Research of Inflation Processes in Ukraine in Crisis Conditions

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Abstract: The purpose of the article is a research of the level of inflation in Ukraine based on the analysis of the dynamics of the annual consumer price index. In connection with the crisis phenomena in the economy, which are the consequences of the COVID-19 pandemic and Russian military aggression, the problem of restraining excessive price growth becomes the most important condition for the implementation of the socio-economic and monetary policy of the state. The impact of macroeconomic indicators such as gross domestic product, the hryvnia exchange rate against the US dollar, and the average wage in Ukraine on the growth of consumer prices is studied. With the use of application packages, it is substantiated that the dynamics of the consumer price index is characterized by a random component and cannot be approximated by elementary functions that depend only on time. With the help of MS Excel spreadsheets, a mathematical model of the dependence of the consumer price index on the rates of growth and decline of the main macroeconomic indicators was built in the form of a multiple regression equation and its adequacy was proven. Based on the constructed model, it was concluded that the exchange rate of the national currency has the greatest influence on the consumer price index. The results of the study can be used in forecasting the annual inflation rate for the next period. Forecasting of the consumer price index for 2022 was made based on the constructed model.

1 INTRODUCTION

The coronavirus pandemic and the quarantine restrictions aimed at containing it have had a negative impact on the global and domestic economy. The beginning of 2022 shocked the whole world with the open military aggression of the Russian regime, which led to crisis phenomena in Ukraine and the world. At the current stage, one of the most urgent problems is the prevention of excessive price growth. In macroeconomics, the situation in Ukraine is called stagflation. Stagflation is characterized by rising prices during crisis phenomena in the economy. The implementation of measures to support a stable level of inflation becomes the most important condition for the implementation of the monetary policy of the state.

In the research, inflationary processes are studied on the basis of the annual consumer price index (CPI) in Ukraine for the period from 2002 to 2021 according to the official website of the State Statistics Service (SSSU, 2022). The consumer price index demonstrates the general level of inflation in the economy and is an indicator of the population's standard of living and social-economic development. The CPI takes place in a center of the indicators of price statistics system and is calculated in Ukraine, starting from August 1991, as part of the program for developing a number of macroeconomic indicators based on international standards. The CPI has become an important economic indicator since its introduction. The value of the CPI is difficult to overestimate, as it directly or indirectly affects the standard of living of the country's population (State Statistics Service of Ukraine, 2022). To curb excessive price growth, the mathematical modeling of the level of inflation based on a scientific analysis of the dynamics of the cost of goods and services, the volume of GDP, the exchange rate of the domestic currency, the level of wages and other macroeconomic factors are needed.

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2 PROBLEM STATEMENT AND SOLUTIONS

Considering the impact of inflation on socio-political and economic life, various aspects of its research are presented in the works of many domestic and foreign scientists. The mutual influence of the growth of consumer prices and inflationary expectations in Ukraine was studied in the work of Khokhych (Khokhych, 2020). In the work of Gitis et al. (Gitis et al., 2020), the problem of the impact of rising consumer prices on the level of income of the population is raised. In the article by Kuzheliev et al. (Kuzheliev et al., 2020), the impact of inflation and other monetary policy instruments on key economic indicators in Ukraine during periods of stability and crisis is considered.

Sarel (Sarel, 1996) analyzed the possibility of a nonlinear impact of the CPI on economic growth, when this indicator is critical – 108. Below this value, the CPI does not affect growth, or may even have a slightly positive effect.

In the works of Macovei and Scutaru (Macovei and Scutaru, 2016; Macovei, 2020), the influence of the consumer price index on the economic growth of Romania was investigated on the basis of annual data from 1991 to 2018 and it was proposed to use a nonlinear regression model. The results of the study show a close relationship between the consumer price index (CPI) and the gross domestic product (GDP).

The analysis of the use of the value unit index for curbing inflation in Latin American countries was carried out by Yereshko and Hafarov (Yereshko and Hafarov, 2020).

Shinkarenko et al. (Shinkarenko et al., 2021) examines the behavior of the consumer price index in Ukraine for the period from January 2010 to September 2020 by month. The characteristics of the initial time series, the analysis of auto-correlation functions made it possible to reveal the trend of their development and the presence of annual seasonality. To simulate the behavior of the consumer price index and forecast for the following months, 2 types of models were used: the additive ARIMA*ARIMAS model, better known as the Box-Jenkins model (Box et al., 2015) and the exponential smoothing model with Holt-Winters seasonality estimation (Gardner Jr., 1985). As a result of using the STATISTICA package, the most adequate models reflecting the monthly dynamics of the consumer price index in Ukraine were built. However, the rapid deterioration of the economic situation in Ukraine in connection with open Russian military aggression does not allow the application of these models.

