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FOOD SECURITY RISK IN UKRAINE: ASSESSMENT AND FORECAST

Purpose. *The paper's purpose is to analyze and predict the food security index in Ukraine and to estimate the risk level of its reduction.*

Methodology / approach. *The following models are used for forecasting: the Holt's two-parameter model – to forecast the dynamics of caloric content of the daily diet and integral food security index; the ARIMA model – for modeling the food economic affordability. The autocorrelation function structure analysis is used to determine the adequacy of the models. The article discusses the procedure of assessing food security risk based on the properties of the econometric forecast error. The annual data of Ukraine were used for assessing the forecasts for the time interval between 1995 and 2018.*

Results. *The paper presents the results of predicting the food security index in the context of macroeconomic instability. The trend (deterministic) and random components for the level of calorie consumption are revealed. The forecast of food availability is presented. The forecast estimates of the Food Security Index of Ukraine for the period up to 2022 are considered. The assessment of price elasticities, household incomes and inflation for basic food products is made. As a result of assessing the level of macroeconomic instability, the structural elements of food security for Ukraine were identified. The article assesses the dynamics of changes in consumption of certain commodity items of foodstuff as components of food security. There is a creation of an alternative methodology for forecasting individual economic indices in the absence of stable trends in the economy of the country based on the use of econometric analysis proposed in the research. It substantiates the use of multi-step methods of forecasting economic indices. It is proved that the integrated forecast of the food security index of Ukraine is in satisfactory state and shows a slight upward trend during the period 2020–2022, but the risks of a decline in the integral index are somewhere beyond satisfactory.*

Originality / scientific novelty. *The results of the individual food security indices forecast, and the integral Food Security Index of Ukraine analysis it is possible to state a satisfactory condition that is unlikely to change in the near future. The alternative forecasting method for individual economic parameters in conditions of the unstable national economy trends is firstly proposed.*

Practical value / implications. *The reported forecast values indicate a decrease in the adequacy of consumption for most foodstuffs. This is most pronounced for the consumption of products of animal origin, which are far from the norm. The non-structural forecasts indicate current trends in the state of food security, which will persist if the impact on the food system by the general state of the country's economy remains unchanged. The main results of the study can be used to estimate the food affordability risks and risks of health deterioration for the population.*

Key words: *food security, integral index, food security risk, risk of reduction, forecast, elasticity index.*

Introduction and review of the literature. Food security is an important characteristic of the state economic potential. Food security is a condition whereby "all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (Report…, 1996). This definition incorporates several needs: availability of food, access to food, and for the food to be culturally appropriate. There are many factors in today's global environment that exacerbate food security. It is true, we live in an age where we are growing and producing more food than ever before. We have enough food to feed the world's population, but it is not distributed properly nor is all food culturally appropriate across the globe. Local food access differs dramatically and the greatest difference exists between developed and developing countries. The primary reason for this inequity is an income-related difference between these populations (Hazell and Wood, 2008). It must be stated though, that in every country of the world there is hunger, and this often falls along economic and social lines.

Globally, food production has kept ahead of demand for many years; currently about one billion people do not have such access. This is due to a combination of biophysical, socioeconomic and political factors. New research concepts, tools and methods are needed to understand and improve governance of the complex interactions between these factors if such food insecurity is to be overcome. This is especially the noticeable at the regional (sub-continental) level where many stakeholder groups and actors are involved in setting policies and making decisions that affect food security outcomes. Also, the Council for Food and Agriculture defined food security as "the policy that allows a country to get a higher level of food self-procuring as a result of integrated forces to increase the production of needed products, to improve supply systems, food consumption, malnutrition elimination" (World Food Summit, 1996).

