Price Monitoring Automation with Marketing Forecasting Methods

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Summary
The main aim of the article is to solve the problem of automating price monitoring using marketing forecasting methods and Excel functionality under martial law. The study used the method of algorithms, trend analysis, correlation and regression analysis, ANOVA, extrapolation, index method, etc. The importance of monitoring consumer price developments in market pricing at the macro and micro levels is proved. The introduction of a Dummy variable to account for the influence of martial law in market pricing is proposed, both in linear multiple regression modelling and in forecasting the components of the Consumer Price Index. Experimentally, the high reliability of forecasting based on a five-factor linear regression model with a Dummy variable was proved in comparison with a linear trend equation and a four-factor linear regression model. Pessimistic, realistic and optimistic scenarios were developed for forecasting the Consumer Price Index for the situation of the end of the Russian-Ukrainian war until the end of 2023 and separately until the end of 2024.

Keywords:
Consumer Price Index, Pricing, Linear Multivariate Regression, Forecast, Excel.

1. Introduction

Price management is an important component of both macro-level government regulation of the economy and micro-level marketing management of the firm. Price management is not so much a pricing process as it is a monitoring of the dynamics of market prices, price indexes, consumer demand, and inflation expectations. It is the accuracy of the results of monitoring market prices in a changing market environment that determines the reliability of price planning and forecasting. The process of price forecasting is complex, knowledge-intensive and requires significant intellectual resources. In addition, forecasting needs to take into account as much as possible the external environment, in particular the current situation in the economy, politics and international relations. Also, in the context of the information society and developed consumer markets, automation is another key factor in the effectiveness of price monitoring. The problem of price monitoring automation through marketing forecasting methods is in the interest of many stakeholders: public authorities, producers of goods, works, services, sellers, consumers, which proves its actuality at the current stage of economic development.

2. Theoretical Consideration

When considering price management as a component of state regulation of the economy, the focus should be on monitoring and forecasting consumer prices, as consumption is the basis of aggregate demand and GDP formation. The scientific works of scholars in the field of price management, on which our study is based, are overwhelmingly focused on methodological support for

Thus, N. Spanoudakis and P. Moraitis propose an argumentation-based approach for automating the decision-making process of an autonomous agent for product pricing [1]. A. Haji, and M. Assadi have proposed a solution to the problem of new product pricing by developing a fuzzy expert system taking into account the main influencing factors on price [2]. N. Biloshkurska proposed a methodology for adaptive pricing [3]. M. Capinski, and E. Kopp have proved that the fundamental methodology (and practice) of derivative securities evaluation in continuous-time models is consistent with discrete-time theory [4]. S. Liozu, and A. Hinterhuber investigated the influence of pricing orientations in industrial companies and their relationship to organisational structure and decision theory [5]. Ch. Lo, and K. Skindilias applied the continuous-time Markov chain approximation (MCA) method to a generalized jump-diffusion with a specific focus on derivatives pricing and on model calibration [6]. A. Calabrese, and F. Francesco provided a demand-based pricing approach

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based on the user-friendly technique of service blueprint [7]. E. Pergler et al. introduced the integration of value and pricing into the Performance Journey Mapping framework [8]. Y. Braouezec offered a new simple approach to price European options in incomplete markets using the sole no-arbitrage principle and this only requires to make use of a one-period model [9]. Formalisation and multivariate statistical assessment of the main macroeconomic factors influence on pricing and conditions in perfect competition markets has been carried out in [10]–[11]. B. Denkena, M.-A. Dittrich, and S. Stamm have developed and implemented a new methodology for a dynamic bid price system by using correlations of revenue management in production planning to level the resource utilization [12]. J. Januardi, and E. Widodo represented an analytical pricing model in the dual-channel of the green supply chain by using a response surface methodology to handle the uncertainty problem [13], and used game theory to predict competitor behaviour, obtaining Nesh equilibrium [14]. V. Tang presented a normative methodology, for value-pricing B2B services, using a Nash Equilibrium mechanism [15]. M. Kholod et al. developed a smart pricing model taking into account cost classification and indirect taxes [16]. V. Kozyk et al. have developed an econometric model of the pricing of R&D products for transfer between business entities, taking into account market variability which based of use the Mamdani model in the Fuzzy Logic Toolbox component of the MATLAB software package [17].

Given the broad methodological apparatus used in the analysed papers [1]–[17], as well as relying on [18]–[20], it should be noted that the problem of automating price monitoring by means of marketing forecasting methods has been little studied and should be thoroughly investigated.

The process of price monitoring automation using marketing forecasting methods is knowledge-intensive and multistage. Thus, at the preparatory stage it is necessary to decide on the object of forecasting, formalisation of the forecasting model and the software to be used. Given the full-scale invasion of Ukraine's sovereign territory by the Russian Federation on 24 February 2022, a key indicator reflecting the state of consumption in the country and affecting the population' welfare is consumer inflation. This is why the object of our research is the Consumer Price Index, and the automation of consumer price monitoring through marketing forecasting methods is the goal of scientific investigation. Methods of multivariate statistical analysis should be used to automate the monitoring of consumer prices, as most price management studies are based on these methods. As far as software is concerned, the statistical processing functionality of Excel is sufficient. Figure 1 proposes the author's algorithm for automating the management of consumer price monitoring using marketing forecasting methods.

