The use of Ternary Diagrams in the Analysis and the Mathematical Modeling of Bank Assets Structure

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ABSTRACT

The objectives pursued in this paper are: to obtain by means of ternary diagrams imagistic representations of the structure of assets in credit banking institutions operating in Romania in case of stability, turbulence and intense manifestation of the crisis; identifying functional discontinuities and achieve a comparative database. The ultimate goal of this paper is reporting the results obtained from comparative database to find out what signals preceding a turbulent situation in the banking sector and how far away is the banking system by the normal situation.

1. Introduction

The major structural changes in the aggregate balance sheet of the credit institutions, especially in the structure of balance sheet assets, require additional analysis to identify patterns and/or macroeconomic forecast, which will contribute, by offering bank support policy decisions, to avoid positioning the banking system in a bad situation. These structural changes in the context of the increased intensity of the global crisis, left their mark on the banking system, with effects more visible since December 2008. In the area of lending, banks have focused so much attention to the population sector, and especially on consumer credit, which in the period 2006-2008 saw a significant share in the total loans to the population. Thus, in 2008 a value of 77.5% of total loans to households was recorded [6], given the consumers' real need of goods but also because of the bank lax policies in their fierce competition to increase their portfolio of clients and profits. Therefore the development of the Romanian banking system was rather unhealthy which is also reflected in the size of the bad loans and losses reported.

The synthetic analysis of the indicators of the bank assets provides valuable information about their dynamic structure, insufficient though to identify the exact causes and mechanisms behind the turmoil of the Romanian banking system. Changes intrinsic to the structure of bank assets and evolution of the indicators concerned in close correlation may account for some behavioral changes in the banking system in terms of financial and banking policies.

However, a simple reading of a table (be it even with the best quality data) or analysis of a two-dimensional graphics (no matter how neat), by limiting the degrees of freedom in the 2D space limits the quality of information we want to get. For this reason there will be an analysis of the dynamics of bank assets structure in 3D (three-dimensional) space. Working in 3D space in conjunction with a software that uses appropriate mathematical functions can provide spectacular information generated by the structural changes in banking assets, information that, in a 2D space, could go unnoticed. The ternary diagrams represent an instrument, offering a very efficient graphic representation for the characterization of a system that can be described using three variables (or "constituents"), whose sum is always invariable. Although the ternary diagrams area of application is not limited to a certain field, generally they are used in fields such as mineralogy, geology, metallurgy, hydrology or chemistry.

The paper is structured in four chapters and conclusions. In Chapter 1-Introduction-are shown the importance to study the bank assets structure in the global crisis occurred in 2007, and strengths to the use of ternary diagrams in the analysis compared to using two-dimensional graphics. In Chapter 2-Stage of knowledge- is presented a study using ternary diagrams as an alternative method of analyzing a system. Chapter 3-Methodology-includes judgment and steps to be taken in order to achieve the suggested, based on knowledge of the real system. In Chapter 4 - Analysis and modeling the structure of bank assets using ternary diagrams- is presented the study itself.

2. Literature review

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A study about the ternary diagrams application as an alternative method of analyzing a system, called “Graphical tool for energy analysis: concepts and an example of application” was presented by Almeida, Barella and Giannetti during the “Advances in Energy Studies” international workshop, which took place in Unicamp, in Brasil, between 16-19 June 2004 [1]. The study was focused on evaluating the economical efficiency of six electricity production systems, also called “variables” (geothermal, hydroelectric, wind power, natural gas, oil and coal), which together represent the energy system of a whole country (in our case, Italy). For being able to make an analysis based on the ternary diagrams, the authors cut down on the number of “variables” based on the source used for producing the energy, and grouped them in two categories: renewable (geothermal, hydroelectric, wind power) and non-renewable (natural gas, oil, coal). This way made it possible to analyze each group made out of three variables, using the ternary diagrams. The advantages spotted by the authors while using the ternary diagrams are: the inner research of the information, the diagram sensitivity and the synergy. If the sensitivity term can be explained as the response time to the small variations of the system ‘constituents’, then the synergy term indicates cooperation, co-action, co-activity, being defined by the authors as “the combined power of a working together group of factors, that is bigger than the altogether power given by each factor separately” [1]. The authors conclude that “using the ternary diagrams for system analysis allows not only the real situation evaluation of a certain process, but also the ability to identify the critical parameters that need to be modified in order to enhance the entire system performance [...] and it also allows the system behavior prognosis according to the changes made [1].

The three authors final conclusion of the shown above study, is that “the ternary diagrams make the analysis results instant viewing possible and they also make a comparison between different systems or different moments of the same system possible”[1].