3 MAIN RESULTS

Inflationary processes are studied on the basis of the following macroeconomic indicators: the annual consumer price index in Ukraine (CPI), the annual gross domestic product (GDP) calculated in US dollars, the exchange rate of the hryvnia against the US dollar (HR) and the level of average wages (AW), converted in US dollars for the period from 2002 to 2021. The array of data was compiled on the basis of the reports of the State Statistics Service of Ukraine (SSSU, 2022) and the National Bank of Ukraine (NBU, 2022). The resulting array of data is shown in table 1.

To build a model and forecast the level of inflation, we first find the main statistical characteristics of the dynamic series under investigation. They are shown in table 2.

Numerical characteristics of the CPI range show that the consumer price index fluctuated in the interval from 99,4% to 143,3% during the studied period. The mean square deviation of 6,63 shows that the variation of the consumer price index for the studied period is quite small.

The characteristics of the GDP series show that during the studied period the volume of the gross domestic product gradually increased from 50 133 million US dollars to 183 310 million US dollars. The mean square deviation of 32130,572 indicates the absence of anomalous values of the indicator except for certain years.

The statistics of the HR series show a gradual depreciation of the national currency from 5,05 to 27,2 per US dollar. The mean square deviation of 8,344 shows that hryvnia exchange rate jumps in some years were quite insidious.

Numerical characteristics of a number of wage earners show that the average wage in Ukraine gradually increased from USD 70,59 to USD 430,21. The mean square deviation of 83,025 indicates that the growth of the indicator occurred gradually.

In order to clearly display the dynamics of the consumer price index in Ukraine during 2002-2021, a diagram of the indicator was constructed (figure 1).

The constructed trend equation shows that CPI forecasting using standard time series forecasting methods is not possible, as the correlation coefficient is very small. The series has neither a trend nor a seasonal component, therefore, in order to make an adequate forecast, it is necessary to identify the factors that have the greatest influence on the dynamics of the CPI.

Since the indicators chosen for the model have fundamentally different dimensions, it is impossible

Table 1: Some macroeconomic indicators in Ukraine for 2002-2021.

Years	CPI	GDP	HR	AW	CPI	GDP	HR	AW
2002	99,4	59286	5,29	70,59	-	-	-	-
2003	108,2	50133	5,33	86,74	1,082	1,183	0,992	1,229
2004	112,3	64883	5,32	111,02	1,123	1,294	0,997	1,280
2005	110,3	86142	5,12	157,3	1,103	1,328	0,963	1,417
2006	111,6	107753	5,05	206,51	1,116	1,251	0,985	1,313
2007	116,6	142719	5,05	267,87	1,166	1,325	1,000	1,297
2008	122,3	179992	5,27	343,43	1,223	1,261	1,043	1,282
2009	112,3	117228	7,79	245,05	1,123	0,651	1,479	0,714
2010	109,1	136419	7,94	283,12	1,091	1,164	1,019	1,155
2011	104,6	163160	7,97	331,24	1,046	1,196	1,004	1,170
2012	99,8	175781	7,99	379,42	0,998	1,077	1,003	1,145
2013	100,5	183310	7,99	409,59	1,005	1,043	1,000	1,080
2014	124,9	131805	11,89	292,32	1,249	0,719	1,487	0,714
2015	143,3	90615	21,84	162,60	1,433	0,687	1,838	0,556
2016	112,4	93270	25,55	203,02	1,124	1,029	1,170	1,249
2017	113,7	112154	26,60	267,16	1,137	1,202	1,041	1,316
2018	109,8	130832	27,20	325,99	1,098	1,167	1,023	1,220
2019	104,1	153781	25,85	406,40	1,041	1,175	0,950	1,247
2020	105,0	155568	26,96	430,21	1,050	1,012	1,043	1,059
2021	110,0	200090	28,78	506,42	1,100	1,286	1,068	1,177

Table 2: Characteristics of dynamic series for 2002-2021.

Indicator	Average value	Average deviation	Minimal value	Maximal value
CPI	112,3	6,630	99,4	143,3
GDP	126419,1	32130,572	50133	183310
HR	13,2	8,344	5,05	27,20
AW	272,7	83,025	70,59	430,21

to build a function that will accurately reflect the impact of GDP, HR and SP on the CPI. In such cases, it is necessary to standardize the data. Methods of standardization of research factors are described in detail in works (Shinkarenko et al., 2019; Matskul et al., 2020). The method of eliminating different dimensions is also used, which is based on the comparison of growth rates of time series (for example, (Kozak et al., 2017)). This is what we used in our work to analyze inflationary processes.

