

Forecasting Analysis of the Hungarian CPI Based on the Arima Model

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Abstract. Since the twenty-first century, under the influence of economic system reform and economic globalization, Hungary's economic development has prospered, and the GDP index has increased significantly, however, while the country's economic development level has increased year by year, the consumer price index has also shown a year by year increasing trend. Consumer price index (CPI) is closely related to the quality of life, employment and economic stability. In this paper, the CPI in 2021 is taken as the base (100), and the data from 1990 to 2021 are statistically analyzed, and the ARIMA model is used to make time-series forecasts. Based on the ADF test, autocorrelation and partial autocorrelation plots for the determination of the series parameters, the ARIMA (1, 1, 0) model is obtained, and the final results are obtained for the ten data forecasts after 2021. The results show that the Hungarian consumer price index will still grow in the next ten years, but unlike the exponential growth after 2017, the growth rate slows down in the next ten years, indicating that the economic situation will stabilize in the future and price fluctuations will not be too high.

Keywords: ARIMA model, consumer price index, inflation.

1. Introduction

1.1. Reaserch Background

Hungary is a landlocked, developed country in the center of Europe, at the crossroads of Eastern and Western Europe and the Baltic Sea south to the Balkans. After the fall of fascism in Hungary after World War II, the Soviet Union transformed it into a public socialist state. In the 1970s Hungary experienced rapid economic development and a rise in the material standard of living. However, due to institutional problems and Soviet policies, Hungary's domestic conflicts further intensified in the late 1980s. 1989-1990, the Hungarian Socialist Workers' Party (HSP) announced that it would relinquish its position as the ruling party and establish a multi-party system and parliamentary democracy as a state under the rule of law. Figure 1 shows the GDP situation and growth rate of Hungary after the introduction of the market economy system in 1990. As can be seen from the figure, Hungary's GDP index increased significantly and noticeably during the two decades of 1990-2009 thanks to the development of economic globalization and institutional transformation, and the economic growth rate was low in 2010-2015 due to the impact of the European debt crisis. After the European debt crisis, Hungary's economic growth rate returned to the average level. 2020 after the Hungarian economy by the impact of the new crown epidemic, there are large fluctuations.

The energy crisis triggered high inflation after the energy crisis erupted because Hungary's energy prices and food prices had previously remained low for a long time, and because of Hungary's high dependence on Russian natural gas.

Hungarian economist Gaisa said Hungary's high inflation is mainly from the Russian-Ukrainian conflict and the negative impact of sanctions against Russia, and now look at the entire European Union almost every country inflation index is very high. The Orbán government has taken a series of measures to control inflation, including mandatory discounts, price monitoring, and boycott of the EU's plan to impose a total ban on oil and gas imports from Russia.

High energy prices have burdened the Hungarian economy, undermining its competitiveness and industrial performance, and many small and medium-sized enterprises (SMEs) have gone out of business because of difficulties in sustaining their operations, for which the Hungarian government

has introduced low-interest loans and deferred lending measures specifically for SMEs to alleviate the pressure on their operations.

