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Modeling the stability dynamics of Ukrainian banking system

Abstract

The article is stressed on the stability indicator of the banking system as binary variable, which takes a single value in unstable condition and non-zero value otherwise. It is offered to explore stability dynamics of Ukrainian banking system as time series, suggested to perform stability indicator on the basis of stationary time series verification by adaptation of the Forster-Stewart method to the peculiarities of the research subject. In the article it is relevant to identify the main factors of stability indicator formation, realize decomposition of a system - forming components of the variable to be explained on the base of autoregression trend-seasonal additive or multiplicative models.

Keywords: stability index of the banking system, stability dynamics, time series, decomposition analysis, regression analysis.

JEL Classification: G10, G21.

Introduction

Liberalization of economic relations and expansion of globalization caused the rapid development of consumer and financial markets. At the same time, mentioned factors adversely affected the financial market and its segments, especially the banking system, because banks play the most important role in the financial market and are major financial intermediaries in our country. Besides, the fluctuation in banking sector can also be the reason of economic circumstances instability in the country. Therefore, it raises the question of necessity to carry out research and develop economical mathematical model, which could make possible to identify the factors of banking system stable development and find out the mechanism of its regulation on the basis of regression and decomposition analysis.

1. Research results

Modern literary analysis in the context of the banking system stability detection and evaluation [2, 5, 10, 13, 15] allows to systematize the existing approaches and consider this category as the ability of the system to maintain stable basic characteristics in time in condition of insignificant market fluctuation, to accept and resist the influence of external factors adequately, and to maintain the condition of a long-term dynamic equilibrium [1.12, 1.14]. Based on the above-mentioned approach, it is suggested to transform the stability of the banking system as its ability to maintain state for a long-term dynamic equilibrium. Therefore, the purpose of this article is modeling the dynamics and forecasting stability of the banking system on the example of Ukraine.

Achieving this purpose involves the formulation and solution of the following objectives:

♦ offer a quantitative estimation (indicator) of the banking system stability characteristics;
♦ identify major factors of the dynamic stability concept formation and explore its main trends and regularities;
♦ formalize the relationship between the seasonality (cyclicality) factors of the banking system stability and the integral indicator;
♦ to determine the influence of the stability indicator on the basic of characteristics of the banking system functioning;
♦ forecast the stability of Ukrainian banking system within 2014-2015.

Studying the stability of the banking system requires using the input information base, which consists of the following time-series data [1.6, 1.7]: the equity capital, assets, credits and liabilities, interest incomes and net profit/(loss) during 2009-2012 years in the context of the quarterly data. These statistical data are presented in Table 1.

Let us look at the diagram of dynamics of characteristics indicators of the Ukrainian banking system, presented in Figure 1. In this illustration we can see two scales: the left one is used to display the data in the form of the bar graph, the right one – respectively, in the form of the dynamics schedules. Analysis of above-mentioned figure allows to make conclusions about the oscillation trends regarding such indicators as interest incomes and net profit/(loss), while in the context of other indicators the ongoing trend is observed. The indicated fact can be the cause of violation of the banking system stability of Ukraine.

Table 1. Input information base, thousand UAH

| Time period  | Equity capital | Credits and liabilities (loans) | Assets | Net profit/loss | Interest income |
|--------------|----------------|---------------------------------|--------|----------------|-----------------|
| 01.01.2009   | 119263048      | 741815978                       | 928086498 | 7304241   | 88370294        |
| 01.04.2009   | 117061585      | 737913200                       | 870636535 | -7019821 | 32440838        |
| 01.07.2009   | 112597492      | 735094597                       | 864694968 | -14321422 | 61849586        |