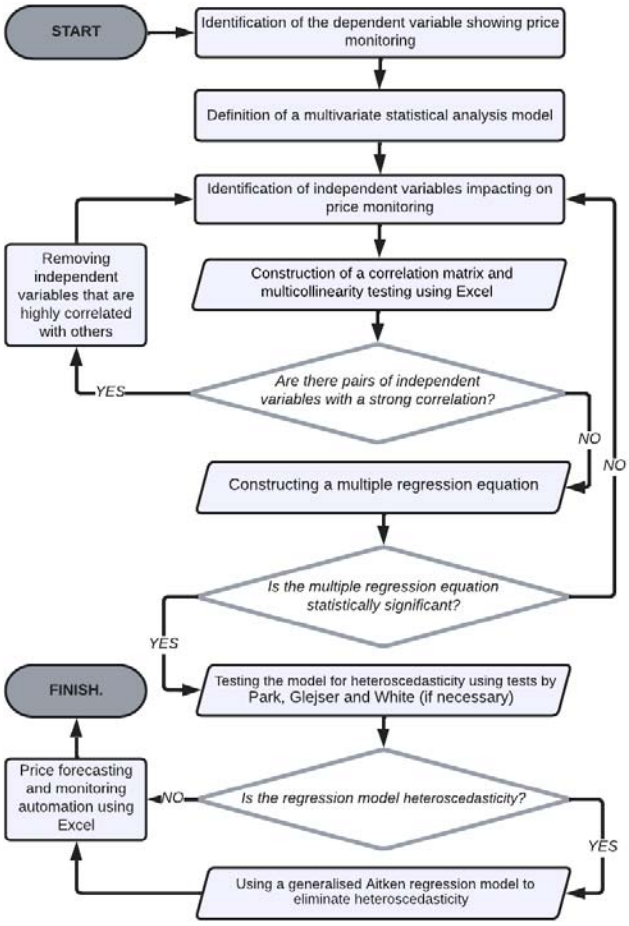

Fig. 1 The management algorithm for price monitoring automation
Source: *Authors' elaboration using Lucidchart.*

The algorithm in Figure 1 shows a comprehensive approach to automating price monitoring using multivariate statistical analysis and marketing forecasting methods. Following this algorithm, the independent variable chosen is the Consumer Price Index (*CPI*), the value of which is justified above. Speaking of the Consumer Price Index, it should be noted that in both marketing pricing and macroeconomic analysis, aggregate price indexes take the lead, because it is they that reflect the monthly price dynamics in a country.

We choose a multivariate statistical analysis model by simulating the alignment of the Consumer Price Index series for 2017–2022 (Figure 2).

Figure 2 shows the monthly evolution of the Consumer Price Index in Ukraine from January 2017 to July 2022 (67 months). The value of the baseline Consumer Price Index is summarised here in points to December 2016. The graph also shows that over the last 6 years and 7 months consumer prices in Ukraine have risen by 75.6 % and the average monthly consumer price increase was 0.9 %. At the same time, the 5 months of large-scale invasion of Ukraine by the Russian Federation

have seen an accelerated increase in consumer prices of 22.7 %. Three trend lines – linear, power and logarithmic – are constructed to define the multivariate statistical analysis model. Figure 2 shows that the linear model with the highest approximation level of 0.914 is the most reliable. This is why a linear multiple regression has been used in forecasting consumer prices.

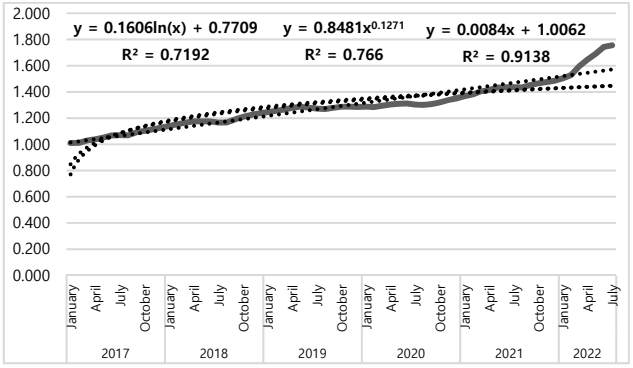

Fig. 2 Dynamics of Consumer Price Index in Ukraine for 2017–2022 (in points to December 2016)

Source: *Generated and calculated according to the data given in [21].*

The accelerated increase of the Consumer Price Index of +22.7 % from February to July 2022 is primarily due to the martial law, which must necessarily be taken into account in a linear multiple regression model, the general form of which is as follows:

$$\hat{y} = a_0 + a_1 x_1 + a_2 x_2 + ... + a_i x_i + a_d D + \varepsilon_i, \quad (1)$$

where $\hat{y}$ is the dependent variable;

$x_1, x_2, \ldots, x_i$ are independent variables, $i = \overline{1; m}$;

$a_1, a_2, \ldots, a_i$ are regression model parameters that show the percentage change in the dependent variable when the dependent variable increases by 1 %;

a_0 is a constant that shows the value of the dependent variable when all independent variables are 0;

D is a Dummy variable that is entered into the model to formalise the martial law in the economy and has a value of 0 and 1 only;

a_d is a parameter under the Dummy variable that shows the percentage change in the dependent variable under war conditions;

ε_i is the residual of the model.

The Formula (1) contains a Dummy variable that formalises the state of war so that each month from January 2017 to January 2022 is assigned the value 0, and from February to July 2022 the value 1. A value of 0 means that there is no martial law in the economy, and a value of 1 means that the economy is in a martial law situation.

In order to identify the independent variables that affect the Consumer Price Index, it is necessary to monitor prices in the main consumer markets. Thus, consumer markets can be grouped into the following groups: food and non-alcoholic beverages; alcoholic beverages, tobacco; clothing and footwear; housing, water, electricity, gas and other fuels; furnishings, household equipment and routine maintenance of the house; health services; communication services; recreation and culture services; education services; restaurants and hotels services; miscellaneous goods and services [21].