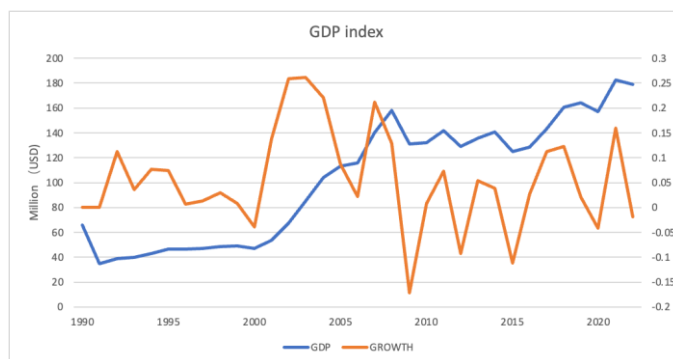


Figure 1. Hungarian GDP index

1.2. CPI index

This article focuses on the Hungarian Consumer Price Index (CPI) for the last thirty years, which is an essential concept in macroeconomic research area reflecting changes in the price level of consumer goods and services related to the life of the population, and an indispensable indicator for the country's overall economic situation analysis and policy setting. In the national economic accounting system, CPI reflects the level and efficiency of government management and the resource distribution. In addition to observing and analyzing the extent to which changes in retail prices of consumer goods and prices of services affect the real cost of living expenditures of urban and rural residents, the CPI is also suitable for measuring inflation and deflation and reflecting changes in the purchasing power of money. At the same time, because prices and stock prices move in the same direction, the CPI index can also have an impact on the stock market to a certain extent. the CPI index has a certain lag, so it is very necessary to forecast the CPI index, on the one hand, it is conducive to the government authorities for the prediction of the data and the actual economic situation of the timely adjustment of the policy to improve people's livelihoods; on the other hand, the CPI forecast value reflects the price trend can, to a certain extent, be used to analyze the impact of consumer goods retail prices and service price changes on urban and rural residents' actual living expenses. On the other hand, the trend of price changes reflected in the CPI forecast can provide guidance for domestic and foreign investors to a certain extent.

$$CPI = \frac{\text{the value of a group of fixed commodities at current prices}}{\text{the value of a group of fixed commodities at base-period prices}} \times 100\% \quad (1)$$

As can be seen from formula 1, the smaller the CPI index is, the smaller the price fluctuation is, the more stable the economy is, and the less impact it has on people's livelihood.

2. Data description

Data on the Hungarian consumer price index (CPI) are derived from the Hungarian Housing Public Expenditure Database (HHPED) for 1990-2023, which summarizes Hungary's central government expenditures on housing from the official Budget Act and the Winding Up Accounts Act, as well as from other sources (e.g., the Central Statistical Office). For ease of observation and measurement, this paper uses the value of the consumer price index used by PRICE_DEFLATOR for conversion to 2021 prices (2021=100).

Figure 2 illustrates the trend of the CPI index for 1990-2021 with the 2021 data as the base period, and it is clear from the figure that there is an overall upward trend and a faster growth rate most of the time. The price deflator shows a clear linear growth trend until 2012, and the data shows a steady state during the five-year period from 2012-2017, with a clear exponential growth trend after 2017. This indicates that the price level in Hungary has increased at a high rate in the last three decades. Especially in the last five years, Hungary's inflation has been high due to the impact of international

events such as the New Crown epidemic that hit economic globalization and the energy crisis in Europe due to the Russian-Ukrainian conflict. As can be seen in the figure, the CPI deflator shows an exponential growth trend, which is undoubtedly a huge impact on the national life and also seriously affects the economic stability of Hungary.

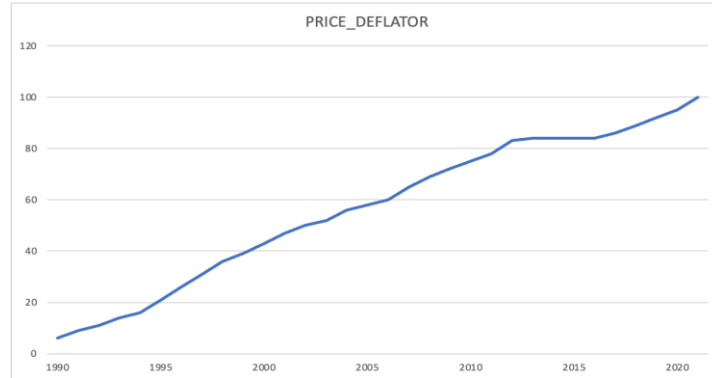


Figure 2. Consumer Price Deflator Index

3. Method

The autoregressive integrated moving average model can be shortened to “arima model”, is one of the most popular and widely used statistical methods for time series forecasting. In the following paper, the elements of the model will be introduced separately.

3.1. AR (Auto Regression) model

An autoregressive model builds a relationship bridge between current and historical values. The predictions of variables will be shown from using it's own time data.

The general P-order autoregressive model AR:

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \dots + \alpha_p X_{t-p} + \mu_t \quad (2)$$

If the random perturbation term is a white noise ($\mu_t = \epsilon_t$), it is called a pure AR(p) process, denoted:

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \dots + \alpha_p X_{t-p} + \epsilon_t \quad (3)$$

The critical process of autoregressive model is to determine an order p , which indicates the number of the periods of historical values are used in this model to predict the current value. But there are some limitations to the autoregressive models. The first one is the data quantities, because ar-model makes predictions by using their own data only, which may omit the influence of external factors on predicted values. The next limitation is the time series data used in model must be smooth, which means the data needs to present continuous, consistent and observable features. And Autoregression can only be used to predict phenomena that are correlated with their own prior periods (this feature can also be called “autocorrelation of the time series”).