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Table 1 (cont.). Input information base, thousand UAH

| Time period | Equity capital | Credits and liabilities (loans) | Assets | Net profit/loss | Interest income |
|-------------|----------------|-------------------------------|--------|----------------|-----------------|
| 01.07.2009  | 112597492      | 735094597                     | 864694968 | -14321422      | 61849586        |
| 01.10.2009  | 117968018      | 747775459                     | 88995833 | -20943905      | 91832989        |
| 01.01.2010  | 120207619      | 726295788                     | 873449574 | -31491841      | 119083052       |
| 01.04.2010  | 126646323      | 720948600                     | 87496709 | -4423405       | 28204679        |
| 01.07.2010  | 127162304      | 719569876                     | 885255711 | -8306141      | 55334622        |
| 01.10.2010  | 132802031      | 744082347                     | 917497456 | -9998904     | 84739672        |
| 01.01.2011  | 137725113      | 750536379                     | 942083904 | -13026584     | 11334120        |
| 01.04.2011  | 138404527      | 768065850                     | 950033185 | -210786      | 28123028        |
| 01.07.2011  | 147816550      | 789549434                     | 1019811043 | -1062004   | 54007633        |
| 01.10.2011  | 151866259      | 815319860                     | 1029162518 | -5641491   | 82993044        |
| 01.01.2012  | 155486926      | 813863749                     | 1054272287 | -7707548     | 113352487       |
| 01.04.2012  | 162236166,3    | 670016569                     | 1082473105 1724830,4 28027965,26 |
| 01.07.2012  | 163775906,4    | 67956093,8                    | 1104395259 1552033,4 56296229,75 |
| 01.10.2012  | 165810129,5    | 686335697,4                   | 1117445882 2775150,2 88377226,86 |
| 01.01.2013  | 170198201,8    | 694381044,8                   | 1127179379 4898805,5 119278015,7 |

Fig. 1. Diagram of the dynamics of input data indicators

Modeling the dynamics stability of the banking system is suggested to perform on the basis of stationary time series verification by adaptation of the Forster-Stewart method to the peculiarities of the research subject. Therefore, the stationary time series is a process, which is characterized by constant mathematical expectation and variance (without trends), autocorrelation function depends on two subsequent periods of time, but not from a specific time period. It is recommended to analyze the stages of the proposed approach practical implementation in more details with consideration of the mentioned definition.

Stage 1. Creation the research information base by collecting statistical data in the context of the relevant indicators dynamics of quantitative estimation of the stability of Ukrainian banking system (see Table 2); comprehensive analysis of their basic regularities. Such indicators are: the rate of growth of net profit/loss; the capital adequacy of banks, interest margin, ROA (return on assets), ROE (return on equity) (Figure 2).

Table 2. Relevant indicators of quantitative estimation of the Ukrainian banking system stability

| Time period | The rate of growth of net profit/loss,% | The capital adequacy of banks, proportion (10^-2) | Interest margin, proportion (10^-2) | ROA, proportion (10^-2) | ROE, proportion (10^-2) |
|-------------|---------------------------------------|-----------------------------------------------|---------------------------------|--------------------------|--------------------------|
| 01.01.2009 | -                                     | 12.88                                         | 11.91                           | 0.79                     | 6.12                     |
| 01.04.2009 | -1.96                                 | 13.45                                         | 4.40                            | -0.81                    | -0.00                    |
| 01.07.2009 | 1.04                                  | 13.02                                         | 8.41                            | -1.66                    | -12.72                   |
| 01.10.2009 | 0.46                                  | 13.26                                         | 12.28                           | -2.35                    | -17.75                   |
| 01.01.2010 | 0.50                                  | 13.76                                         | 16.40                           | -3.61                    | -26.20                   |
| 01.04.2010 | -0.86                                 | 14.47                                         | 3.91                            | -0.51                    | -3.49                    |
| 01.07.2010 | 0.88                                  | 14.36                                         | 7.69                            | -0.94                    | -6.53                    |
| 01.10.2010 | 0.20                                  | 14.47                                         | 11.39                           | -1.09                    | -7.53                    |
| 01.01.2011 | 0.30                                  | 14.62                                         | 15.10                           | -1.38                    | -9.46                    |
| 01.04.2011 | -0.98                                 | 13.91                                         | 3.66                            | -0.02                    | -0.15                    |
| 01.07.2011 | 4.04                                  | 14.49                                         | 6.95                            | -0.10                    | -0.72                    |
The necessary condition for the application of Forster-Steward method for modeling the stability dynamics of the banking system is the homogeneity of the considered time-series data levels.