Thus, the independent variables in the linear multivariate Consumer Price Index model are:

i) Food Price Index – *FPI*;
ii) Alcohol and Tobacco Price Index – *ATPI*;
iii) Clothing and Footwear Price Index – *CFPI*;
iv) Utilities and Energy Price Index – *UEPI*;
v) Price Index for Furnishings, Household Equipment and Routine Maintenance of the House – *PIFHE*;
vi) Health Price Index – *HPI*;
vii) Transport Price Index – *TPI*;
viii) Communication Price Index – *CmPI*;
ix) Recreation and Culture Price Index – *RCPI*;
x) Education Price Index – *EPI*;
xi) Restaurants and Hotel Price Index – *RHPI*;
xii) Miscellaneous Goods and Services Price Index – *MGSPI*.

It is clear that the highlighted 12 groups of consumer goods form the basis of consumption expenditures of Ukrainians, the price of the vast majority of which is formed in the respective competitive markets for goods, works, and services under the influence of supply and demand. However, the markets for water, electricity, gas and other fuels are mostly natural monopolies and therefore strictly regulated by public authorities.

Consumer price monitoring is an important part of price management, both for producers and regulators, especially in a market economy. After all, producers of consumer goods, when applying market pricing methods, must take competitors' prices into account. Regulatory authorities monitor consumer prices to protect consumers from inflationary shocks.

Table 1 summarises the monthly dynamics of the main Consumer Price Indexes. Using the data in Table 1, we have determined the overall increase in consumer prices in Ukraine between January 2017 and July 2022, as well as the average monthly increase:

i) overall, consumer prices have risen by an average of 0.86 % each month, and have risen by 77.3 % in the last 5 years and 7 months;
ii) the prices of food and non-alcoholic beverages have risen by an average of 1.01 %, and for the entire period of the study increased by 96.5 %;

Table 1: Monthly dynamics of the Consumer Price Index's main components (in points over the previous month)

