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## **Parametric Early Warning System Model for Ukraine**

There have been several crises in the world economy since the end of the last century. The center of the crises and the velocity of outspreading were variable and influenced a lot of countries with different levels of economic development. Among certain countries, the developing economies were ones that have suffered the most, considering a level of openness, weak institutional framework, and market vulnerability to unpredictable external and internal shocks. As a result, international financial organizations headed by the IMF as well as central banks of developed countries and private institutions have taken active measures to counteract the devastating consequences of the crises. In such a way, the general attention of the academic community has focused on the elaboration of efficient instruments for avoiding destabilizing processes to come. One of the instruments widely used because of its proved activity is the Early Warning Systems (EWS) approach.

EWS models classify into two main classes: non-parametric (i.e. crisis signal extraction) and parametric (i.e. regression-based). The non-parametric method takes its origin after publishing in 1998 the notable work of Kaminsky, Lizondo, and Reinhart demonstrated the so-called signals approach to examine empirical evidence on currency crises (Kaminsky, Lizondo & Reinhart, 1998). The advantages of the method are the ability to analyze a lot of variables for undertaking crises' markers, determination of thresholds endogenously, and operation with limited samples of binary data. The weak point of the signals approach is a disability to check individual variables for statistical significance because of a binary association between the early warning arguments and the crisis markers.

The parametric method was developed by Frankel and Rose in 1996 to predict currency crises (Frankel & Rose, 1996). The technique employs logit/probit regression to determine early warning arguments through the procedure of maximum likelihood estimation. The dependent variable of the regression is binary data. The strong point of the method is an ability to test regressors for significance, including correlation and other statistical characteristics, as well as estimation of crises probability. The disadvantage of the logit/probit modeling is a requirement to operate with extended time series plus restriction imposed on the number of individual variables due to preserving a degree of freedom. The common drawback of EWS models is a lack of institutional and political factors. The parametric method proves more appropriate if the object of study is a country with a limited set of indicators (Percic, Apostoiaic & Cocris, 2013).

One of the members of the developing world and, according to the several extended classifications, the emerging market economy of Ukraine didn't stay aside from the destructive processes and entered crises in 2008 and 2014. The following recessions and the deceleration of economic dynamics have come to GDP drop by -30%. The negative consequences remain rather dramatic that, after four years of recovering, the growth rate has hardly surpassed the point of 3% a year. At the same time, the debt burden has increased from 9,7% of GDP in 2007 to 52,3% in 2018, accompanied by terrific currency devaluation more than 3,5 times. The macro stabilization measures, taken to stimulate economic growth, have not been very productive. The question of whether Ukraine will be able to go through a newly coming world crisis without a much loss of economic stability is still open. In this regard, an urgent issue for the vulnerable developing economy of Ukraine is to detect and monitor the valuable macroeconomic indicators that follow critical points of economic imbalance for preventing negative outcomes of expected downturns.

The paper pursues a goal to develop a model using logit/probit introduction to determine early warning arguments and their appropriate thresholds for Ukraine. The advantages of the suggested modeling technique are the usage of the output gap as a dependent variable of the logit/probit regression and determination of the compound indicators as early warning arguments that follow the country-specific patterns with particular attention to the breakpoint issue. The output gap is evaluated using a multivariate (MV) filter and Okun's law definition. The procedure of expanding quarterly GDP to monthly data employs an interpolation technique of higher frequency values based on the Chow-Lin regression method. The determined in the work early warning arguments are the demand-supply gap, the world price of raw materials, and the broad money indicator.

The crisis events can be of different reasons. Regarding the latest classification developed by Laeven and Valencia, there are three types of crises: the currency crisis, the sovereign debt crisis, and the banking crisis (Valencia & Laeven, 2018). The vast majority of the EWS study dedicated to currency crises with a substantial contribution of IMF. The reasonable explanation of why the scientific community pays more attention to the given issue is the intensified currency dynamics often accompany the recession associated with crisis events and ordinarily ended in the excessive devaluation of the domestic currency.

In view of numerous publications discussing the development of practical EWS models, there are many relevant studies which debate on the significance of various macroeconomic indicators for interpreting crisis

events. The effectiveness of non-parametric and parametric frameworks in many respects is due to the accurate selection of EWS indicators. In this context, Frankel and Saravelos have done a great job of summarizing analytical results of 83 papers to rate the leading indicators of crises. According to their study, the five most significant indicators in decreasing order of rank position are reserves (relative to GDP, M2, short-term debt, 12 months ch.), real exchange rate (change, over/under valuation), GDP (growth, level, output gap), credit (nominal or real growth), and current account (Current Account/GDP, Trade Balance/GDP) (Frankel & Saravelos, 2012).

