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Early Warning System: Logit/Probit introduction for Ukraine

Abstract. Introduction. There have been several crises in the world economy since the end of the last century. The developing economies were ones that have suffered the most considering the level of openness, the weak institutional framework, and the market vulnerability to unpredictable shocks. One of the instruments widely used to prevent crises is the Early Warning System models.

Purpose. The paper pursues the goal to develop Early Warning System model using logit/probit regression to determine early warning arguments and their appropriate thresholds for Ukraine.

Results. The regression algorithm corresponds to the determination of the dependent binary variable associated with the output gap followed by the selection of independent early warning components. The method of integral composite coincident and leading indicators employs to reproduce the quarterly dynamics of real GDP.

1. The arranged coincident indicator depends on the industrial production, agriculture, construction, and the domestic retail trade.

The expanded to monthly data quarterly GDP is exploited for the evaluation of the output gap using multivariate filter and Okun's law definition. The 2% difference between the actual and potential GDP is applied for generating binary data of the output gap.

2. The two components of the integral leading index, the world prices of wheat and Russian gas plus the world price of steel figure out one independent variable of logit/probit regression marked as the world price of raw materials. Another one independent variable is arranged by monitoring the demand-supply gap.

3. The obtained probit results are more statistically significant in comparison to the logit model. The marginal effects are 1% for the world price of raw materials and 3% for the demand-supply gap.

Conclusions. Considering the higher marginal grade, between two early warning components the demand-supply gap is more sensitive for predicting crises in Ukraine. In the following study, the other early warning components have to be examined for higher predicting capability.

Keywords: early warning systems; logit/probit modeling; integral composite indicators; output gap; Okun's law.

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Система раннього попередження: logit/probit апробація для України

Анотація. З кінця минулого століття у світовій економіці мали місце кілька криз. Найбільше постраждали країни, що розвиваються, яким властиві високий рівень відкритості економіки, слабкі інституції та підвищена вразливість до непередбачуваних шоків. Одним із інструментів, які широко використовуються для запобігання кризам, є моделі раннього попередження.

Метою статті є розробка logit/probit регресії для визначення індикаторів раннього попередження та встановлення їх граничних рівнів для України. Алгоритм побудови регресії передбачає оперування залежною бінарною вибіркою, представленою ВВП-розривом, з подальшим відбором незалежних компонентів. Для відтворення квартального розподілу реального ВВП використано метод інтегральних композитних співпадаючого і випереджувального індикаторів. Побудований інтегральний співпадаючий індекс охоплює промислове виробництво, сільське господарство, будівництво і роздрібну торгівлю. Розширену до місячних значень вибірку ВВП використано для оцінки ВВП-розриву, яку проведено за допомогою інструменту багатовимірної фільтрації та закону Оукена. Різницю у 2% між фактичним і потенційним ВВП використано для формування бінарної вибірки ВВП-розриву. Два компоненти інтегрального випереджувального індексу світові ціни на пшеницю та російський газ, а також показник світової ціни на сталь є складовими однієї незалежної змінної logit/probit регресії світової ціни на сировину. Визначення другої незалежної змінної пов'язано з моніторингом розриву між сукупними попитом і пропозицією. Отримані результати probit регресії є більш статистично значущими порівняно з logit моделюванням. Граничне значення складає 1% для показника світової ціни на сировину і 3% для показника розриву між попитом і пропозицією. При порівнянні визначених показників за характеристикою

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граничного рівня впливу, більш вагомим індикатором попередження криз в Україні є розрив між попитом і пропозицією. У подальшій роботі необхідно провести дослідження на предмет можливого включення інших компонентів раннього попередження для підвищення точності прогнозу.

   Ключові слова: системи раннього попередження; logit/probit моделювання; інтегральні композитні індикатори; ВВП-розрив; закон Оукена.

Introduction. 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 spreading were changeable and affected a lot of countries with different levels of economic development. Among certain countries, the developing economies were ones that have suffered the most considering the level of openness, the weak institutional framework, and the 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 steps to counteract the devastating consequences of the crises. In such a way, 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 effectiveness is the Early Warning System (EWS) models.

EWS models are classified into two main categories: non-parametric (i.e. crisis signal extraction) and parametric (i.e. regression-based). The non-parametric method takes its origin after the notable work of Kaminsky, Lizondo, and Reinhart published in 1998 where scientists demonstrated the so-called signals approach to examine empirical evidence on currency crises [1]. The advantages of the method are the ability to analyze a lot of variables for undertaking crises' markers, determine thresholds endogenously, and operate with limited samples of binary data. The shortcoming 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 crises markers.

The parametric method was developed by Frankel and Rose in 1996 to predict currency crises [2]. 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 side 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 drawback 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 weak point of EWS models is a lack of institutional and political factors. If the object of study is country with a limited set of indicators, the parametric method proves more appropriate [3].