Year	Month	*FPI*	*ATPI*	*CFPI*	*UEPI*	*PIFHE*	*HPI*	*TPI*	*CmPI*	*RCPI*	*EPI*	*RHPI*	*MGSPI*	*CPI*
2017	January	1.010	1.012	0.957	1.003	1.004	1.006	1.027	1.004	1.005	1.011	1.016	1.007	1.010
	February	1.015	1.017	0.972	1.002	1.002	1.008	1.020	1.005	1.013	1.004	1.012	1.008	1.011
	March	1.012	1.013	1.105	1.050	1.001	1.004	1.007	1.025	1.008	1.002	1.009	0.996	1.018
	April	1.012	1.013	1.009	1.005	1.003	1.005	1.014	1.027	1.003	1.000	1.009	0.981	1.009
	May	1.024	1.027	0.990	1.008	1.002	1.007	1.005	1.001	0.997	1.001	1.008	0.999	1.013
	June	1.034	1.026	0.975	1.005	1.000	1.005	0.998	1.000	1.003	1.004	1.015	1.007	1.016
	July	1.003	1.016	0.956	1.006	1.001	1.005	1.000	0.999	1.002	1.001	1.016	1.003	1.002
	August	0.994	1.014	0.976	1.003	0.999	1.002	1.008	1.000	1.000	1.001	1.011	1.004	0.999
	September	1.020	1.027	1.089	1.004	1.007	1.005	1.015	1.004	1.003	1.120	1.014	1.008	1.020
	October	1.011	1.013	1.024	1.005	1.003	1.010	1.024	1.008	1.007	1.002	1.019	1.002	1.012
	November	1.009	1.006	0.993	1.008	1.007	1.008	1.020	1.009	1.002	1.000	1.014	1.028	1.009
	December	1.016	1.006	0.976	1.003	1.002	1.008	1.018	1.006	1.001	1.000	1.018	1.031	1.010
2018	January	1.021	1.011	0.961	1.004	1.009	1.014	1.030	1.028	1.012	1.014	1.013	1.011	1.015
	February	1.010	1.014	0.972	1.004	1.013	1.011	1.015	1.007	1.007	1.004	1.011	1.008	1.009
	March	1.012	1.013	1.096	1.003	1.008	1.008	0.993	1.006	1.010	1.002	1.009	1.008	1.011
	April	1.011	1.015	1.021	1.002	1.004	1.006	1.003	1.013	1.001	1.000	1.011	0.981	1.008
	May	0.992	1.018	0.996	1.001	1.006	1.006	1.006	1.004	0.994	1.000	1.002	0.998	1.000
	June	0.995	1.016	0.976	1.003	1.002	1.001	1.006	1.003	0.998	1.005	1.011	1.004	1.000
	July	0.980	1.018	0.954	1.005	1.002	1.000	1.007	0.998	1.002	1.002	1.010	1.008	0.993
	August	0.993	1.009	0.974	1.005	1.003	1.001	1.015	1.001	1.004	1.001	1.006	1.003	1.000
	September	1.017	1.008	1.086	1.002	1.006	1.013	1.028	1.021	1.006	1.100	1.005	1.013	1.019
	October	1.015	1.023	1.026	1.006	1.007	1.009	1.031	1.033	1.008	1.001	1.023	1.008	1.017
	November	1.014	1.011	0.994	1.061	1.006	1.009	1.005	1.017	1.003	1.001	1.010	1.034	1.014
	December	1.019	1.010	0.975	1.007	1.000	1.008	0.984	1.011	0.998	1.001	1.012	1.030	1.008
2019	January	1.022	1.012	0.954	1.026	1.005	1.009	0.983	1.025	1.007	1.014	1.008	1.008	1.010
	February	1.009	1.012	0.965	1.005	1.001	1.006	0.999	1.015	1.008	1.004	1.007	1.008	1.005
	March	1.004	1.009	1.113	1.003	0.998	1.004	1.005	1.022	1.002	1.001	1.007	1.000	1.009
	April	1.015	1.012	1.019	1.002	1.002	1.006	1.010	1.011	0.999	1.000	1.008	0.976	1.010
	May	1.010	1.013	0.985	0.993	1.003	1.003	1.015	0.998	0.997	1.000	1.004	1.007	1.007
	June	0.988	1.012	0.970	0.986	0.998	1.004	1.003	0.998	0.999	1.004	1.010	1.003	0.995
	July	0.993	1.011	0.955	0.977	1.002	1.001	0.989	0.999	1.001	1.002	1.011	1.005	0.994
	August	0.996	1.008	0.972	0.991	0.998	1.000	0.994	1.009	0.997	1.003	1.006	1.005	0.997
	September	1.003	1.010	1.087	0.998	1.001	1.001	0.996	0.999	0.995	1.099	1.002	1.014	1.007
	October	1.010	1.008	1.019	0.996	0.997	1.003	0.993	1.042	1.003	1.004	1.011	1.013	1.007
	November	0.998	1.008	0.986	1.028	0.999	1.003	0.997	0.998	1.001	1.000	1.007	1.015	1.001
	December	1.000	1.008	0.966	0.977	0.994	0.997	0.992	0.997	0.990	1.000	1.004	1.022	0.998
2020	January	1.005	1.008	0.944	1.017	0.997	1.000	0.993	1.008	1.000	1.014	1.006	1.017	1.002
	February	0.996	1.008	0.957	0.980	1.000	1.005	1.001	1.003	0.997	1.003	1.006	1.009	0.997
	March	1.004	1.009	1.128	0.972	0.998	1.014	1.007	1.006	1.002	1.002	1.002	0.990	1.008
	April	1.022	1.009	1.004	0.968	1.004	1.021	0.987	1.000	0.996	1.000	1.000	0.970	1.008
	May	1.013	1.011	0.986	0.972	1.001	1.003	0.980	0.999	0.992	1.000	1.003	1.002	1.003
	June	1.004	1.005	0.972	0.996	0.998	1.001	1.012	1.010	0.997	1.003	0.998	1.000	1.002
	July	0.985	1.005	0.952	1.012	0.999	1.003	1.012	1.003	1.005	1.001	1.010	1.001	0.994
	August	0.985	1.005	0.970	1.057	1.003	1.009	1.012	1.009	1.001	1.001	1.001	1.003	0.998
	September	0.993	1.006	1.079	1.036	1.002	1.004	1.005	1.000	0.994	1.110	0.993	1.005	1.005
	October	1.012	1.009	1.020	1.044	1.004	1.004	1.002	1.000	1.009	1.001	1.011	1.005	1.010
	November	1.015	1.008	0.975	1.080	1.004	1.007	1.009	1.001	1.006	1.001	1.003	1.026	1.013
	December	1.018	1.005	0.954	1.001	0.995	1.004	1.007	1.001	1.002	1.000	1.004	1.032	1.009
2021	January	1.015	1.010	0.960	1.060	1.000	1.004	1.010	1.010	1.006	1.012	1.003	1.013	1.013
	February	1.022	1.013	0.965	0.982	1.005	1.005	1.016	1.002	1.009	1.006	1.009	1.006	1.010
	March	1.022	1.007	1.127	1.000	1.005	1.007	1.018	1.000	1.004	1.003	1.008	0.997	1.017
	April	1.012	1.009	1.009	1.004	1.002	1.009	1.006	1.001	1.001	1.003	1.006	0.968	1.007
	May	1.018	1.007	0.994	1.039	1.005	1.005	1.007	1.022	0.992	1.002	1.000	0.997	1.013
	June	0.998	1.010	0.972	1.004	1.006	1.004	1.010	1.000	1.006	1.003	1.011	1.004	1.002
	July	0.999	1.008	0.948	1.006	1.004	1.001	1.011	1.001	1.007	1.000	1.012	1.008	1.001
	August	0.992	1.004	0.970	1.006	1.003	1.000	1.008	1.006	1.003	1.001	1.005	1.004	0.998
	September	1.012	1.008	1.079	1.005	1.005	1.004	0.999	1.006	0.994	1.132	1.000	1.007	1.012
	October	1.011	1.006	1.012	0.991	1.005	1.010	1.011	1.017	1.013	1.001	1.015	1.014	1.009
	November	1.012	1.006	0.979	1.000	1.004	1.006	1.012	1.006	1.013	1.001	1.010	1.027	1.008
	December	1.013	1.002	0.964	0.999	0.997	1.004	0.998	1.001	1.001	1.001	1.008	1.044	1.006
2022	January	1.025	1.009	0.943	1.007	0.997	1.005	1.013	1.011	1.000	1.016	1.009	1.007	1.013
	February	1.024	1.012	0.958	1.002	1.007	1.012	1.037	1.003	1.010	1.002	1.013	1.006	1.016
	March	1.062	1.013	1.130	1.005	1.029	1.056	1.042	1.008	1.015	1.000	1.017	1.012	1.045
	April	1.042	1.048	1.005	1.006	1.040	1.032	1.021	1.018	1.027	1.001	1.016	0.980	1.031
	May	1.027	1.039	0.998	1.004	1.018	0.991	1.102	1.010	1.002	1.000	1.031	1.006	1.027
	June	1.032	1.024	0.986	1.006	1.025	1.005	1.112	1.009	1.013	1.001	1.013	1.017	1.031
	July	1.008	1.013	0.965	1.005	1.022	1.005	0.997	1.021	1.012	1.001	1.016	1.018	1.007