In recent studies, it is a common rule to use gap indicators, which prove to give better results. The gap indicator is a ratio between the actual and smoothing data obtained in the vast majority of cases by performing the Hodrick-Prescott (HP) filter. Csontos and Szalai have completed well-grounded research to examine financial and macroeconomic imbalances in 10 Central and Eastern European countries employing non-parametric and parametric EWS models. The threshold value of the credit/GDP gap was 3-4 percentage points depending on 1-3 years of the forecast horizon. The similar values for the credit growth gap, investment gap, real exchange rate gap, and capital flow gap were respectively 7, 2-3, 2, and 2 percentage points (Csontos & Szalai, 2014).

The methodology used in the paper employs a logit/probit approach. The given approach is used to develop a model of behavioral choice or event arrangement. It is commonly accepted the analyst does not know the complexity of the underlying relationship and any representation of reality is mixed to some degree. So, the common assumption of the choice model evaluation is to reveal indicators-factors that affect the decision making process.

Upon building the EWS model, the primary task is to select among the number of predetermined indicators the ones which can be treated as early warning components and divide them into two main classes of dependent and independent variables. Charging all known indicators as a potential-dependent variable of logit/probit regression to capture all types of crises, we have chosen an output gap. The given indicator follows the expected dynamics of the business cycle and responds well to economic downturns provoked by unpredictable internal and external shocks (Domonkos et al., 2017).

There are several well-known methods to evaluate the output gap. Considering simplicity and strong practical issue to perform potential output dynamics, among the most proficiently used are the technique utilizes a single-variate filter (mostly HP), the “hybrid” solution as a combination of

single-variate filter and production function approach, and the MV filter conducted by separating trend component (former potential output) from a cyclical one. The methodology keeps much attention to relationships between output and other macroeconomic variables, for example, the approximation of “Okun’s rule of thumb” based on empirical observation. The MV filter is proved to be more reliable because of the elimination of several obstacles native to the singlevariate filter operation, such as the end of the sample problem and the misspecification of the deterministic trend which has to comply with shock responding (Alichi, 2015).

The applied in the paper evaluation of the output gap employs MV filter and Okun’s law definition. The latest approbation of the method for Ukraine was presented by Bohdan in 2018 using direct calculation and the Kalman filter on yearly data for 1998 2017 (Bohdan, 2018). Considering a low discrepancy between the data of the potential GDP obtained by two methods, the present paper has utilized the simpler alternative of calculation. From the practical point of EWS modeling, the validation of the intersection of the baseline of potential GDP with the actual data is more important than the level of accuracy of the two methods.

In most cases, GDP data is published quarterly. We employ the Chow-Lin regression method of interpolating higher frequency values to transform quarterly data into monthly ones. The method demonstrates good results but performs data smoothing with somewhat loss of information. The binary dependent variable of the logit/probit regression constitutes crises events defined as a deviation from the specified levels above and below of output gap dynamics.

The selection of the independent variables of the regression is a product of the logit/probit modeling technique. Several econometric characteristics have to be taken into account while choosing the correct arguments of the regression. They are McFadden R-squared data, the p-value of each of the independent variables, and the number of correctly predicted cases. The power quality of the logit/probit modeling is the determination of critical values of the regressors which treated as thresholds of the arguments.

The selected sample contains quarterly and monthly data and covers the period 2005-2019. We manipulate with the data published regularly by the State Statistics Service of Ukraine and the National Bank of Ukraine as well as the sources presented by the international organizations and monitoring agencies (Tab. 1).

The data magnitude is Y-o-Y measured in 2007 constant prices. We employ the HP filter to evaluate the natural rate of unemployment (with the smoothing parameter 14400 used for monthly observations). The HP filter

and other statistical operations performed in the econometric package Gretl. We apply the moving average (MA) smoothing operation of actual and potential GDP before generating the binary data of the output gap as well as exponential MA transformation for several arguments of logit/probit regression.