Recently, approaches to the concept of food security has changed, and an integrated index has been recommended, which significantly simplifies comparative assessments in a particular country over time and the comparison of the food security level of individual countries (Alekseeva, 2015). This is especially true of time intervals of macroeconomic instability when consumption is influenced by many other factors outside the agricultural sector. Food security relates directly to nutrition and health. Typically, food security is thought of as being related to availability and access of foodstuffs. Yet, the threat to food security also lies with urbanisation, income disparity, overpopulation, ecosystem degradation, animal health, and food wholesomeness (Havas and Salman, 2011).

The continuation of research focused on producing food is not surprising, given its long-established momentum and on-going investment, and the undeniable need of having to produce more food in the years ahead. Nevertheless, despite the fact, the world currently produces enough food for everyone; the number of food-insecure people world-wide currently attests that our understanding and approaches are insufficient. New concepts, tools and approaches are needed to address the broader food security agenda. These developments were however largely uncoupled from research by the biophysical community but, given the multiple dimensions of food security, the need for interdisciplinary, even transdisciplinary approaches are now well accepted (Ericksen et al., 2009; Gregory et al., 2005). Indeed, food security research is, in fact, a very good example of the need for much-enhanced interdisciplinary, with social science, economics and the humanities all playing critical roles in addition to the biophysical sciences and accepting this acknowledges contributions of many different disciplines. The presence of food security at the macro level does not guarantee food security at the micro-level. This creates a serious management problem – how to ensure food safety at all levels of the national economy.

The food security debate understandably has focused on aspects of food production and this has been long the subject of major research investment. Increasing production has always been an important strategy to help alleviate food insecurity, and it is still today (Pingali et al., 2005). There is hence still a strong sentiment that producing more food will satisfy society's needs, and theoretically, this is, of course, the case: produce enough and everyone will be fed. However, although more than enough food is currently produced per capita to adequately feed the global population, about 925 million people remained food insecure in 2010 (FAO, 2020).

Several factors influence the food security of the country: production volumes, weather conditions, geographical location and others, including even corruption. Taking the aforementioned into account, calculation of the food security index requires simultaneous consideration of various parameters on which the rating is based. Food security can be measured in different ways. The most frequently used source for assessing the number of food-insecure people in the world is probably the report: The State of Food Security and Nutrition in the World.

The Economist Intelligence Unit designed and constructed the Global Food Security Index (GFSI) as a single criterion for different countries (GFSI, 2019). The index is comprised of three basic components: *economic affordability, physical accessibility, and food quality and safety*. The presence of a single index significantly simplifies the implementation of the task of analyzing and forecasting the Food Security Index.

The review of conceptual framework indicates that the GFSI has to be interpreted as a food security environment rating. It focuses on the food security determinants rather than on the food security outcomes. It includes some of the usual food security determinants such as food supply, food share in total expenditure, poverty or nutritional policies and enlarges to less direct determinants like access to financial services, corruption, political stability and so on. It thus only partially overlaps with existing food security indicators. Indicators included in the GFSI are measured at the national level and not at the household level. Inequality indicators are not included. The GFSI is thus measuring the average situation in the countries rather than focusing on food insecure households. The GFSI exhibits good statistical properties.

The existing forecasting methods that can be used to forecast the integral Food Security Index are considered. The standard hypothesis of forecasting consists in the ability to divide time series into trend and random components when the continuation of the trend component provides the forecast and the error at the base interval determines its confidence intervals. However, the fact is that in the period of existence of independent Ukraine, the intervals of stable growth did not last for more than 8 years

(State Statistics…, 2019) (the interval of the Ukrainian economy decline was longer – 11 years), and therefore there are points of tendency breaking when growth is followed by the fall and vice versa. This means that a forecast based on a trend component is hardly feasible.

In addition to trend-based methods, there is the Box-Jenkins method of time series analysis and forecasting (ARIMA model). The ARIMA model is defined by three parameters: the order of autoregression, the order of the differencing operator for bringing the series to stationarity, the order of moving average errors of previous time intervals. If there is a seasonal component, then it can be reproduced in the ARIMAS model, but for the series of annual and larger discreteness the seasonal component cannot be taken into account (Chan, 2010).