Source: *Formed by the authors according to the data given in [21].*

iii) the prices of alcohol and tobacco products increased by an average of 1.21 % per month and increased by 124.4 % over the entire study period;
iv) clothing and footwear prices decreased by an average of 0.20 % each month, and decreased by 12.4 % over the entire survey period;
v) the prices of housing, water, electricity, gas and other fuels rose by an average of 0.66 % per month and increased by 54.9 % over the entire study period;
vi) prices for furnishings, household equipment and routine maintenance of the house increased by an average of 0.41 % per month, and increased by 31.9 % over the entire study period;
vii) health care prices increased on average by 0.65 % per month and by 54.1 % over the entire study period;
viii) transport prices increased by an average of 1.04 % each month, and increased by 100.3 % over the entire study period;
ix) communication prices increased by an average of 0.79 % per month and increased by 69.9 % over the entire study period;
x) recreation and culture prices increased by an average of 0.32 % each month and rose by 23.8 % over the entire study period;
xi) education prices increased by an average of 1.05 % each month, and rose by 101.3 % over the entire study period;
xii) the prices of restaurants and hotels rose by an average of 0.91 % each month, and increased by 83.0 % over the entire survey period;
xiii) the prices of miscellaneous goods and services increased by an average of 0.66 % each month, and rose by 55.8 % over the entire survey period.

According to the price monitoring automation management algorithm (see Figure 1), in the experimental part of the study, a multicollinearity test was conducted, a linear multiple regression model was built, its statistical significance was assessed, a heteroscedasticity test was conducted and consumer price forecasting under wartime conditions was implemented.

3. Experimental Consideration

The basis of the experimental part of the study is the construction of a linear multiple regression model and the forecasting of the Consumer Price Index, taking into account the influence of the main factors and using market research methods. However, these procedures are preceded by testing for a strong stochastic relationship between the independent variables, called multicollinearity. A multicollinearity test should be carried out in order to introduce into the model only independent variables whose stochastic relationship is sufficiently weak, because otherwise multicollinearity will lead to unpredictable results. This can be as distortion of statistical estimates, inconsistency of the results obtained with reality and economic logic, making it impossible to use the model in forecasting. This is why multicollinearity must be identified and, if detected, eliminated by introducing only those independent variables into the model whose stochastic relationship is negligible.

The test for multicollinearity was conducted using the methodology proposed in [22]. This methodology assumes that the statistical significance of the even correlation coefficient can be determined using the F-test. In our case we should find the critical value of F-test for 67 values of 2 independent variables using the Excel formula: = FINV(0,05;1;67-1-1); $F = 3.9886$. Then all values of the pairwise correlation coefficient, which will correspond to F-test values less than the critical 3.9886, show that there is no multicollinearity. We find the value of the even correlation coefficient (r), to which corresponds the value of $F = 3.9886$ by the formula:

$$F = \frac{r^2}{1-r^2} \cdot \frac{n-m-1}{m}, \tag{2}$$

where m is the number of independent variables;
n is the number of values in the data set of one variable.

Substitute the known values into Formula (2):

$$\begin{aligned} F = 3.9886 &= \frac{r^2}{1-r^2} \cdot \frac{67-1-1}{1} = \frac{65r^2}{1-r^2}; \\ 65r^2 &= 3.9886 \cdot (1-r^2); \\ 65r^2 &= 3.9886 - 3.9886r^2; \\ 68.9886r^2 &= 3.9886; \\ r^2 &= 0.0578; \\ r &= \sqrt{0.0578} = \pm 0.2404, \end{aligned} \tag{3}$$

Consequently, there will be no multicollinearity between pairs of independent variables whose pairwise correlation coefficients fall within the range of values:

$$r \in [-0.2404; 0.2404]. \tag{4}$$

Guided by Table 1, using the Excel function Excel “Data Analysis ⇨ Correlation”, a correlation matrix is obtained (Table 2).

Out of 66 pairwise correlation coefficients, only 41 (62.1 %) show the absence of multicollinearity between the independent variables. However, the Food Price Index has a strong correlation with the vast majority of other independent variables, except the Utilities and Energy Price Index, the Price Index for Furnishings, Household Equipment and Routine Maintenance of the House, the

Education Price Index, and the Miscellaneous Goods and Services Price Index. To decide whether to introduce independent variables without multicollinearity into the model, the strength of their relationship to the dependent variable must still be considered. Thus, the strongest correlation with the Consumer Price Index is in the Food Price Index ($r = 0.91$), the Price Index for Furnishings, Household Equipment and Routine Maintenance of the House ($r = 0.686$), and the Health Price Index ($r = 0.612$); while the weakest correlation with the Consumer Price Index is in the Education Price Index ($r = 0.127$) and the Miscellaneous Goods and Services Price Index ($r = 0.004$).