**Table 1 – Data description**

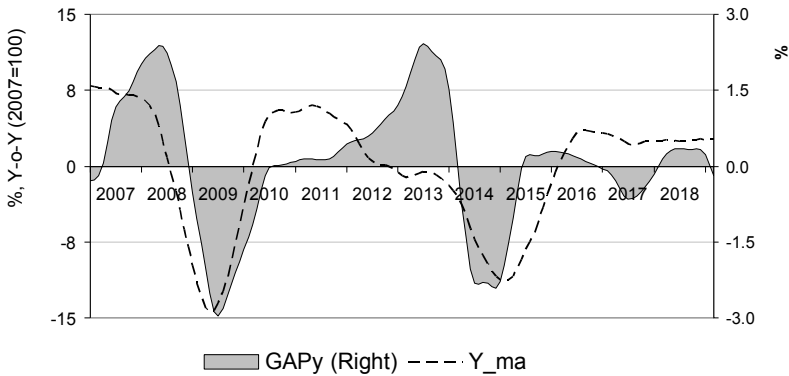
<b>Indicator</b>	<b>Description</b>	<b>Source</b>
GDP	-	<a href="http://www.ukrstat.gov.ua/operativ/menu/menu_e/nac_r.htm">http://www.ukrstat.gov.ua/operativ/menu/menu_e/nac_r.htm</a>
Unemployment rate	percent of the total population aged 15-70	<a href="http://www.ukrstat.gov.ua/operativ/operativ2017/rp/eans/eans_e/Arch_bnsmv_e.htm">http://www.ukrstat.gov.ua/operativ/operativ2017/rp/eans/eans_e/Arch_bnsmv_e.htm</a>
M2	broad money	<a href="https://old.bank.gov.ua/files/3.1-Monetary_Statistics.xls">https://old.bank.gov.ua/files/3.1-Monetary_Statistics.xls</a>
Russian natural gas price	average import border price and a spot price component (Europe, including UK)	<a href="https://www.indexmundi.com/commodities/?commodity=russian-natural-gas&amp;months=180">https://www.indexmundi.com/commodities/?commodity=russian-natural-gas&amp;months=180</a>
Wheat price	hard red winter, ordinary protein, FOB gulf of Mexico	<a href="https://www.indexmundi.com/commodities/?commodity=wheat&amp;months=180">https://www.indexmundi.com/commodities/?commodity=wheat&amp;months=180</a>
Steelmaking commodity price	fob export [not spot prices] for pig iron shipped from Brazil	<a href="https://www.steelonthenet.com/files/pig-iron.html">https://www.steelonthenet.com/files/pig-iron.html</a>

We manipulated with Okun’s law definition to evaluate the potential GDP of Ukraine. The obtained monthly distribution of GDP used as actual data. The average elasticity of the change in the unemployment rate to GDP was 3. We took a 2% degree of the difference between the actual and the potential GDP to generate binary data of the output gap, in such case, the qualitative response variable (Cerovic et al., 2018, Fig. 1).

The binary data of the output gap associated with crises employed as the dependent variable of logit/probit regression. There were three independent variables favored to be early warning arguments in the model: supply-demand gap, the world price of raw materials, and broad money supply.

The first independent variable of logit/probit regression, the supply-demand gap, was arranged by monitoring the relationship between aggregate demand and supply. Regarding the quantity theory of money and the equation of exchange, the change in demand for real cash balances should equal the change in real output if the change in money velocity is constant. There is a way of detecting the destabilizing processes that usually bring to crises while breaking the given balance. We employed the difference between the change in real GDP Y-o-Y and the change in real

M2 Q-o-Q. The newly composed variable identified as a supply-demand gap. The comparatively lower period of change Q-o-Q for the real M2 was chosen because there is less than a year, about three months in the case of Ukraine, for the issued into circulation and incorporated in economic transactions money to produce the final output of goods and services.



**Figure 1.** The comparative dynamics of GDP and the output gap of Ukraine in 2007:M01-2019:M03

*Source: State Statistics Service of Ukraine and the author's computation results.*

The second independent variable dealt with the dynamics of the world price of raw materials. The economy of Ukraine is comparatively small, open, and susceptible to the world market situation, especially the market of raw materials. Among an array of raw materials, the most prompted ones are world prices of the wheat, the Russian gas, and the steel. We built a composite variable of the three ones to manipulate the world prices of raw materials. The equivalent weights of the components of the newly composed variable were determined by imposing a linear restriction of the sum on the regressors' coefficients that should be equal to 1 in regard to GDP as a dependent variable. The values of the coefficients of the world prices of the wheat, the Russian gas, and the steel were respectively 0,28, minus 0,39, and 0,34. The negative mark before one of the components took into account the direction of impact on the economy of Ukraine.

The third early warning argument, the change in broad money supply, was taken because of being a main factor of inflation. The inflation, among the other potential incentives of macroeconomic imbalance,

becomes an important indicator once it reaches a dangerous position that has to be considered to prevent crises and maintain sustainable growth.

Gretl software package for econometric analysis approximates logit/probit regression using the technique of Maximum Likelihood Estimation, which is why the computer iterates before giving the results. The captured probit results were more statistically significant in comparison to the logit model. The corresponding marginal effects for the supply-demand gap, the world price of raw materials, and the broad money supply were respectively 4,0%, 0,7%, and 0,4%. In other words, an additional percent of the rise in the supply-demand gap increased the probability of crises in Ukraine by 4,0% and for the indicators of the world price of raw materials and the broad money supply by 0,7% and 0,4% respectively (Tab. 2). Regarding the higher marginal grade, the demand-supply gap is more significant among the given early warning arguments for predicting crises in Ukraine.