When modeling relationships in dynamic series, relative values are widely used. This is due to their greater elasticity in time compared to absolute values. In addition, it helps eliminate multicollinearity and autocorrelation of the residuals. We will assume that the CPI is modeled by a function of the Cobb-Douglas-Tinbergen type (Yankovoy and Yankovoy, 2019):

$$I = \gamma \cdot Q^{\alpha} \cdot G^{\beta} \cdot K^{\lambda} \cdot e^{\mu t}. \quad (1)$$

where I is the consumer price index (%), Q is GDP (millions of US dollars),G is the hryvnia exchange rate (US dollars), K is the average wage (US dollars). Parameters α, β, γ and μ are elasticity coefficients: α characterizes the increase in the CPI per unit of GDP growth at unchanged HR and SP, β is the increase in CPI per unit of increase in HR at unchanged GDP and SP, Λ is the increase in CPI per unit of increase in SP at unchanged GDP and HR, μ — CPI growth due to factors not included in the model.

Applying logarithmic differentiation to the Cobb-Douglas-Tinbergen function, taking into account that each factor depends on time, we obtain a linear model that describes the relationship between growth rates:

$$i = \mu + \alpha \cdot q + \beta \cdot g + \lambda \cdot k. \quad (2)$$

where i, q, g, k are the growth rates of CPI, GDP, HR and AW, respectively. In the future, the rate of growth of the indicator will be understood as the ratio of its next level to the previous one. Note that this approach avoids reducing the indicators to one dimension. Table 1 shows the growth rates of each of the studied indicators.

To determine the general trend of the behavior of the time series, a diagram was constructed that reflects the dynamics of the growth rates of the consumer

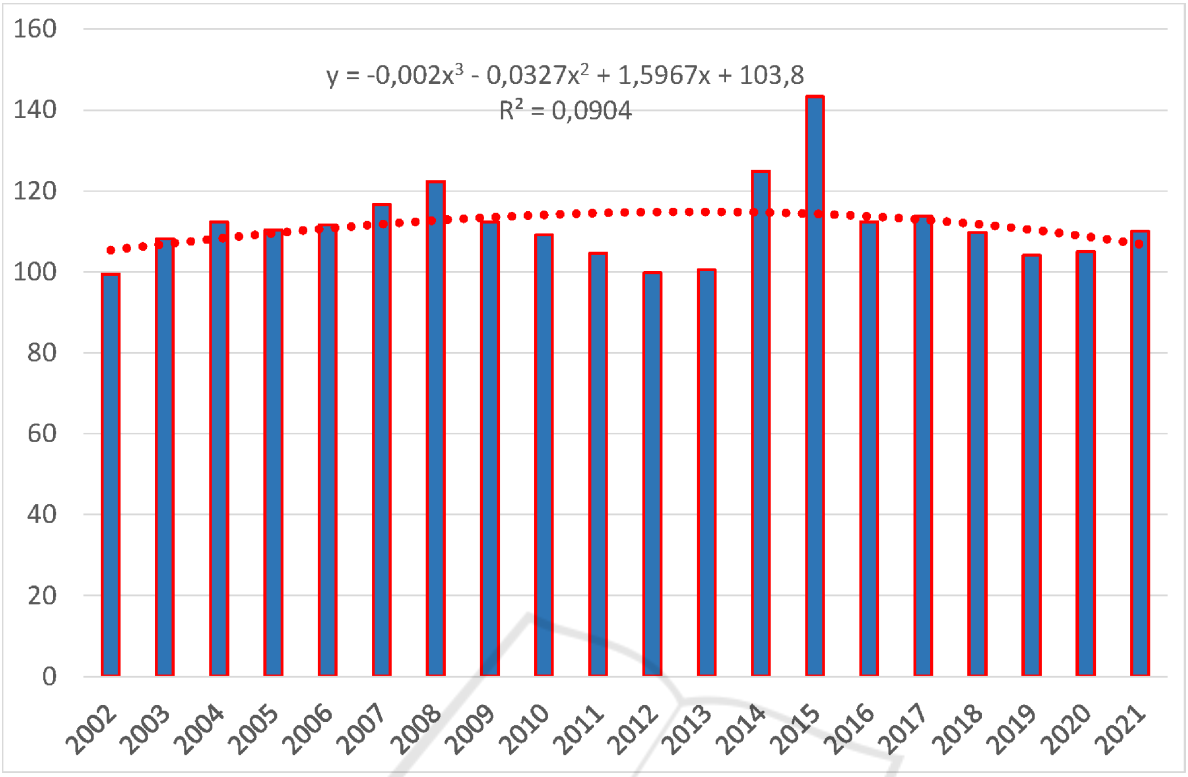

Figure 1: Dynamics of the consumer price index in Ukraine for 2002-2021.

price index, the gross domestic product, the hryvnia exchange rate, and the average wage (figure 2).