Table 2: Correlation matrix of all Consumer Price Indexes

	FPI	***ATPI***	***CFPI***	***UEPI***	***PIFHE***	***HPI***	***TPI***	***CmPI***	***RCPI***	***EPI***	***RHPI***	***MGSPI***	***CPI***
FPI	1												
ATPI	0.4142*	1											
CFPI	0.2571*	0.0486	1										
UEPI	0.0202	–0.0588	–0.0085	1									
PIFHE	0.5546*	0.6124*	0.1745	0.0551	1								
HPI	0.6148*	0.1642	0.3476*	–0.0170	0.5881*	1							
TPI	0.3753*	0.4366*	0.0696	0.0496	0.5477*	0.1168	1						
CmPI	0.2591*	0.0946	0.1723	0.1837	0.2079	0.1621	0.1043	1					
RCPI	0.4390*	0.3502*	0.0423	0.1496	0.6433*	0.4877*	0.3866*	0.3144*	1				
EPI	–0.0057	–0.0139	0.4381*	0.0475	–0.0125	–0.0483	–0.0410	–0.0370	–0.2062	1			
RHPI	0.3499*	0.5355*	–0.0995	–0.1065	0.4353*	0.1342	0.4952*	0.2178	0.5257*	–0.2915*	1		
MGSPI	0.0101	–0.2677*	–0.2355	0.2060	–0.1093	–0.1492	0.0341	–0.0427	0.0481	0.0550	0.1391	1	
CPI	0.9100	0.4925	0.4556	0.1744	0.6862	0.6118	0.5932	0.3301	0.5212	0.1272	0.3982	0.0039	1

* $r \notin [-0.2404; 0.2404]$, *so there is multicollinearity between the pair of independent variables.*

Source: *Formed and calculated from data in Table 1, using Excel.*

Consequently, based on the data in Table 2, four independent variables are identified, between which the correlation is not significant. They are: the Alcohol and Tobacco Price Index, the Clothing and Footwear Price Index, the Utilities and Energy Price Index, and the Communication Price Index. The correlation matrix is repeatedly generated (Table 3).

Table 3: Matrix of pairwise correlation coefficients between Consumer Price Index (dependent variable) and selected Consumer Price Indexes (independent variables)

	ATPI	***CFPI***	***UEPI***	***CmPI***	***CPI***
ATPI	1				
CFPI	0.0486	1			
UEPI	–0.0588	–0.0085	1		
CmPI	0.0946	0.1723	0.1837	1	
CPI	0.4925	0.4556	0.1744	0.3301	1

Source: *Formed and calculated from data in Table 1, using Excel.*

All of the pairwise correlation coefficients in Table 3 fall within the range of values given by Formula (4). This means that there is no multicollinearity between the independent variables entered into the linear multivariate regression model.

In order to automate the monitoring of consumer prices it is necessary to test 3 marketing forecasting methods and choose the most reliable one using Excel functionality and, due to martial law from the end of February 2022, caused by a large-scale invasion of the sovereign territory of Ukraine by the Russian Federation.

The first marketing forecasting method is trend analysis, shown in Figure 2. This method consists in using the formula with the highest level of approximation to extrapolate the series of trends in the Consumer Price Index.

The second marketing forecasting method consists in modelling a linear multivariate regression of the relationship between the Consumer Price Index and the Alcohol and Tobacco Price Index, the Clothing and Footwear Price Index, the Utilities and Energy Price Index, and the Communication Price Index.

The third marketing forecasting method is a linear multivariate regression with a Dummy variable and the same independent variables as in the second method. The introduction of a Dummy variable is practised in order to formalise a qualitative factor that has a significant impact on the independent variable. In Ukraine, such a qualitative factor was the imposition of martial law as a result of a large-scale invasion by the Russian Federation. It is clear that this factor affects the growth of consumer prices, so the months in which martial law was in effect are assigned a Dummy variable value of 1, while the previous ones are assigned a value of 0.

After assessing the statistical significance and adequacy of the multiple regression equations of the second and third models, the reliability of the Consumer Price Index forecast is analysed by comparing the estimated values from January 2022 to July 2022 with the actual values of the 3 methods.

So, from the statistical data in Table 1, we construct a linear four-factor regression model using the Excel function Excel “Data Analysis ⇨ Regression” (Figure 3).

From the data in Figure 3, we can see that the linear four-factor regression model is statistically significant, as the results of F-test and t-test were satisfactory.

SUMMARY OUTPUT

Regression statistics	
Multiple R	0.70967
R Square	0.50363
Adjusted R Square	0.47160
Standard Error	0.00670
Observations	67

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	0.00282	0.00071	15.72647*	6.17311E-09
Residual	62	0.00278	0.00004		
Total	66	0.00560			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95 %*	*Upper 95 %*
Intercept	0.11716	0.13650	0.85828	0.39404	–0.15570	0.11716
ATPI	0.55634	0.10780	5.16079**	0.00000	0.34085	0.55634
CFPI	0.07313	0.01652	4.42582**	0.00004	0.04010	0.07313
UEPI	0.07563	0.04036	1.87388**	0.06566	–0.00505	0.07563
CmPI	0.17772	0.08920	1.99238**	0.05074	–0.00059	0.17772

** > 3.9959 (=FINV(0,05;1;67-4-1)), so the multiple R is statistically significant;*

*** > 1.6698 (=T.INV.2T(0,95;67-4-1)), so regression coefficients are statistically significant.*

Fig. 3 Results of a linear four-factor regression modelling of the Consumer Price Index

Source: *Modelled using Excel according to the Table 1 data.*

The regression equation according to Figure 3, is as follows:

$$CPI = 0.117 + 0.556\ ATPI + 0.073\ CFPI + 0.076\ UEPI + \\ + 0.178\ CmPI + \varepsilon \quad (5)$$

The Formula (5) shows that the biggest influence on the Consumer Price Index is exerted by the Alcohol and Tobacco Price Index, as a 1 % increase in the Consumer Price Index results in an increase of 0.556 %, the cumulative influence of other factors is only 0.326 %.