As for the state of knowledge in the area of analysis, modeling and ternary diagrams tracing the asset structure of credit institutions operating in Romania, we have not identified studies of other researchers.

3. Methodology

In order to formalize the problem so as to achieve ternary diagrams of the structure, the reasoning will include a number of assumptions, observations, conditions and limitations on the data generating mechanism. A first step in order to simplify the real system is to study the inertia of processes. Consequently, it will be seen how the dynamics of the analyzed economic indicators was in the period 2004-2010 in order to establish its evolution law. To visualize the changes in the structure of assets in credit institutions use was made of the software program Statistica for plotting 3D ternary diagrams developed by State-Soft company [7]. The graphical representation of a time series highlights the most important features of its data: presence or absence of trends, the existence of cycles, certain levels or breaks, etc., but to identify painful moments of a structure 3D plotting of the ternary diagrams is needed. These representations are very sensitive even at extremely small variations of the structure constituents, the result of the structure changing being a change in the pattern of the image.

Key-moments about changing the structure of bank assets are translated into deformation (even mutilation) of the ternary diagram shape. Note that these shape changes do not coincide with the maximum (or minimum) levels of the indicators that goes into bank assets.

4. The use of ternary diagrams in the analysis of bank assets structure

Dynamics of the assets structure in the credit institutions operating in Romania

The most important information that can be obtained from Table 1 is related to the dramatic variation of some indicators, while other indicators have had a more modest variation.

| Table 1. Assets of credit institutions operating in Romania (percent of total assets) |
|---------------------------------|-----|-----|-----|-----|-----|-----|
| Indicators                      | 2004| 2005| 2006| 2007| 2008| 2009|
| Foreign assets of which:        | 94,3| 96,5| 97,4| 98,3| 98,5| 96,9|
| Claims on central bank and credit institutions of which: | 36,5| 40,0| 34,9| 28,8| 23,8| 18,6|
| - Claims on central bank        | 28,5| 37,5| 31,3| 24,9| 21,8| 15,7|
| Claims on home non banking sector of which: | 48,1| 48,5| 54,8| 61,2| 63,4| 67,5|
| - Claims on government sector   | 2,4 | 1,9 | 1,6 | 3,7 | 5,0 | 12,7|
| - Claims on corporations        | 32,7| 30,2| 30,8| 29,9| 29,2| 27,3|
| - Claims on households          | 13,0| 16,4| 22,4| 27,6| 29,2| 27,5|
| Other assets                    | 9,6 | 8,0 | 7,7 | 8,3 | 11,3| 10,8|
| Foreign assets                  | 5,7 | 3,5 | 2,6 | 1,7 | 1,5 | 3,1 |
| **TOTAL**                       | 100 | 100 | 100 | 100 | 100 | 100 |

Source: NBR, Financial Stability Report, 2010

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Thus it can be seen that there are indicators that have large variations in the period 2004-2010 and indicators whose variation is not as significant. In the period 2004-2010 in June the largest variations were reported for the following indicators:

- claims on central bank and credit institutions from a minimum of 16.2% to a maximum of 40% (percentage of the change in total assets 23.8%)
- claims on government sector, from a minimum of 1.6% to a maximum of 14.2% (percentage of the change in total assets 12.6%)
- claims on households, from a minimum of 13% to a maximum of 29.3% (percentage of the change in total assets 16.3%).

Indicators whose share of the variation in the total assets was modest are the following:

- foreign assets, from a minimum of 1.4% to a maximum of 5.7% (percentage of the change in total assets 4.3%)
- other assets, from a minimum of 7.7% to a maximum of 11.3% (percentage of the variation in total assets 3.6%;)
- claims on corporations from a minimum of 27.3% to a maximum of 32.7% (the percentage change in total assets of 5.4%)  

**Observation 1**

Above, we identified two groups of indicators, the first consisting of indicators whose share of the variation in total assets exceeds 12% and the second group consisting of indicators whose variation in total assets is less than 5.5%. The literature states that "all connections and interdependencies that occur between individual factors, groups factors and phenomena or processes taken as whole or in part to their structural causes of specific or common evolutionary ways, ways that highlight the first in the form of stochastic regularity" [2]. Based on this observation we shall impose a first limitation.