One of the members of the developing world and, according to the several extended classifications, the emerging markets Ukraine didn't stay aside the

mentioned above devastating processes and entered crises in 2008 and 2014. The retardation of dynamics induced by the following recessions has brought to GDP drop by -30%. The negative consequences are so dramatic that after four years of recovering the growth rate on average has not surpassed the level of 2% 3% a year. At the same time, the debt burden has increased from 9.7% of GDP in 2007 to 61.5% in 2017 with outstanding currency devaluation more than 3.5 times. The macro stabilization measures, initiated to stimulate economic growth, have not been very productive. The question is still open whether Ukraine will be able to go through a new crisis without much loss. In this regard, an urgent issue for Ukraine addressed to the complicated economic situation is to identify and monitor indicators of macroeconomic imbalance for preventing negative outcomes of feasible downturns.

The paper pursues a goal to develop EWS model using logit/probit regression to determine early warning arguments and their appropriate thresholds for Ukraine. The distinctive points of the modeling technique are the usage of the output gap as a dependent variable of the logit/probit regression which follows crises events and two-stage selection algorithm for fixing monthly sample of the arguments. The output gap is evaluated using a multivariate (MV) filter and Okun's law definition. The technique for expanding quarterly GDP to monthly data employs a procedure of building the integral coincident index. The following step of compositing integral leading index is used for selecting EWS components. The selection proceeding also considers country-specific patterns with particular attention to the breakpoint issue.

Short literature review. The crises events can be of different reasons. Regarding the latest classification developed by Laeven and Valencia, there are three types of crises: currency crisis, sovereign debt crisis, and the banking crisis [4]. The vast majority of EWS study is 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 accompanies the recession associated with crises events and ordinarily ended in the excessive devaluation of the domestic currency.

Counting 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

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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) [5, p. 218].

In the 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. Csortos and Szalai have completed well-grounded research to examine financial and macroeconomic imbalances in 10 Central and Eastern European countries using non-parametric and parametric EWS models. The threshold value of 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 [6, p. 19 20].

Methodology. The methodology used in the paper employs a logit/probit approach. Upon building 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 crisis, we have chosen output gap. The given indicator follows expected dynamics of the business cycle and responds well to economic downturns provoked by unpredictable internal and external shocks [7, p. R36].

There are several well-known methods to evaluate 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 elimination of several obstacles native to the single-variate filter operation, such as the end of the sample problem and the misspecification of the deterministic trend which has to comply with shock responding [8, p. 4 5].

The applied in the paper evaluation of output gap employs MV filter and Okun's law definition. The latest approbation of the method for the case of Ukraine was presented by Bohdan in 2018 using direct calculation and the Kalman filter on yearly data for 1998 2017 [9].

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.

The binary dependent variable of the logit/probit regression constitutes crises events (Ct) defined as a deviation from the specified levels (k1, k2) above and below of output gap (GAPtY) dynamics:

$$C_t = \begin{cases} 1, & \text{if } k1 < GAP_t^Y < -k2 \\ 0, & \text{if otherwise} \end{cases} \qquad (1)$$

Unlike the common practice to test the crises indicators to be the independent variables of logit/probit regression, we provide a selection procedure that consists of two stages. At the first stage, we employ the method of compositing integral coincident and leading indicators. We follow the technique used in the applied study for the composition of the integral coincident and leading indicators for Jordan [10]. The general idea of the method is to arrange arguments correlated with the dependent component represented by the output or other aggregate variables. The algorithm consists in creating ordinary least square (OLS) regression by establishing independent variables keeping in mind R2 value but also the distribution of t-ratio statistics, the test for normality of residuals, and the CUSUM test. The variables are separated into two main classes counting a presence/absence of delay. The variables correlated with the dependent component without delay make up the coincident indicator and the same results but with delay are worked for compositing the leading indicator. The ability to expect crises, from the one hand, is a matter of test for a cyclical component, and, from the other hand, the leading value can be used for predicting the dynamics of the dependent variable keeping in mind the delay interval.

In most cases, GDP data is published quarterly. There are two regular ways to transform quarterly data into monthly ones: by interpolating higher frequency values and by composing regression using independent variables of monthly data. The first mode demonstrates good results but performing data smoothing. The second mode takes into account the economic interpretation of independent variables. We employ the second mode where the constant coefficients of the regression built on quarterly data are used to make the same regression but built on monthly data.

The final selection of independent variables performed at the second stage is a product of logit/probit modeling. In such a way, the newly formed regressors serve as early warning arguments obtained by manipulating with an array of the leading components of the integral composite index.