Homogeneity means the absence of atypical, anomalous observations, as well as the distortion of the trend. Anomalous level is a separate value of the time series, which does not correspond to the potential of the economic system, being studied, and which, while remaining the level of the time series, has a significant influence on the values of the basic characteristics of the time series. For detection of the anomalous levels of time series it is proposed to use the Irwin method. This method is based on the comparison of the time series neighbor values and the calculation of its characteristics $\lambda_t$. The calculated values are compared with the critical value, $\lambda_c$, and if they do not exceed critical, then the corresponding levels are considered to be normal. In Table 3 the anomalous levels of the studied time series are marked with bold, which should be avoided by calculating the average value among the previous and the next relatively anomalous levels of the corresponding time series.

Obtained anomalous values (in Table 3) can be explained as follows:

- Interest margin, ROA, ROE on 01.04.2009, and the rate of growth of net profit/loss on 01.07.2009 are explained by the beginning of the crisis in the Ukrainian banking system, and getting much smaller or even negative values of profit.
- The anomaly of values of interest margin, ROA, ROE on 01.04.2010 can be explained by a certain improvement of the situation in the Ukrainian banking sector, especially the significant reduction of the banks expenses.

- Interest margin on 01.04.2011 is explained by the fourfold decrease of interest incomes in connection with a significant decrease of credit activity of banks. At the same time the anomaly of this indicator on 01.04.2012 is connected with the crisis recovery of the national system and the achievement of a much bigger level of interest income compared to the previous period.

- The anomaly of values of the growth rate of net profit/loss on 01.07.2011 and 01.01.2012 is linked. In the first case, with the increase in the volume of damage, and in the second case, on the contrary, with the transition of the domestic banking system to the profitable operation.
The comprehensive analysis of time series, presented in Figure 2, allows to determine the main tendencies in change of the national banking system index stability. Therefore, clear linear trend of development is observed in the context of capital adequacy and the return on assets of banking institutions, while the seasonal variations are typical for such indices as interest margin and return on capital. The above-indicated variations of the mentioned indicators cause the oscillation trends in the dynamics of the banking system stability indicator.

Fig. 2. Diagram of the relevant indicators dynamics of quantitative estimation of the Ukrainian banking system stability

Formalization and quantification of the revealed laws is proposed to realize with the use of mathematical methods by decomposition of the considered time series filtering trend \((F(t))\), seasonal (cyclic) \((S)\) and random components.

The autoregression trend-seasonal multiplicative model of return on equity:

\[
ROE_t = a + \beta \times ROE_{t-m} + F(t) \times S = 0.002 + 0.31 \times ROE_{t-4} + 0.60 \times (0.01 \times (-0.16) \times (-0.24) \times 0.98 \times 1.26 \times 1.99) \\
\]

where \(ROE_t\) is the return on equity at time moment \(t\); \(d_1, d_2, d_3, d_4\) is the indicator of the first (second, third, fourth) quarter, which takes the values: “1”, if time moment of calculation corresponds to the first (second, third, fourth) quarter; “0” otherwise.

Figure 3 below presents graphical representation of equation (1).

The trend-seasonal additive model of interest margin:

\[
PM_t = F(t) + S = (-0.01, +0.10) + 0.41d_1 + 0.81d_2 + +1.18d_3 + 1.51d_4 \\
\]

where \(PM_t\) is the interest margin at time moment \(t\).

Figure 4 below presents graphical representation of equation (2).
The trend-seasonal multiplicative model of ROA:

$$ROA_t = 0.001 + 0.43 \times ROA_{t-1} + 0.22 \times (0.01t - 0.02) \times (-0.24)_{d1} \times 0.97_{d2} \times 1.26_{d3} \times 2.01_{d4}, \tag{3}$$

where $ROA_t$ is the return on assets at time moment $t$.

Figure 5 below presents graphical representation of equation (3).

The trend-seasonal additive model of the rate of growth of net profit/loss:

$$RGP_t = F(t) + S = (8.39t + 4.40) - 71.52d_1 + 91.59d_3 - 33.58ld_4, \tag{4}$$

where $RGP_t$ is the rate of growth of net profit/loss at time moment $t$.

Figure 6 below presents graphical representation of equation (4).