**Limitation 1.** We shall create a composite indicator (Ac) as the sum of the weights of the indicators having little variation, in order to restrict the number of indicators and simplify the mathematical modeling.

\[
Ac = \Sigma (Aa + Ae + Cc) \tag{1}
\]

Where: 
- Aa = Other assets  
- Ae = Foreign assets  
- Cc = Claims on corporations

Thus, we have limited to 4 the number of indicators in Table 1 and we denote them A1, A2, A3, A4 in the table below (Table 2)

<table>
<thead>
<tr>
<th>Indicators/year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 = AC = Foreign assets + +Other assets + Claims on corporations</td>
<td>48,1</td>
<td>41,7</td>
<td>41,1</td>
<td>39,9</td>
<td>42</td>
<td>41,2</td>
</tr>
<tr>
<td>A2 = Claims on central bank and credit institutions</td>
<td>36,5</td>
<td>40</td>
<td>34,9</td>
<td>28,8</td>
<td>23,8</td>
<td>18,6</td>
</tr>
<tr>
<td>A3 = Claims on government sector</td>
<td>2,4</td>
<td>1,9</td>
<td>1,6</td>
<td>3,7</td>
<td>5,0</td>
<td>12,7</td>
</tr>
<tr>
<td>A4 = Claims on households</td>
<td>13</td>
<td>16,4</td>
<td>22,4</td>
<td>27,6</td>
<td>29,2</td>
<td>27,5</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: data processing author

**Observation 2:** The mean value of indicator A1 since 2005 (considered in the event of a year of maximum stability in the Romanian banking sector) calculated by summing and dividing multianual values to the number of measurements considered (i.e. 5) is:

\[
V_{med} = \frac{41,7 + 41,1 + 39,9 + 42 + 41,2}{5} = 41,18
\]

Scattering of the annual time series A1 around V_{media} value is within the range (-1.28, 0.82), so it is small. As such, we shall put a first condition:

**Condition 1:** V_{2005}=V_{2006}=V_{2007}=V_{2008}=V_{2009}=41,1=constant

**Hypothesis:** We believe that 2005 was a year of stability in the banking sector.

**Rationale:** Seven of fourteen banking specific indicators recorded in 2005 the best values: solvency ratio, Tier 1 ratio, leverage ratio, Overdue and doubtful (net value) / Total equity, credit rate risk, the NPL and liquidity. Net profit in the banking system (ROA) recorded in 2005 the second largest value (highest value was recorded in 2004) and the indicator ROE (net profit / equity to average) recorded the third highest (second largest value registered in 2004 and highest in 2008) [3].
The ternary diagram is a graphical representation of the structural composition of any physical quantities consisting of three homogeneous constituents whose sum is always constant: 
\[ X_1 + X_2 + X_3 = \text{cst} \] [8].

In other words, to achieve specific ternary diagrams of the structure of assets in banking institutions operating in Romania, we must first ensure that the bank indicator is a homogeneous structure and, secondly, we must identify the three constituents that should observe the above condition.

The homogeneity of a statistic data structure is given by the homogeneity of the values used in the analysis. The characteristic values of each indicator used in this paper are the annual values published by the central bank that we know that: \( \Sigma A_n = 100\% \), \( n = 1,2,3,4,..., n \) as it can be seen from table no.1

To choose the three constituents (indicators) that we shall work with, we use condition 1 and limitation 1, which has reduced the number of indicators to only 4 and a second limitation will be imposed.

**Limitation 2:** In order to achieve ternary diagrams and view structure changes only three indicators shall be used which meet the condition:

\[ X_1 + X_2 + X_3 = \text{cst}. \]

To identify the 3 indicators and demonstrate that the second condition necessary to achieve the ternary diagrams is accomplished, we started from a known fact:

\[ A_1 + A_2 + A_3 + A_4 = 100 \text{ or:} \]
\[ A_2 + A_3 + A_4 = 100 - A_1 \]

But, according to condition no.1 \( (A_1 = 41,1 = \text{constant}) \) the above equation becomes:

\[ A_2 + A_3 + A_4 = 100 - 41.1 = 58.9 \]
\[ A_2 + A_3 + A_4 = \text{58.9 = constant} \]

In conclusion, the second condition is fulfilled and the indicators chosen for drawing the structure diagrams are: \( A_2, A_3 \) and \( A_4 \).

**Observation 3:** The composite indicator \( A_1 \) is a constant, and since there is no variation, it could not make any structural changes to be reflected in a change in the ternary diagram shape. Therefore we can say that imaging representations to be obtained for the dynamic evolution of the three indicators chosen for research purpose, will accurately meet the dynamics of the entire evolutionary process of the asset structure in credit institutions as a whole.

Variables chosen for the program STATISTICA denoted Var1, Var2, Var3, Var4.