The forecast (ex-ante) is commonly executed on the horizon of all available information. However, in the case of long enough time series, it makes sense to build a forecast model, for example, at 95 % of the time series, leaving 5 % for comparing the forecast and actual data (ex-post forecast). Although the expectation that the model that has been tested thus provides the best forecast (ex-ante) is not always realized, this technique is widely used (Ledolter, 2011).

The outcome of the global food systems is supposed to ensure food security for everyone including both social and environmental welfare (Ingram, 2020). The food security definition includes the four pillars: availability, access, utilization and stability, but the indicators used by FAO (FAO, 2006) have so far focused on nutrition indicators without including socio-economic groups or the environmental sustainability of the food system. Environmental determinism has always been an influential strand of the food security discourse. One weakness of many computer models and scenario forecasts is their failure to factor in technological change, adaptive behavior and political responses to climate change. (Parry et al. 1999; Fischer et al. 2002). Moreover, extreme climate events such as cyclones, floods and droughts affect food supplies severely and thus food security. The overall impact of climate change on food security differs across regions and over time (Parry et al., 1999; Gregory et al., 2005). The impact will depend on a country's socio-economic status.

Concerning food security risks, climate change (Kadiyevskyy and Klymenko, 2014; Bahorka, 2019) and financial risks (Johnson et al., 2017) have recently been identified as the greatest threats.

A significant factor affecting economic security is that economic growth should occur not in certain parts of the country but to be spread over its entire territory. Instability of prices and incomes of the population significantly affect the lowest-income categories of the population, so in addition to the average values of the parameters that affect food security, indicators also include variability values in food security (Wiesmann, 2006; Vasylieva, 2018; Ingram, 2011).

Despite the upward trend in agricultural exports, due to macroeconomic instability, there has been a significant deterioration in economic affordability, which negatively affects the integral Food Security Index (GFSI, 2019).

Ukraine has considerable agricultural production potential (Kaletnik et al., 2019;

Skrypnyk et al., 2019) However, according to the evaluation methodology, the production availability is not yet the key to a stable level of integrated food security (FAO, 2006; GFSI, 2019). The degree of incompleteness of institutional change has a significant negative impact on food security. The analysis based on the data of the agricultural business reports shows that the efficiency of a significant share of agricultural enterprises is low. There is no systematic approach to the implementation of agrarian innovations in the country, as a result of which the risks of their introduction for small and medium-sized businesses are significantly increasing.

The degree of food security risk is also affected by the insufficient level of information support for the agricultural sector. As a result, there are regular price shocks (price leaps) for certain commodity items that could be avoided in the context of better analysis of global food and domestic production trends.

The purpose of the article. The paper's purpose is to analyze and predict the food security index in Ukraine and to estimate the risk level of its reduction.

Results and discussion. The food security assessment based on the Global Food Security Index (GFSI), a global ranking of food security and efficiency of government agencies in providing them (GFSI, 2019) are considered. It assesses the food security situation across a set of 113 countries. To this end, 28 indicators are used, some of which are determined by the peer review method. Indicators are differentiated into 3 groups: quality, safety, financial and physical accessibility of food. The values of the indicators are normalized (the minimum value takes the value of 0, the maximum value takes the value of 100), after which each of them is assigned a weight using expert estimates, and as a result, for each country, the values of the indicators characterizing the state of food security are obtained.

There are different normalization algorithms for indicators whose growth contributes to the growth of food security (direct action) and inverse action (Kaletnik et al., 2019; Jones et al., 2013).

The normalization process and subsequent weighing of the index values allow for an integrated assessment of food security in each country and enables the contrasting, ranking and comparison of different countries around the world in terms of overall food security (in GFSI interpretation) as well as the financial and physical accessibility and quality of food.