Stage 2. Determination of two numerical sequences $k$ and $l$ basing on the comparison of each input time series value (consistently one of a whole array selected indicators) with the previous one according to the following principle: in the context of the numerical sequence $k$ – a single value, if the time series level (except the first one) is greater than all the previous ones, and a non-zero value otherwise, within the sequence $l$ – a single value, if the time series level (except the first one) is less than all the previous ones, and a non-zero value otherwise. See Table 4.
Table 4. Monotonicity characteristics of time series of Ukrainian banking system stability relevant indicators

| Date       | Growth of net profit/loss | Capital adequacy of banks | Interest margin | ROA | ROE | Growth of net profit/loss | Capital adequacy of banks | Interest margin | ROA | ROE |
|------------|---------------------------|---------------------------|----------------|-----|-----|---------------------------|---------------------------|----------------|-----|-----|
| 01.01.2009 | 0                         | 1                         | 0              | 0   | 0   | 0                         | 1                         | 1              | 1   | 1   |
| 01.04.2009 | 0                         | 1                         | 0              | 0   | 0   | 0                         | 1                         | 1              | 1   | 1   |
| 01.07.2009 | 1                         | 0                         | 0              | 0   | 0   | 1                         | 1                         | 0              | 1   | 1   |
| 01.10.2009 | 0                         | 0                         | 1              | 0   | 0   | 0                         | 0                         | 0              | 1   | 1   |
| 01.01.2010 | 0                         | 1                         | 1              | 0   | 0   | 1                         | 0                         | 1              | 1   | 1   |
| 01.04.2010 | 0                         | 1                         | 0              | 0   | 0   | 1                         | 0                         | 1              | 1   | 1   |
| 01.07.2010 | 0                         | 0                         | 0              | 0   | 0   | 0                         | 1                         | 1              | 1   | 1   |
| 01.10.2010 | 0                         | 0                         | 0              | 0   | 0   | 0                         | 1                         | 1              | 1   | 1   |
| 01.01.2011 | 0                         | 1                         | 0              | 0   | 0   | 1                         | 0                         | 1              | 1   | 1   |
| 01.04.2011 | 0                         | 0                         | 0              | 0   | 0   | 1                         | 1                         | 1              | 1   | 1   |
| 01.07.2011 | 1                         | 0                         | 0              | 0   | 0   | 0                         | 1                         | 1              | 1   | 1   |
| 01.10.2011 | 1                         | 1                         | 0              | 0   | 0   | 0                         | 1                         | 1              | 1   | 1   |
| 01.01.2012 | 0                         | 0                         | 0              | 0   | 0   | 0                         | 1                         | 1              | 1   | 1   |
| 01.04.2012 | 0                         | 1                         | 0              | 0   | 0   | 0                         | 1                         | 1              | 1   | 1   |
| 01.07.2012 | 0                         | 0                         | 0              | 0   | 0   | 0                         | 1                         | 1              | 1   | 1   |
| 01.10.2012 | 0                         | 0                         | 0              | 0   | 0   | 0                         | 1                         | 1              | 1   | 1   |
| 01.01.2013 | 0                         | 1                         | 1              | 0   | 0   | 0                         | 1                         | 0              | 0   | 1   |

Stage 3. Calculation of the monotonicity characteristics (variables $c$ and $d$), fading or slacking off each time series of relevant indicators of quantitative estimation of the Ukrainian banking system stability:

$$c = \sum_{i=2}^{n} (k_i + l_i) d = \sum_{i=2}^{n} (k_i - l_i), \quad \text{(5)}$$

where $k_i$ ($l_i$) is the value of the numerical sequence $k$ (respectively, $l$) at time moment $t$.

