early potatoes, but also the development of the weather and the date of the start of the harvest." (MoA, 2021d) Therefore, similarly as in case of milk, also here the projections of SARIMA and ARIMA models differ significantly. Both predict price increase, but SARIMA expect unrealistic decrease since 07/2022 to third quarter of 2023 (see Fig. 1). ARIMA model envisioned increase of the price up to 15,2 CZK/kg in January 2023 followed by decrease. In the context of the whole time series we may expect the stabilization of the consumer price in the near time period.

Figure 1 Comparison of forecasts (07/2022 – 06/2023) of consumer prices of commodities (CZK)



Milk		
Chicken		
Potatoes		
Sugar		

Eggs		

Source: own processing

For sugar price, the algorithm chose models that project changes almost every month. The pattern is somehow similar to the development of real price, nevertheless, the ARIMA model is less realistic – the volatility probably will not have that regular pattern. SARIMA on the other hand, corresponds to the reality that the price of sugar has been increasing since the third quarter of 2021 (see Fig. 1). It should increase up to 22 CZK/kg. ARIMA model expect lower price (18 CZK/kg). Pechrová and Šimpach (2017) projected the consumer prices of sugar by ARIMA(1,1,1) model. Their forecast in medium variant forecast predicted prices of sugar crystal from 18.4 CZK/kg to 19.1 CZK / kg. Our current forecast is more similar to their upper variant (23.0 CZK / kg). The consumer price of sugar does not traditionally copy the development of prices of industrial producers. Agricultural producers' prices are dependent on prices of agricultural inputs – seeds, plant protection products and fertilizers. "These prices are not created in the Czech Republic, but are due to the development of the EU market, which is directly dependent on the development of commodity prices on world markets." (MoA, 2021e) Therefore, the projection of consumer prices is difficult.

Also, the prices of eggs increased significantly during 2021, but SARIMA and ARIMA predict stabilization on the higher level in 2022–2023. However, SARIMA model expects low volatility between 33 to 35 CZK/10 pieces, ARIMA model predicts slight increase up to 34 CZK/10 pieces in February 2023 and then mild decrease below 33 CZK/10 pieces.

Our results can be compared to those of Šimpachová Pechrová and Šimpach (2017). They used ARIMA(1,0,0) with constant and impulses in crisis months (03, 05, 07/2012) to model the consumer prices of eggs. They expected price from 2.56 CZK/pc to 2.61 CZK/pc in next 12 months since 09/2016. Currently, the prices are much higher. Significant role on price formation will have import (mainly from Poland and Germany) as "the number of laying hens in domestic farms is gradually decreasing" (MoA, 2021c). In 2020 in comparison with 2019, the agricultural producers prices increased, but consumer prices decreased, so there is no clear positive relationship between those prices. (see MoA, 2021c).

4 Conclusion

The rapid increase of consumer prices could have societal consequences, so the government can take measures to support low income households. For policymaking and planning, a projection of the consumer prices development in the future is needed. Therefore, the aim of the paper was to project the prices of basic food: bread, butter, milk, poultry, potatoes, sugar, and eggs.

The correct model was chosen by algorithm implemented in the econometric software automatically based on Akaike criterion. For bread prices forecast, an ARIMA model is preferred. In case of butter, both models forecast slight decrease of price. But in comparison with previous period of sharp increase, this looks like stagnation. We cannot clearly conclude which model is better as the development pattern is similar. In case of milk projection, SARIMA is in contrast with ARIMA, but both models could be real as the price of milk is very volatile and is increasing and decreasing throughout the whole period. For price of chicken, both forecasts are in contrary. SARIMA model projects decrease while ARIMA slight increase up to asymptote 76 CZK/kg. This is probable development as the price of chicken was low in 2020 in comparison with previous period, so the increase probably will continue. Similar situation is for potatoes where ARIMA model projects certain stabilization after reaching a peak price at the end of the year 2022. SARIMA model projects more realistic development of sugar price. In case of eggs price, both models project stabilization, so it cannot be concluded which model is more preferred.

However, econometric correctness and the best fit of the model was not a guarantee that the model would have the best projection powers, or that the projected values would meet the expectations based on the economic theory and practical experiences. There are other determinants that influence the price of the agricultural commodities that only the price in previous period. So, the autoregressive process and moving average are not sufficient to explain the development of consumer prices of food. Those depend on prices of inputs (agriculture producers' prices, energies), industrial producers'

prices, and the agrarian-food trade relations. Each commodity and hence also food product have specific situation and the relation between price of input and output has different magnitude. Therefore, the projection of the final price for consumer is difficult and the results must be taken with caution. Special regression models, VAR models or neural network models can be also used for price projections. For example, Hansen (2020) recommends that combination of linear and nonlinear models is useful in forecasting commodity prices shall be used.

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