This methodology is specific because all countries have identical indicators of equal weight, i.e. they do not take into account national or regional specificities. According to the results of the GFSI survey in 2017, Ukraine is ranked 63rd in the overall rating with 54.1 points. It is ranked 59th with 55.7 points in terms of economic accessibility of food, and 78th with 50.2 points in terms of availability and sufficiency; as for the quality and safety of food – it is ranked 51st with 61 points accordingly (GFSI, 2019).

An integral index, similar to the method of obtaining Global Food Security Index, is subdivided into three components (sub-indexes), each with indicators from a set of legally defined food security indicators as well as the self-sufficiency ratio (SSR). The latter ratio and the food sovereignty index better characterize physical accessibility to food resources. In general, the inclusion or removal of the self-sufficiency ratio in the list of food security indicators is a disputable issue (the top three world leaders for this ratio include two countries – Ireland, Singapore – without a strong domestic production). The indicators are subdivided into sub-indexes as follows:

1. Economic (social) accessibility: economic affordability of products (share of food costs in the total consumer household cash expenditure, %);

2. Physical (production accessibility): self-sufficiency by major product groups (ratio of production to domestic consumption (feed, seeds, consumption fund); food sovereignty index of major product groups (ratio between the volume of imports of a particular product in kind and its capacity in the domestic market);

3. Sufficiency of consumption: sufficiency of consumption index of the main product groups (the ratio between the actual consumption of an individual product and its rational norm). The same index includes the energy value of consumption.

A forecasting methodology and related models are suggested, comprising the following implementation steps:

1. Based on the type of inertia determined by the autocorrelation function, the predictive model is selected.

2. The time interval of observations is divided into the baseline used to build the model and the forecast (test) to verify the forecast.

3. The models are compared based on the generally recognized statistical characteristics at the baseline interval.

4. The adequacy of the forecasting model is analyzed based on the autocorrelation of errors.

5. Models that have been tested for adequacy are compared for accuracy (ex-post estimation). The selected forecasting model is used to build the forecast.

For the forecast, we used time series calories of daily intake with a discretion of 1 year in the time interval from 1995 until 2018. The analysis of the autocorrelation of daily calorie intake indicates the presence of the trend in the time series: the autocorrelation coefficient for a delay of up to three years exceeds the standard error threshold, and the subsequent coefficients gradually approach zero. During the analysis of the autocorrelation of errors and accuracy evaluation of the models, it has been concluded that the smallest errors are provided by Holt's two-parameter method with the following parameters: $Alpha(level) = 0.9999$ and $Gamma\ (trend) = 2196$.

Through the calculations and the forecast made on their basis, we can conclude that the daily energy value of the human diet in 2022 is expected to decrease by 38 kcal as compared to 2017 and to be fixed at 2639 kcal (Fig. 1).

It should be emphasized that under the conditions of macroeconomic instability only a slight decrease in the caloric content of the daily diet was maintained due to the deterioration of its quality, which has long-term consequences for the deterioration of health and working capacity of the lowest-income categories of the population.

Similarly, we calculated forecast values for predicting the economic food affordability. According to the analysis of the time series, the presence of a trend was proved. The related models for Daily Calorie Intake are proposed: linear regression –

$Y_t = 71{,}082 - 1{,}293 \cdot t$; regression indicator – $Y_t = 73{,}206 \cdot 0.976^t$; ARIMA (2,0,1)μ; Holt's linear exponential smoothing – Alpha (level) = 0.999 and Gamma (trend) = 0.117.