The result of introducing a Dummy variable into a linear multiple regression model is the data in Figure 4.

SUMMARY OUTPUT

Regression statistics	
Multiple R	0.80541
R Square	0.64868
Adjusted R Square	0.61988
Standard Error	0.00568
Observations	67

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	0.00363	0.00073	22.52632*	1.00467E-12
Residual	61	0.00197	3.22618E-05		
Total	66	0.00560			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95 %*	*Upper 95 %*
Intercept	0.42012	0.13057	3.21765	0.00207	0.15904	0.68121
ATPI	0.28293	0.10643	2.65827**	0.01002	0.07010	0.49576
CFPI	0.07218	0.01402	5.14985**	0.00000	0.04415	0.10021
UEPI	0.07839	0.03424	2.28979**	0.02551	0.00993	0.14685
CmPI	0.14861	0.07588	1.95856**	0.05474	–0.00312	0.30034
Dummy	0.01432	0.00285	5.01858**	0.00000	0.00861	0.02002

-1)), so the multiple R is statistically significant;

-1)), so regression coefficients are statistically significant.

Results of a linear five-factor regression modelling with Dummy variable for the Consumer Price Index

Source: *Modelled using Excel according to the Table 1 data.*

From the data in Figure 4, we can see that the linear five-factor regression model with the Dummy variable is statistically significant, as the results of F-test and t-test were satisfactory. The regression equation according to Figure 4, is as follows:

$$CPI = 0.420 + 0.283\ ATPI + 0.072\ CFPI + 0.078\ UEPI + \\ + 0.149\ CmPI + 0.014\ D + \varepsilon \quad (6)$$

It follows from Formula (6) that the biggest influence on the Consumer Price Index growth is exerted by the Alcohol and Tobacco Price Index, as its 1 % increase results in a 0.283 % increase in the Consumer Price Index. A 1 % increase in the Clothing and Footwear Price Index results in a 0.072 % increase in the Consumer Price Index. A 1 % increase in the Utilities and Energy Price Index is equivalent to a 0.078 % increase in the Consumer Price Index. A 1 % increase in the Communication Price Index results in a 0.149 % increase in the Consumer Price Index. The impact of martial law is estimated at +0.014 % increase in the Consumer Price Index.

Thus, we obtained 3 statistically significant linear models for consumer price forecasting: the trend equation, the four-factor regression equation and the five-factor regression equation with Dummy variable. The reliability of the proposed forecasting methods is tested by calculating monthly data of the 2022 baseline Consumer Price Index (up to December 2016) for each of the models and estimating relative deviations (Table 4).

Table 4: Reliability of marketing forecasting methods

Month	Fact	Trend	Regression equation:		Percentage deviations from actual values (+/–):		
			4 factors	5 factors	Trend	4 factors	5 factors
January	1.504	1.519	1.490	1.489	0.956	–0.957	–1.001
February	1.528	1.527	1.496	1.515	–0.084	–2.100	–0.853
March	1.597	1.535	1.524	1.563	–3.860	–4.580	–2.162
April	1.647	1.544	1.571	1.615	–6.241	–4.607	–1.910
May	1.691	1.552	1.608	1.662	–8.209	–4.922	–1.695
June	1.743	1.561	1.631	1.703	–10.487	–6.456	–2.349
July	1.756	1.569	1.645	1.739	–10.631	–6.291	–0.969
Average	1.635	1.544	1.565	1.610	–5.608	–4.292	–1.564

Source: *Calculated from Table 1, Figure 2, Formulas (5) and (6).*

Table 4 shows that the largest deviations from the actual values were in the trend model (–5.6 % of the difference between the mean values), while the smallest deviations from the actual data were in the five-factor linear regression model with a Dummy variable (–1.6 % of the difference between the mean values). Therefore, the five-factor linear regression model with a Dummy variable is the most reliable marketing forecasting method in our study to be used for forecasting the Consumer Price Index and developing forecasting scenarios.

According to the management algorithm for price monitoring automation (see Figure 1), the penultimate step is to test the marketing forecast model for heteroscedasticity. The results of the Park and Glejser heteroskedasticity tests for the five-factor model with a Dummy variable are shown in Table 5.

Based on the data in Table 5, the results of the Park test and the Glaser test indicate that the five-factor linear regression model with a Dummy variable is homoscedastic, so it is appropriate to apply it in forecasting the Consumer Price Index and developing forecasting scenarios. The White test is not necessary in this case.

Table 5: Results of the Park and Glejser heteroskedasticity tests

Parameter	Park test* [23]	Glejser test* [24]

	$\ln \varepsilon_i^2 = a + b_j \ln x_j + v_i$,		$\lvert\varepsilon_i\rvert = a + b_j x_j^k + v_i$,	
	parameter value	t-test	parameter value	t-test
b_1	–2.6801	–0.0964**	–0.0209	–0.4190**
b_2	–0.3878	–0.0910**	–0.0016	–0.2155**
b_3	–5.2472	–0.5127**	–0.0056	–0.3043**
b_4	–5.4013	–0.2438**	–0.0113	–0.2823**

** where ε_i is i-th residual of model; v_i is a random remainder; a and b are parameters whose statistical significance needs to be assessed; k is some number.*