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Data description. The selected sample contains quarterly and monthly data and covers the period 2005 2018. The quarterly data are used for compositing integral coincident indicator. 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. They are the Organization for Economic Co-operation and Development (for quarterly GDP data by countries), the European Union (for production in the industry by countries of the euro zone), the IndexMundi data portal (for the wheat price of FOB Gulf of Mexico and Russian natural gas), and the Steelonthenet.com steel portal (for steelmaking commodity prices).

The data are seasonally adjusted using TRAMO analysis. We apply econometric package Gretl for taking TRAMO analysis and other statistical operations. The

dimension of the data is Y-o-Y in 2007 constant prices apart from the actual and potential GDP measured in real values. We check for stationarity using the Augmented Dickey-Fuller test. We exploit HP filter to evaluate the dynamics of the natural rate of unemployment (with the smoothing parameter 14400, as is common for monthly data) and, before generating the binary data of the output gap, take moving average (MA) smoothing of the monthly data of the actual and potential GDP.

Results. The GDP data is regularly published in Ukraine on a quarterly base. We develop two OLS regressions of integral composite coincident and leading indicators to reproduce the quarterly dynamics of real GDP of Ukraine (GDP$_r$). The arranged coincident indicator depends on the following components: industrial production (Prod$_r$), agriculture (Argic$_r$), construction (Const$_r$), and domestic retail trade (Commod$_r$):

$$\Delta GDP_r = 0.411 \times Prod_r + 0.095 \times Agric_r + 0.054 \times Const_r + 0.013 \times Commod_r \qquad (2)$$

$$[13.72]^* \qquad [5.54] \qquad [3.98] \qquad [8.98]$$

Centered R2 = 0.97; F(4, 47) = 385.07
*t-statistics in brackets.

The integral leading index consists of five elements: gross fixed capital accumulation, business outlook index, exchange rate, and the world prices of wheat and Russian gas. The constant coefficients of the given equation are used to compose the same regression but manipulating with monthly data.

We use Okun's law definition to evaluate potential GDP of Ukraine. The obtained monthly distribution of GDP

is used as actual data. The elasticity of the change in unemployment rate to change in GDP is 3. The dynamics of the actual and the potential GDP are similar except the marked difference before the crises in 2008 and 2014. We take 2% level of the difference to generate binary data of output gap, in such case, the qualitative response variable [11, p. 21] (Fig.1).
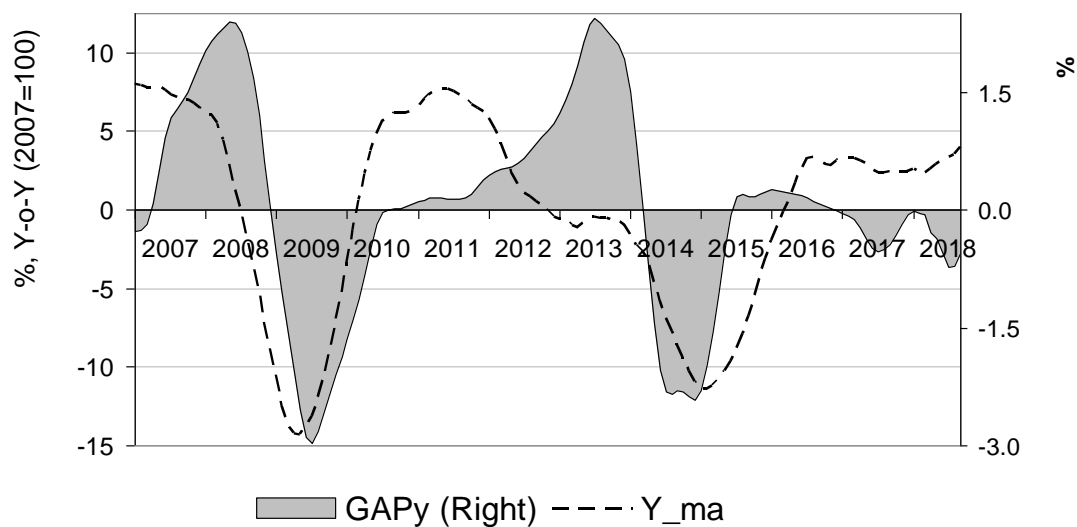

Figure 1 – **The comparative dynamics of GDP and the output gap of Ukraine in 2007:M01 2018:M09**

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

We proceed to the next section of logit/probit modeling. The binary data of output gap associated with crises employs as a dependent variable in the logit/probit regression. We examine components of the integral

leading indicator built in the previous section of the study to select independent variables of the logit/probit regression. Among the variables, the most prompted ones are the world prices of wheat and Russian gas. We modify

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the specification by adding data of the world price of steel and obtain new variable titled the world price of raw materials. The equivalent weights of the components of the newly composed variable are determined by imposing a linear restriction of the sum on the regressors' coefficients which should be equal to 1. The dependent variable of the regression is the monthly data of GDP of Ukraine ranked as Y-o-Y; the independent variables are the world price of wheat, Russian gas, and steel of the same dimension. The values of the obtained coefficients are respectively 0.24, -0.38, and 0.38.