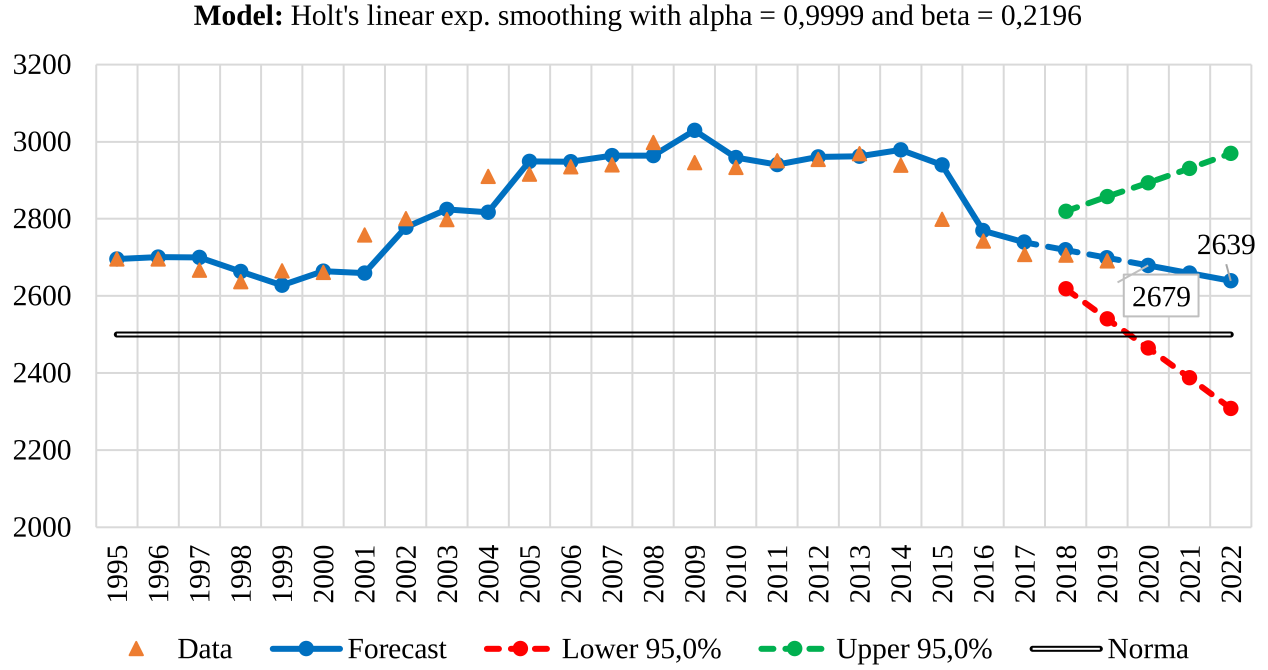

Fig. 1. Daily Calorie Intake Forecast (Holt's linear exponential smoothing)

Source: designed by the authors.

After comparing the errors at the baseline and check intervals, the ARIMA (2,0,1)μ model was selected for the forecast, which predicted a 49 % share of the Food Affordability in 2020–2022 time-period (Fig. 2).