The analysis of the constructed trend lines shows that fluctuations in the level of the consumer price index are closely related to the behavior of the volume of the gross domestic product, the hryvnia exchange rate, and the average wage. To confirm the hypothesis about the presence of a close relationship between the specified factors, the correlation coefficients between the indicators were calculated. The obtained coefficients are shown in table 3.

Table 3: Correlation matrix of CPI, GDP, HR and AW.

	CPI	GDP	HR	AW
CPI	1	-0,43485	0,790091	-0,54429
GDP	-0,43485	1	-0,87949	0,954285
HR	0,790091	-0,87949	1	-0,91172
AW	-0,54429	0,954285	-0,91172	1

The calculated coefficients allow us to conclude that the rate of growth of the consumer price index is most affected by fluctuations in the hryvnia exchange rate (a 1% devaluation of the hryvnia leads to an increase in the CPI by 0,79%). The influence of the growth rates of the gross domestic product and average wages is moderate and negative, that is, an increase in the GDP growth rate by 1% will lead to a decrease in the CPI by 0,43%, the consequence of an increase in the growth rate of GDP by 1% is a decrease in the CPI by 0,54%.

A regression equation was built using the MS Excel:

$$i = -0{,}335 + 0{,}545 \cdot q + 0{,}764 \cdot g + 0{,}007 \cdot k. \quad (3)$$

where i, q, g, k are the growth rates of CPI, GDP, HR and AW, respectively (figure 3).

The equation has good statistical indicators of correlation and regression analysis. The multiple correlation coefficient $R = 0{,}961$ shows that the volume of GDP, the hryvnia exchange rate and the average salary directly affect the change in the CPI (covering about 9% of the influencing factors). The standard error of the regression $S_y = 0{,}031$ is quite small, which indicates that the model corresponds to the economic process. The calculated value of the F-criterion is $F = 55{,}766$, its significance is $F = 4{,}97 \cdot 10^{-8}$. The calculated value is significantly less than 0,01, therefore, with a 99% level of reliability, it is possible to assert, according to Fisher's test, that the constructed model is adequate to the empirical data.

Let's check the reliability of each of the coefficients of the constructed equation: for the first coefficient