3.2. MA (Moving Average) model

In an AR model, if μ_t is not a white noise, it is usually considered to be a q-order moving average. i.e.

$$\mu_t = \epsilon_t + \beta_1 \epsilon_{t-1} + \dots + \beta_q \epsilon_{t-q} \quad (4)$$

Where ϵ_t denotes a white noise sequence.

Specially, when X_t equals to μ_t , which means the current values of the time series unrelated to the historical values, but depend only on a linear combination of historical white noise:

$$X_t = \epsilon_t + \beta_1 \epsilon_{t-1} + \beta_2 \epsilon_{t-2} + \dots + \beta_q \epsilon_{t-q} \quad (5)$$

One point to note is that the effect of historical white noise in the AR model is indirectly affecting the current predicted values (by affecting the historical time series values).

3.3. ARMA model

Combining AR(p) with MA(q) yields a general autoregressive moving average model ARMA(p, q):

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \dots + \alpha_p X_{t-p} + e_t + \beta_1 e_{t-1} + \beta_2 e_{t-2} + \dots + \beta_q e_{t-q} \quad (6)$$

The equation combines the ar-model and ma-model which means that stochastic time series can not only be described by its own historical or lagged values, but also can be explained by random disturbance term. If the behaviors of the series do not change over time, then the past vlues can be used to predict the future values.

3.4. ARIMA model

Generalising the autoregressive (AR) model, the moving average (MA) model and the difference method yields the differential autoregressive moving average model ARIMA(p, d, q), where d is the order in which the data are to be differenced. Smooth series is the elementary condition of the arima model, which means the variance of the time series do not vary over time. In this paper, the historical data of Hungary's price deflator for the period 1990-2021 is used to forecast and analyze the future values, and this set of time-series data satisfies the arima modeling requirements.

4. Parameterization

In order to further accurately infer its smoothness statistically, a unit root ADF test is first needed as a way to determine the smoothness.

Table 1. ADF test

Variable	difference	t	P	AIC	Critical Value		
					1%	5%	10%
PRICE_DEFLATOR	0	-1.203	0.672	108.906	-3.689	-2.972	-2.625
	1	-2.925	0.043**	107.993	-3.633	-2.949	-2.613
	2	-3.854	0.002***	105.15	-3.724	-2.986	-2.633

Note: ***, **, * represent 1%, 5%, and 10% significance

levels, respectively.

The results of testing this series show that the p-value of significance on the PRICE_DEFLATOR variable is 0.043** at the first order difference level, which indicates significance and rejects the original hypothesis that this series is a smooth time series. Secondly, the ACF autocorrelation curve and partial autocorrelation curve of PACF of the first difference of the series were calculated using statistical software as shown in Figs. 3 and 4, and the initial estimation of the time series follows the ARIMA(1, 1, 0) model.