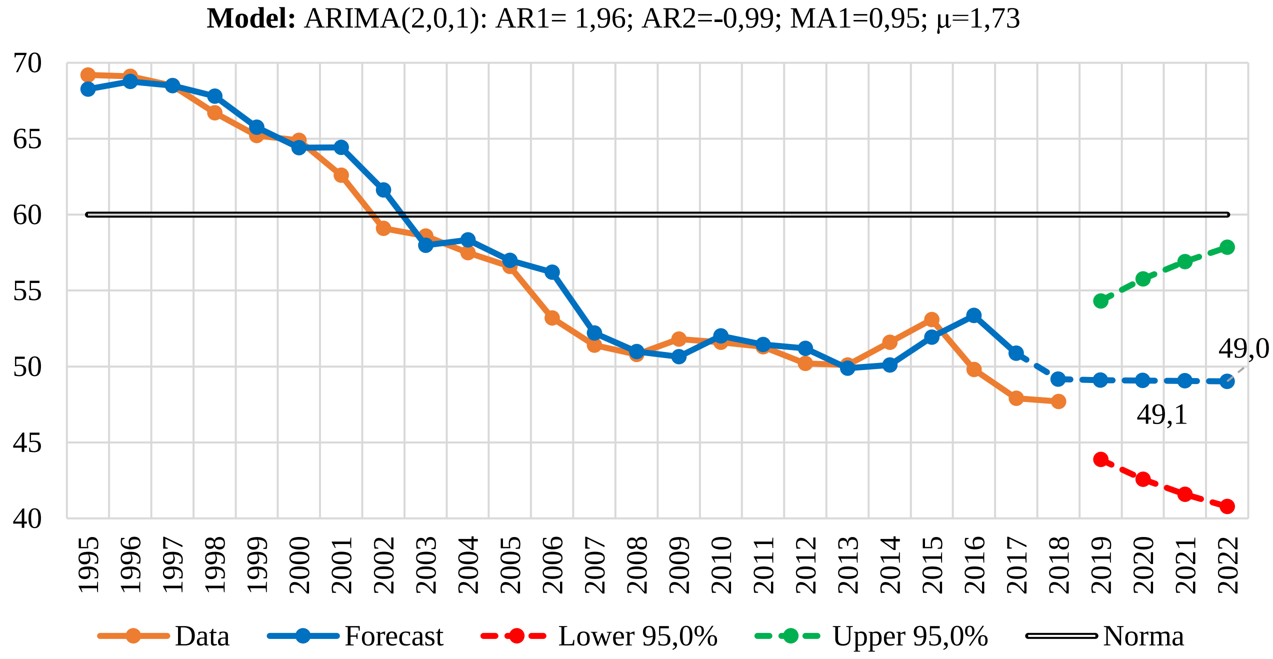

Fig. 2. Food Affordability Forecast (ARIMA model)

Source: designed by the authors.

Usually this index exceeds the indicators of the developed countries by 100–200 %, but the reasons for this are outside the agricultural sector and are determined by the general state of the economy.

In terms of Physical Affordability, the forecast for this index is the most optimistic. The reason is that one of the main indicators of physical affordability – the volume of agricultural products per capita in monetary terms (in USD in 2014 prices) – continues to grow steadily.

The final stage of non-structural forecasting will be the prediction of a definite integral Food Security Index.

According to the forecasting methodology, on the basis of the autocorrelation function, it is determined that there is a trend in the time series of values of the integral index. As a result of the analysis, only two models were tested for adequacy: Holt's model (Alpha = 0.894 parameter, ARIMA (1.0.0) model (AR = 0.977437 parameter). The prediction accuracy value was determined on the basis of MSE. The corresponding values for the models are quite close and make up 0.158 for Holt's model and 0.161 for the ARIMA model (1.0.0). Holt's model is selected following the estimates of the mean square error of the forecast. The forecast obtained for the period 2019–2022 is shown in fig. 3.