*** $t \in [-1.6702; 1.6702]$, so parameters are statistically insignificant.*

Source: *Calculated from Table 1 and Formula (6) using Excel.*

Forecasting the Consumer Price Index using a five-factor linear regression model with a Dummy variable is the final step in the management algorithm for price monitoring automation (see Figure 1). The process of forecasting the Consumer Price Index is carried out in several stages:

i) Stage 1. First, the forecast period is determined, usually no more than half of the analysis periods, i. e. if our case is 67 months, we can forecast for 33 months. We will take the time period to the end of 2024, i. e. 17 months.
ii) Stage 2. It consists of forecasting the independent variables using Excel functions "FORECAST.ETS" and "FORECAST.ETS.CONFINT", to produce predictions with upper and lower confidence intervals.
iii) Stage 3. Here, the forecast values of each independent variable are substituted into Formula (6), and regarding the Dummy variable, we take two variants of the end of the Russian-Ukrainian war: according to the first variant we assume the end of the war until the end of 2023, that is, from August to December 2023 we give Dummy variable 1, and from January to December 2024 we give 0; according to the second variant the war will continue until the end of 2024, that is, from August 2023 to December 2024 we give Dummy variable 1.
iv) Stage 4. In the final step, implement a scenario analysis where the upper confidence interval corresponds to the pessimistic scenario, the forecast value corresponds to the realistic scenario, and the lower confidence interval corresponds to the optimistic scenario.

The result of the described forecasting steps is 2 charts for the Consumer Price Index forecast. The first graph illustrates the dynamics of consumer prices under the scenario where the Russian-Ukrainian war continues until the end of 2023 (Figure 5).

Figure 5 shows the projected trends in the Consumer Price Index under martial law by the end of 2023. In the optimistic scenario consumer prices in Ukraine will grow by 2.8 % per month and by the end of 2024 consumption inflation will reach 256.8 %; in the realistic scenario average monthly growth of consumer prices is projected at +4.3 %, and consumption inflation will reach 300.7 %; in the pessimistic scenario consumer prices will grow by 6.1 % per month and by the end of 2024 consumption inflation will reach 351.7 %.

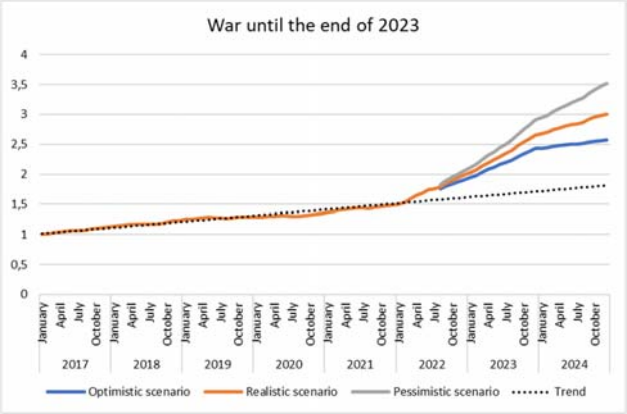

Fig. 5 Consumer Price Index forecast scenarios assuming the Russia-Ukraine war continues until the end of 2023

Source: *Modelled using Excel according to the Table 1 and Formula (6).*

The second graph illustrates the dynamics of consumer prices under the scenario where the Russian-Ukrainian war continues until the end of 2024 (Figure 6).

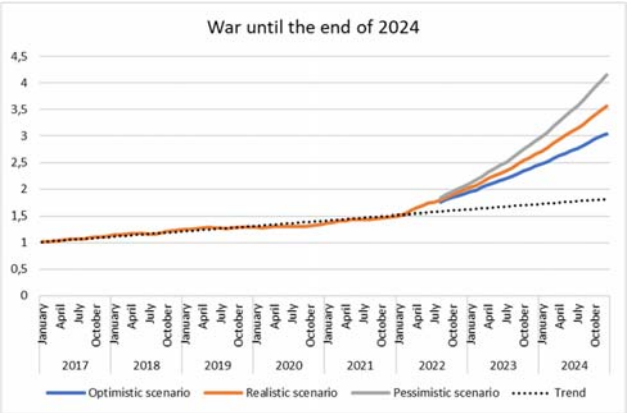

Fig. 6 Consumer Price Index forecast scenarios assuming the Russia-Ukraine war continues until the end of 2024

Source: *Modelled using Excel according to the Table 1 and formula (6).*

Figure 6 shows the projected trends in the Consumer Price Index under martial law by the end of 2024. For instance, in the optimistic scenario consumer prices in Ukraine will grow by 4.4 % per month and by the end of 2024 consumption inflation will reach 304.4 %; in the realistic scenario the average monthly growth of consumer prices is projected at +6.2 %, and consumption inflation will reach 356.0 %; in the pessimistic scenario consumer prices will grow by 8.3 % per month and consumption inflation will reach 416.0 % by the end of 2024.

4. Conclusion

Thus, in solving the problem of automating price monitoring using marketing forecasting methods and Excel functionality under martial law, the authors obtained the following results.

Firstly, an algorithm for managing the automation of price monitoring, using multivariate statistical analysis and marketing forecasting methods in Excel, has been proposed and tested.

Secondly, based on the monthly dynamics of the price indices of major consumer product groups from January 2017 to July 2022, 3 predictive models of the Consumer Price Index are derived: a linear trend equation, a four-factor linear regression equation, and a five-factor linear regression equation with a Dummy variable.

Thirdly, a five-factor linear regression model of the Dummy variable has been proven to be the most reliable in forecasting consumer inflation under a military law. This particular model was used in the forecasting of the Consumer Price Index and scenario analysis in conditions where the martial law in Ukraine will persist only until the end of 2023, and also if the Russian-Ukrainian war does not end until the end of 2024.

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