$$t_1 = 4{,}564, p_1 = 0{,}0004 < 0{,}005,$$

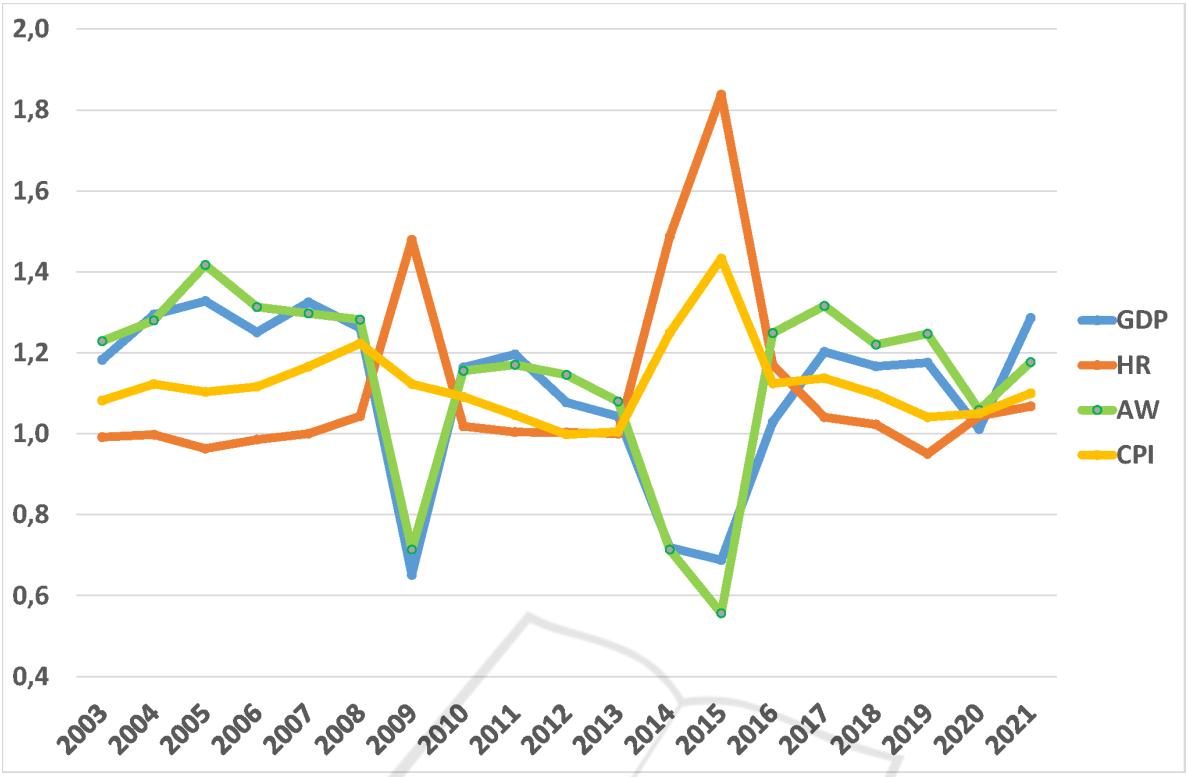

Figure 2: Growth rates of the CPI, GDP, HR and AW in Ukraine for 2003-2021.

RESULTS

Regression statistics	
R	0,960614201
R-square	0,922779642
Normalized R-square	0,906232423
standard error	0,031097824
Observations	19

Analysis of variance

	df	*SS*	*MS*	*F*	*Значимость F*
Regression	3	0,161790955	0,053930318	55,76644728	4,96759E-08
residual	15	0,013539045	0,000967075		
Total	18	0,17533			

	coefficient	standard error	*t-statistic*	*P-value*	
Y	-0,335	0,172	-1,949	0,072	
X1	0,545	0,119	4,564	0,000	
X2	0,764	0,077	9,954	0,000	
X3	0,007	0,124	0,055	0,957	

Figure 3: Results of Regression statistics and Analysis of variance.

therefore, according to the Student's criterion, the coefficient is statistically reliable with a level of 99%, for the second coefficient

$$t_2 = 0{,}077, p_2 = 9{,}89 \cdot 10^{-8} < 0{,}005,$$

therefore, according to the Student's test, the coefficient is statistically reliable at the 99% level, for the third coefficient the value

$$t_3 = 0{,}124, p_3 = 0{,}957 > 0{,}005,$$

therefore the coefficient is not statistically reliable at the 99% level. It is more likely that the problem arose as a result of the close connection between the factors of GDP and AW.

To check the reliability of the built model, we will calculate the forecast value of the consumer price index for the end of 2022, using the data on the gross domestic product, the hryvnia exchange rate and the average salary, which are given on the websites of the Cabinet of Ministers of Ukraine (Ministry of Finance of Ukraine, 2022) and the National Bank of Ukraine (NBU, 2022). According to the given data, a decrease in GDP is expected by 40%. The hryvnia exchange rate is set at UAH 40,0 per USD, up 38,7% from the previous period. The average salary at the end of 2022 is forecast to be UAH 18,535, which at the exchange rate of UAH 40,0 is 440,48 USD, the growth until 2021 is 12,9%. Let's calculate the predicted value of the CPI:

$$i = -0{,}335 + 0{,}545 \cdot 0{,}6 + 0{,}764 \cdot 1{,}39 + 0{,}007 \cdot 0{,}87 = 1{,}417. \quad (4)$$

The calculated value shows that the consumer price index in 2022 will increase by 41,7% compared to 2021.

4 CONCLUSION

The built mathematical model of the dependence of the growth of the index of social prices on the growth of the annual volume of the gross domestic product, the exchange rate of the hryvnia and the level of the average salary is adequate and reliable. Using the regression equation, it is possible to estimate the influence of factors on the change in the CPI and calculate the predicted values of the social price index.

The processing of the array of the consumer price index with the help of application programs proved that the indicator is characterized by a random component and cannot be approximated by elementary functions.

The forecast of the indicator for the end of 2022 showed that, taking into account the crisis in the economy associated with the Russian military aggression, a significant increase in the level of inflation is expected in Ukraine.

For a more detailed study of the causes and rates of growth of the consumer price index, one should consider the change in the value of its individual components (food, non-food, services and other groups of goods), the relationship of the indicator with a similar indicator in neighboring countries (price growth on the world market), the influence of the state debt to the level of inflation in the country.

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