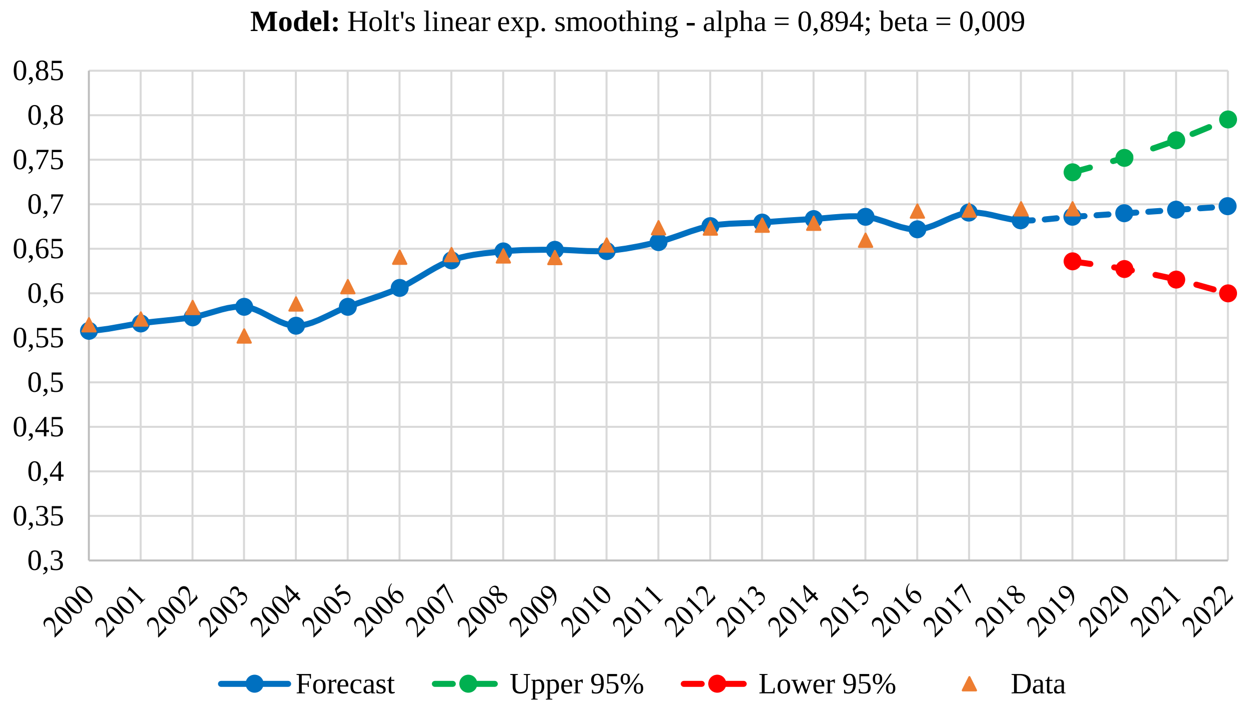

Fig. 3. Integral Food Security Index Forecast (Holt's method)

Source: designed by the authors.

The above calculations show a slight but steady increase in the integral index within 0.6–0.8 (60–80 %) of maximum, which corresponds to a satisfactory level of food security throughout the forecast horizon (2019–2022).

Based on the given forecast, namely, values of 95 % of the forecast interval, it is solved the task of identifying the risks of food insecurity. Mathematically, this task is to determine the probability of an integral index reaching the bottom of a satisfactory level (in line with global standards) food security – 0.6. Therefore, the probability $p(x < 0.6) = 0.025$ or 2.5 % for a given normalized variable (the lower food security margin) practically doesn't differ from the lower 95 % confidence interval. It is an extremely small quantity, respectively, the projected risk of food insecurity is low in 2022. The likelihood of achieving food security in developed countries (more than 0.8) averages not more than 0.1 %, which is even less likely.

Continuing the issue of macroeconomic instability, we assessed the impact of rapid changes in prices and nominal incomes on food security indicators in the time interval 2014–2018. For this purpose, we used the method of estimating the elasticity of demand at the level of nominal income and prices for certain food products which was implemented according to a sample of income and expenditure of households in the time interval from 01.01.2009 to 31.12.2018.The changes in consumption of a certain commodity position $\left(\frac{\Delta C^i}{C^i}\right)$ can be represented as a scalar product of the elasticity vector $\bar{E}^i\left(E_D^i; E_p^i\right)$ for a given position on the vector of macroeconomic instability $\bar{V}\left(\frac{\Delta D}{D}; \frac{\Delta p^i}{p^i}\right)$:

$$\frac{\Delta C_i}{C_i} = E_D^i \cdot \frac{\Delta D}{D} + E_p^i \cdot \frac{\Delta p^i}{p^i}$$

where $\frac{\Delta D}{D}$ and $\frac{\Delta p^i}{p^i}$ – the relative annual changes in nominal income and inflation (changes in prices for individual products which are replaced by a general indicator of changes in consumer market prices).

As a result of calculations (Table 1), changes in consumption by food were obtained.