Stage 4. The comparison of $t$-relations actual values with a critical one and making conclusions regarding confirmation (if the calculated value exceeds the critical one) or reject the hypothesis about trends in average and in the dispersion of the corresponding time series (Table 5). Formulas take the form of:

$$PM = F(t) + S = (-0.01, +0.10) + 0.41d_1 + .. + 0.81d_2 + 1.18d_3 + 1.51d_4, \quad \text{(6)}$$

where $\mu$ is the assessment of the mathematical expectations time series; $\sigma_1$ is the assessment of the mean-square deviations for the value $c$; $\sigma_2$ is the assessment of the mean-square deviations for

Table 5. The dynamics of stability indicator of the Ukrainian banking system

| Date       | $c$ | $d$ | $l_k$ | $l_t$ | $l_l$ | $l_l$ | $R$ |
|------------|-----|-----|-------|-------|-------|-------|-----|
| 01.01.2009 | 4   | -2  | 0.7982| 0.9109| 0     | 0     | 0   |
| 01.04.2009 | 5   | -3  | 0.1303| 1.3663| 0     | 0     | 0   |
| 01.07.2009 | 5   | -3  | 0.1303| 1.3663| 0     | 0     | 0   |
| 01.10.2009 | 5   | -1  | 0.1303| 0.4554| 0     | 0     | 0   |
| 01.01.2010 | 5   | -3  | 0.1303| 1.3663| 0     | 0     | 0   |
| 01.04.2010 | 5   | -3  | 0.1303| 1.3663| 0     | 0     | 0   |
| 01.07.2010 | 5   | -5  | 0.1303| 2.2772| 0     | 1     | 1   |
| 01.10.2010 | 5   | -5  | 0.1303| 2.2772| 0     | 1     | 1   |
| 01.01.2011 | 5   | -3  | 0.1303| 1.3663| 0     | 0     | 0   |
| 01.04.2011 | 5   | -5  | 0.1303| 2.2772| 0     | 1     | 1   |
| 01.07.2011 | 5   | -3  | 0.1303| 1.3663| 0     | 0     | 0   |
| 01.10.2011 | 5   | -1  | 0.1303| 0.4554| 0     | 0     | 0   |
| 01.01.2012 | 5   | -5  | 0.1303| 2.2772| 0     | 1     | 1   |
| 01.04.2012 | 5   | -3  | 0.1303| 1.3663| 0     | 0     | 0   |
| 01.07.2012 | 5   | -5  | 0.1303| 2.2772| 0     | 1     | 1   |
| 01.10.2012 | 5   | -5  | 0.1303| 2.2772| 0     | 1     | 1   |
| 01.01.2013 | 5   | -1  | 0.1303| 0.4554| 0     | 0     | 0   |

Stage 5. Determination of the dynamics banking system stability indicator ($R$) as a time series, the elements of which are calculated as the amount of $t$-relations in the moment of time $t$. The practical implementation of the above-mentioned approach allows to identify time intervals, during which
Ukrainian banking system is characterized by insufficient level of stability (Figure 7). So, the stability indicator takes a value “1” (the fact of an unstable condition) in the second half of 2010, the second quarter of 2011 and during almost the whole year in 2012.

The results, presented in the diagram, entirely confirm the economic model adequacy. So, it is reasonably to say that from 10.05.2010 to 1.09.2012 the Ukrainian banking system was unstable. Exactly during this period the destructive factors of the financial crisis influenced the liquidity of the national banking system most of all. Undoubtedly, during this period there were quarters, when the system managed to return to equilibrium, but this stage was short-continued. Only in the beginning of 2013 the recovery period started.

It should be noted that on the basis of the prediction calculations, we can see a new wave of the crisis in the beginning of 2015. These results are especially interesting because in 2015 the presidential elections will be held in Ukraine. And for our country the relationships between the financial sector and political events are important. In addition, it is obvious that by 2015 the NBU will keep the currency exchange risks in check and provide assistance to troubled banks. So, the seasonal nature of relevant indicators and the cyclical development of repressor of the banking system stability, established at the previous stages of the research, provide the opportunity to get quite adequate predicted results of Ukrainian banking system formation.