Another one independent variable of logit/probit regression is 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 be equal to the change in real output if the change in money velocity is constant. While breaking the given balance, there is a way for detecting the destabilizing processes which usually bring to crises effects. We employ the difference between the change in real GDP ranked as Y-o-Y, and the change in real M2 ranked as Q-o-Q. The newly composed variable is marked as a demand-supply gap. The comparatively lower period of change for the real M2 is used because there is less than the year, about three months for Ukraine, is necessary for the money issued into circulation and incorporated in economic transactions to produce the final output of goods and services.

Gretl approximates ligit/probit regression using technique of Maximum Likelihood Estimation that is why the computer iterates before giving the results. The captured probit results are more statistically significant in comparison to the logit model. The marginal effects are 1% for the world price of raw materials and 3% for the demand-supply gap. In other words, an additional percent of the rise in the world price of raw materials increases the probability of crises in Ukraine by 1% and for the indicator of the demand-supply gap by 3% (Tab. 1, Fig. 2). Considering the higher marginal grade, between two early warning components the demand-supply gap is more sensitive for predicting crises in Ukraine.

Table 1 **Probit, using observations 2005:M01-2018:M10 (T = 166)**
(dependent variable: GAPy, standard errors based on Hessian)

	Coefficient	Std. Error	z	Slope*
const	-1.209	0.154	-7.846	
Dem-Sup	0.146	0.030	4.901	0.032
RawM	0.040	0.011	3.603	0.009

Number of cases 'correctly predicted' = 141 (84.9%)
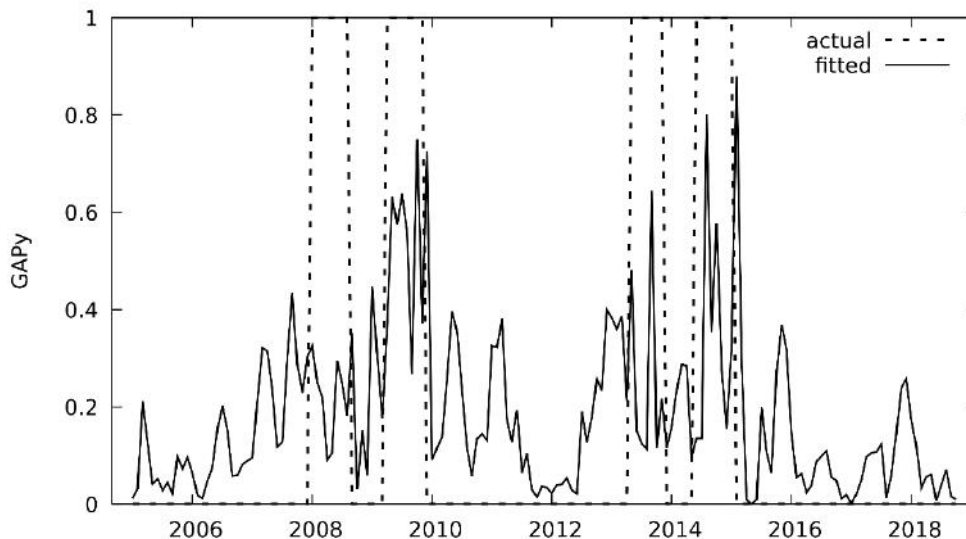*Evaluated at the mean

Source: the author's computation results

Figure 2 – **The actual/fitted plot of probit regression**

Source: the author's computation results

Conclusion. The paper pursues the goal to develop EWS model using logit/probit regression to determine early warning arguments and their appropriate thresholds for Ukraine. The dependent binary variable of the logit/probit model is associated with output gap. We set up integral composite coincident and leading indicators to reproduce quarterly dynamics of real GDP. The coincident index depends on industrial production, agriculture, construction, and the domestic retail trade. The constant coefficients of the equation of the coincident index apply

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to compose the same regression but using monthly data. The monthly data of GDP employ for the output gap estimation using MV filter and Okun's law definition. The difference between the actual and potential GDP of 2% is used for generating binary data of the output gap.

The obtained leading index consists of five components: gross fixed capital accumulation, business outlook index, exchange rate, and the world prices of wheat and Russian gas. The last two components plus the world price of steel make up one independent variable of logit/probit regression titled as the world price of raw materials. Another one independent variable is arranged

by monitoring the relationship between aggregate supply and demand and marked as a demand-supply gap. The obtained probit results are more statistically significant in comparison to the logit model. The marginal effects are 1% for the world price of raw materials and 3% for the demand-supply gap. Considering the higher marginal grade, between two early warning components the demand-supply gap is more sensitive for predicting crises in Ukraine. In the following study, the other early warning components have to be examined for higher predicting capability.

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