Table 1

Change in consumption of main foods for 2014–2018 time interval

Food	Coefficients of elasticity		Changes in consumption				
			2014	2015	2016	2017	2018
	income	price	1.9/24.9*	23.6/43.3*	16.0/12.4*	29.9/13.7*	23.1/9.8*
1. Bread	-0.18	-0.12	-3.3	-9.4	-4.4	-7.0	-5.3
2. Meat	0.54	-0.50	-11.4	-8.9	2.4	9.3	7.6
3. Milk	0.37	-0.32	-7.3	-5.1	2.0	6.7	5.4
4. Fish	0.62	-0.79	-18.5	-19.6	0.1	7.7	6.6
5. Egg	0.12	-0.02	-0.3	2.0	1.7	3.3	2.6
6. Vegetable	0.83	-1.10	-25.8	-28.0	-0.4	9.7	8.4
7. Fruit	0.85	-0.58	-12.8	-5.1	6.4	17.5	14.0
8. Potato	-0.26	-0.18	-5.0	-13.9	-6.4	-10.2	-7.8

Note. *The value means: "Change in income / change in price".

Source: designed by the authors.

The largest negative changes in consumption were observed in 2014 and 2015 when prices increased by 25 % and 43 %, while nominal incomes by only 2 % and 24 % respectively. The biggest negative effects in the reduction of volumes were observed for fish consumption, which decreased by 35 % in two years, and by 2019 was set at 76 % of 2013 consumption. It should be noted, that in 2014–2015 the growth of the food prices significantly exceeded the growth of nominal incomes, but in 2016–2018 the situation changed and the compensation for purchasing power had been noticed; however, it was not equal for all food positions.

In summary, the analysis of the received forecasts does not show improvement in the trends in the food security situation. The reported forecast values indicate a decrease in the adequacy of consumption for most foodstuffs. This is most pronounced for the consumption of food of animal origin, which are far from the norm.

That is, as noted, the non-structural forecasts indicate current trends in the state of food security, which will persist if the impact on the food system by the general state of the country's economy remains unchanged.

Conclusions. The research uses the multi-step methods of forecasting economic indicators, which are primarily based on the analysis of the process structure using the autocorrelation function, comparison of errors at the base interval and comparison of forecast and actual values (ex-post). Out of three core indicators: physical affordability, financial affordability and calorie intake, two of them tend to deteriorate and only physical affordability, which is largely determined by output per capita, tends to increase.

The integral Food Security Index forecast is in satisfactory condition and has shown a slight upward trend over the 2020–2022 time interval. The risks of changes in the integral index are slightly outside the norm level. The probability for the index (the lower food security margin) practically does not differ from the lower 95 % confidence interval, but the likelihood of achieving food security in developed countries more than 0.8.

However, we noted, that a rapid decline in food consumption was observed in almost all studied foods during 2014–2015. The largest decline was observed in vegetable group, which was not offset by growth and at the end of 2018 remained at 63 % and fish – 75 % of 2013 levels. At the same time, the meat market stabilized in 2018 at 97 % of 2013 volume. Thus, agricultural industries, that have already successfully entered the world market, confidently satisfy the domestic market, which cannot be said about the production of fish and vegetable.

Overall, the findings testify, that the risks of unsatisfactory food security in the 2020–2022 are insignificant, however, and it is particularly true for the economic accessibility of food for low-income groups, a continuing satisfactory level of energy value of daily food rations is maintained at the expense of more affordable (cheaper) substitutes and this contributes to the risk of deteriorating health of a large proportion of the population.

The obtained results provide the following managerial decisions. Firstly, the complete transition to the definition of the integral Food Security Index, based on the methodology used in FAO, is hampered by the lack of relevant information. Secondly, it is necessary to stimulate the development of fish and vegetable production in Ukraine with the help of state regulation instruments (soft loans, simplification of conditions for entering the foreign market) to increase the level of food security.

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