Stability of the banking system is determined by a lot of indicators and influences on the formation of the main banking sector indicators. In the research it is relevant to determine the direction and nature of the link between the regressand and the size of equity capital, liabilities and assets for the banking system as a whole [1.12, 1.14]. Therefore, quantification of the regressor on the stability indicator is proposed on the basis of an econometric approach, which presupposes the construction of the multiple non-linear regression equations in such a form [1.9]:

\[
R = -91783.33 - 44754.38 \ln OC - 338405.6 \ln E + 385645.31 \ln A + 1260.82 \ln^2 OC + 8606.86 \ln^2 E - 9744.91 \ln^2 A,
\]

where \( R \) is the indicator of banking system stability; \( OC \) is the equality capital; \( E \) are the liabilities; \( A \) are the assets. Analysis of the equation parameters (5) allows to make the following conclusions. With the increase of the banks equity capital to the amount 177.48 billion (18% of GDP) the level of banking system stability will gradually reduce. Increase of the equity capital above the specified value will cause the revive of Ukrainian banking system stability. A similar tendency is characterized by the liabilities (critical value of 196.59 billion – 19.94% of GDP), in contrast to assets, the influence of which on the effective sign is opposite. Therefore, as the relationships between the stability indicator and assets are presented in the form of polynomial second order branches down, the increase in the assets to the level of 197.87 billion (20.07% of GDP) is accompanied by increase of the variable to be explained. The excess of this factor of specified value gradually leads to the loss of the banking system stable state.

The accuracy and adequacy of revealed regularities are confirmed: by Fisher’s test, the actual value of which 3.52 exceeds a critical permissible level of 3.41; by coefficient of determination at the level of 70, 10%; by statistically significant parameters of the regression equation (t-criterion) [1.11].

**Conclusions**

Thus, modeling the dynamics stability of the Ukrainian banking system allows to define the stability indicator, explore its dynamics as time series, identify the main factors of its formation, realize decomposition of the system – forming components of the stability indicator.
The practical value of the conclusions and recommendations is the following aspects: application of the proposed model approach allows to get an early signal about the imperfection of the existing financial resources management in the context of the banking system and the correction necessity; above-established seasonality of the main factors of the banking system stability provides the opportunity to get a basis for confirmed decision-making; the linear and nonlinear regression dependencies provide the ability to describe quantitatively the regularities and prospects for achieving stability of the system.

References
1. Anderson T.W., Hsiao C. (1981). Estimation of dynamic models with error components, *Journal of the American Statistical Association*, 76, pp. 598-606.
2. Andrews, D. (1993). Tests for parameter stability and structural change with unknown change point, *Econometrica*, 59, pp. 817-858.
3. Bollerslev T. (1986). Generalized autoregressive conditional heteroscedasticity, *Journal of Econometrics*, 31, pp. 307-327.
4. Box G.E.P. and Pierce D.A. (1970). Distribution of residual autocorrelations in autoregressive-integrated moving average time series models, *Journal of the American Statistical Association*, 65, pp. 1509-1526.
5. Chen, Y. (1999). Banking panics: The role of the first-come, first-served rule and information externalities, *Journal of Political Economy*, 107 (5), pp. 946-968.
6. Fama E.F. (1970). Efficient capital markets: A review of theory and empirical work, *Journal of Finance*, 25, pp. 383-417.
7. Filler W.A. (1976). *Introduction to Statistical Time Series*, Wiley, New York, pp. 366-382.
8. Granger C.W.J. (1969). Investigating causal relations by econometric methods and cross-spectral methods, *Econometrica*, 37, pp. 424-438.
9. Granger C.W.J. and Newbold P. (1974). Spurious regression in econometrics, *Journal of Econometrics*, 2, pp. 1045-1066.
10. Kaufman, H. (1986). Debt: the Threat to Financial Stability, in Debt, *Financial Stability, and Public Policy*, Kansas City, Federal Reserve Bank of Kansas City.
11. Keuzenkamp H.A. and Magnus J.R. (1995). On tests and significance in econometrics, *Journal of Econometrics*, 67, pp. 5-24.
12. MacKie-Mason J.K. (1992). Econometric software: A user’s view, *Journal of Economic Perspectives*, 6 (4), pp. 165-187
13. Mishkin, F.S. (1991). Anatomy of a Financial Crisis, NBER Working Paper 3834.
14. Pindyck R., Rubinfeld D. (1991). Econometric models and economic forecasts, Mc. Grow- Hill, Inc. USA, 596 p.
15. Timmermans, Th. and Delhez, Ph. (1999). Restructuring of the Belgian Banking Sector and Financial Stability, BIS Conference Papers 7, March, pp. 55-69.