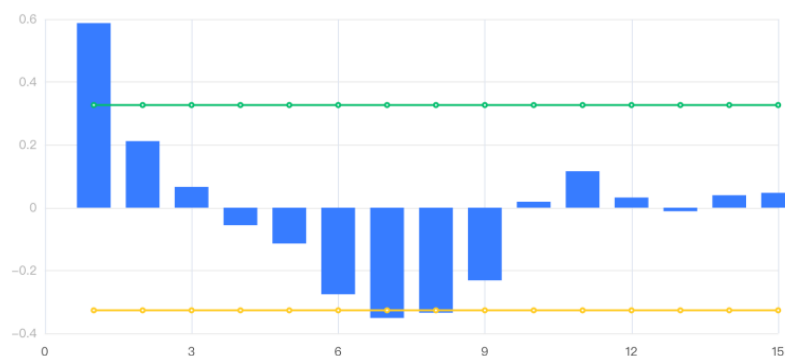


Figure 3. Autocorrelation plot of time series

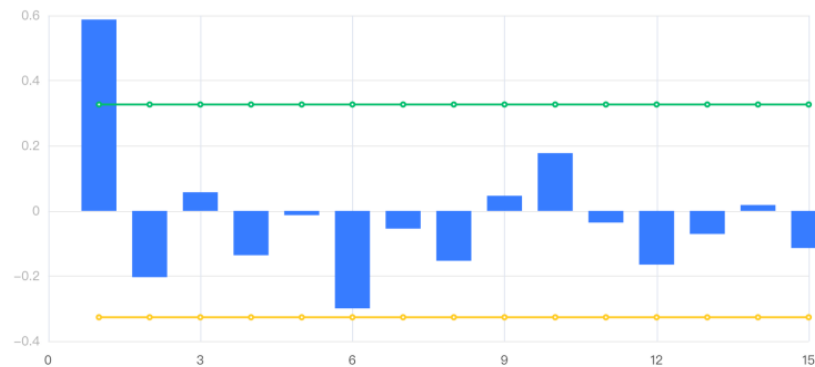


Figure 4. Partial autocorrelation plot of time series

5. Model construction and prediction

Next, this paper attempts to fit the time series using an ARIMA(1, 1, 0) model for testing and obtains the model's Akaike information criterion (AIC) value of 132.68 and Bayesian information critrtion (BIC) of 137.08. as can be seen in Table 2 , the results of the forecasts made on the basis of the model reflecting the regularity of changes followed by the Hungarian price deflator built on historical data show that the Hungarian price deflator still shows an upward trend in the next ten years, but the growth rate has slowed down compared to the post-2017 exponential growth. Figure 5 provides a more visual representation of the projected growth of the price deflator. The different color ranges demonstrate the extreme and minimal value intervals for different confidence levels.

Table 2. Projections of the price deflator for the next ten years (2022-2031)

YEAR	FORECAST	Lo 80	Hi 80	Lo 95	Hi 95
2022	119.4407	117.1423	121.7391	115.9256	122.9558
2023	126.2156	121.7794	130.6518	119.4310	133.0002
2024	131.9063	125.3937	138.4190	121.9461	141.8665
2025	136.8913	128.4299	145.3526	123.9508	149.8318
2026	141.4170	131.1504	151.6835	125.7157	157.1182
2027	145.6436	133.7104	157.5769	127.3933	163.8940
2028	149.6758	136.2014	163.1502	129.0684	170.2831
2029	153.5812	138.6764	168.4860	130.7863	176.3761
2030	157.4042	141.1655	173.6429	132.5693	182.2392
2031	161.1736	143.6847	178.6625	134.4266	187.9206

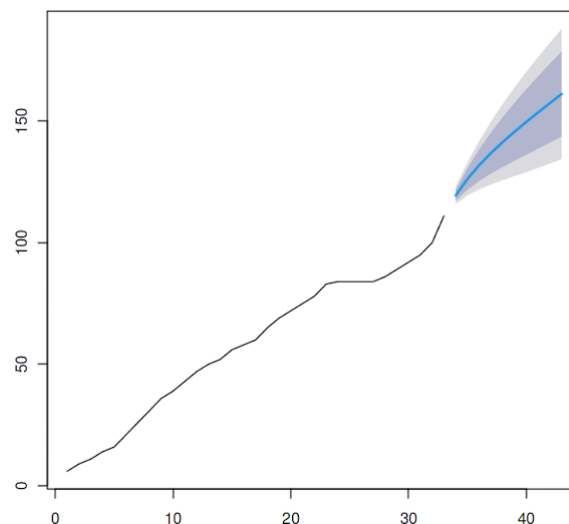


Figure 5. Time series prediction plot

The above figure shows the predicted values of the Hungarian price deflator for the next decade, as shown in the figure. The shaded areas are the predicted time intervals, and the blue line in the middle represents the predicted values. The purple area represents 80% of the execution interval, while the outer gray area represents 95% of the execution interval. At the same time, the narrow bandwidth of the predicted values indicates that the model has good prediction performance.

6. Conclusion

Based on the results of the model, the Hungarian consumer price index has accelerated in recent years, but according to the model, in the long run, the slope gradually decreases in the next few years along with continued but slower growth. This means that Hungary will gradually level off after the price increases of recent years and the economic development will stabilize. However, overall there is still a gap with the base period (2021) indicator, indicating that the inflation problem still exists in Hungary and will continue for some time.

This paper analyzes the consumer price index in Hungary in the past 30 years and constructs an ARIMA model for forecasting based on historical data, and obtains the predicted value of the consumer price index in Hungary in the next ten years. The still rising but slower growth trend indicates that the price level in Hungary is under some control, but inflation still exists and will continue to exist. This result can provide guidance for the Hungarian government in the formulation of monetary and fiscal policy, while the energy crisis in Europe due to the Russian-Ukrainian conflict should also be concerned, which has led to a period of price increases that is also reasonable. In response to the obvious station of inflation, the government can adopt a tight monetary policy, reduce the benchmark interest rate and control the money supply.

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