**Table 2 - Probit, using observations 2006:M01-2019:M03**

(dependent variable: GAPy, (T = 159), standard errors based on Hessian)

	<i>Coefficient</i>	<i>Std. Error</i>	<i>z</i>	<i>p-value</i>	<i>Slope</i>
const	-2,923	0,584	-5,005	5,6E-07	
DemSup_ema	0,467	0,093	5,020	5,2E-07	0,040
RawM_ema	0,079	0,022	3,513	0,0004	0,007
M2	0,045	0,015	3,056	0,002	0,004

McFadden R-squared = 0,4

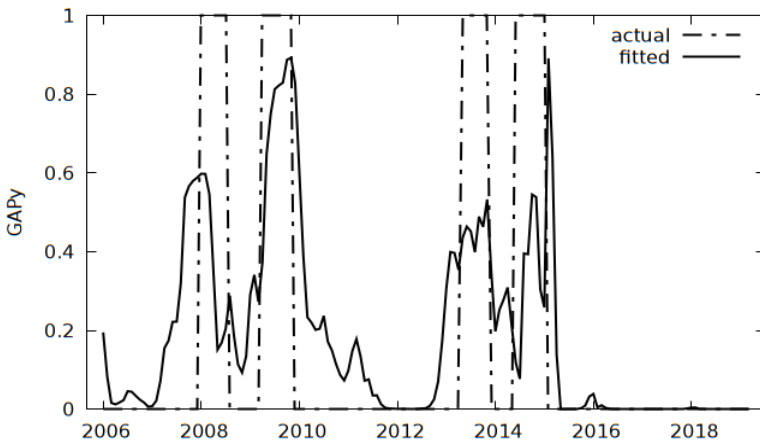
Number of cases 'correctly predicted' = 134 (84,3%)

*Source: the author's computation results.*

The obtained results of the probit regression are important given the culminating positions of the fitted indicator at the beginning, during, and at the end of the crises (Figure 2). The represented dynamics, matching the breakthrough points of the crises, are very similar, including the range of the values. The crises were different in terms of the sources and the nature of the following recessions. It was the shock of the world price of raw materials before 2008 and the financial distress in late 2013. Despite the given facts, we have an almost identical performance of the fitted indicator and comparatively close critical values in the starting and closing positions of the recessions. The last remark indicates that the elaborated probit model demonstrates the high predictive validity of the selected early warning arguments.



There have been several precaution announcements of the leading financial organizations (including the International Monetary Fund) upon ongoing world crisis expecting in the near future. The statements are very strong considering the late contradiction between the USA and the People's Republic of China and the destabilization of raw materials market science in the middle of 2018. The situation for Ukraine is worsening by a long period of postponement of actual reforms that have been at last declared since the end of 2018. There is not enough time to undertake a full package of reform under a given pressure of events. So, Ukraine stands on the threshold of the expected crisis events being unable to be completely prepared for them. The later the crisis comes the more advantages Ukraine has in the efforts to prevent the negative crisis outcomes.



**Figure 2** - The actual/fitted plot of probit regression  
*Source: the author's computation results.*

The paper pursued a goal to develop the EWS model using logit/probit regression and determine early warning arguments and their appropriate thresholds for Ukraine. The dependent binary variable of the logit/probit model associated with the output gap. The multivariate filter and Okun's law definition were employed to evaluate the potential GDP of Ukraine. The quarterly distribution of GDP was transformed into monthly data by applying the Chow-Lin regression method of interpolating higher frequency values. The average elasticity of the change in the unemployment

rate to GDP was 3. The difference between the actual and the potential GDP of 2% used for generating binary data of the output gap.

There were three independent variables favored to be early warning arguments of the logit/probit regression: supply-demand gap, the world price of raw materials, and broad money supply. The obtained econometric characteristics of the probit regression were more statistically significant in comparison to the logit one. The corresponding marginal effects for the supply-demand gap, the world price of raw materials, and the broad money supply were respectively 4,0%, 0,7%, and 0,4%. Regarding the higher marginal grade, the demand-supply gap is more significant among the given early warning components for predicting crises in Ukraine. The probit modeling results are important given the similar culminating positions of the fitted indicator at the beginning, during, and at the end of the crises in 2008 and 2014 that were different in terms of the sources. In the following study, the new arguments of the logit/probit regression have to be examined to perform higher predicting validity.