<table>
<thead>
<tr>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Var1 = Claims on households</td>
</tr>
<tr>
<td>Var2 = Claims on central bank and credit institutions</td>
</tr>
<tr>
<td>Var3 = Claims on government sector</td>
</tr>
<tr>
<td>Var4 = time ( (t=1,2,3,...) )</td>
</tr>
</tbody>
</table>

**Table 4. Choice of variable axes**

Source: Software program Statistica, data processing author

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To get the most information possible the ternary diagrams were plotted both in 3D (to view the dynamic evolution of the indicator amplitudes translated by the changing in the diagram shape) and in 2D (for a better representation of the evolution of the structural composition). In addition, it was presented a rotated image of the diagrams in order to analyze the diagrams from two perspectives. Here are the diagrams obtained.

**Figure 1. Ternary diagrams in 2D and 3D for the structure of the assets in the banking institutions operating in Romania- values achieved in 2005**

Under this assumption it was agreed that year 2005 was a year of stability in the Romanian banking sector. In terms of banking assets structure indicators in Table 1 it can be seen that indicators **Claims on government sector** and **Claims on households** took minimum values while while the Claims on central bank and credit institutions recorded the maximum value. The imaging representation of this situation, under the assumption of stability in the Romanian banking system, was made using 3D and 2D ternary diagrams. Increasing or decreasing in the values of the indicators reported result in alteration of the ternary diagram image in the area and direction in which processes develop with the greatest intensity, while a red signal indicates a too high level of the constituents or a too intense evolution respectively.

Analyzing the diagrams below we can see that the diagram signals a higher level (40%-peak in the analyzed period) for the **Claims on central bank and credit institutions** indicator. In addition, the process that took place with the greatest intensity during 2004-2005 was 3.5% increase in the value of the **Claims on central bank and credit institutions** indicator.

This image will be further used as a model of stability, and we shall refer to it throughout the research.

**Figure 2. The 2D and 3D ternary diagrams for the structure of assets in the credit institutions operating in Romania-values achieved in year 2006**

The year 2006 is considered a key year for the period that followed. More specifically, it is when the indicator **Claims on government** reaches the minimum (1.6%) with the change in the direction of evolution, from decreasing to increasing, is the first year of decline of the **Claims on central bank and credit institutions** indicator, while **Claims on households** indicator registers the highest increase of all the period analyzed (from 16.4 to 22.4). The ternary diagrams do not feature major changes, reflecting the same stability as in the previous year.
Year 2007 is further characterized by a sustained process started in 2006, the credit to the population blows up to more than twice the value recorded 3 years ago (27.6 vs. 13), supported by the central bank policy of continuous reduction in min. reserve requirements. Although the government credit begins to grow, the level is still low.

The ternary diagrams signal these processes by changing the shape/pattern of the area with the most intense activity. The causes of the diagram shape changes are:

a) Claims on households indicator becomes twice over a period of three years;

b) The phenomenon intensity

**Observation 4.** If in previous years there was a single area of intense activity (red - Claims on central bank and credit institutions) ternary diagrams now present two areas (foci). The emergence of the second focus of intense activity signals the appearance of turbulent situations.

**Observation 5:** The ternary diagram changing moment does not coincide with any maximum or minimum moment of any indicator

**Observation 6:** Year 2007 is the year of onset of the crisis according to the rationale and research presented in this paper.

Year 2008 is characterized by an acute crisis started in the previous year. This is the first year when the value of the Claims on households indicator exceeds the Claims on central bank and credit institutions indicator (29.2 to 23.8). The crisis hit in late 2008 and early 2009 is the result of the combined action of the two indicators of cyclical development in the period 2005-2008, Claims on households and Claims on central bank and credit institutions.

**Rationale:** The indicator of bank assets is a homogeneous structure, where the sum of increases and decreases in the values of the constituent indicators is null. In other words, excessive growth of the indicator Claims on households could not take place if other indicators would have not dropped. But as indicator Claims on government sector increased in the period 2006-2008, it logically results that the indicator that had fallen continuously to allow growth of the indicator Claims on households was the Claims on central bank and credit institutions indicator.
Observation 7 - Note that although the weight of indicator **Claims on households** grew up to December 2008, reaching the maximum, the diagram shape has not changed. Reading table on the dynamics of the population claims/debt could indicate that year 2008 was at the peak of the indicator but could not say that slippage occurred in 2007, when banks, in search of high returns, were definitely in favor of the credits to the population.

Observation 8. Although in 2008 banks have reported the highest profits, their costs will be seen in later years when the rate of credit risk has increased exponentially as seen in the table below.

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit risk rate</td>
<td>2.9</td>
<td>2.6</td>
<td>2.8</td>
<td>4.0</td>
<td>5.95</td>
<td>13.53</td>
<td>18.36</td>
</tr>
</tbody>
</table>


Figure 5. The 2D and 3D ternary diagrams for the structure of assets in the credit institutions operating in Romania-values achieved in 2009

Year 2009 represents for the Romanian banking system a turning point, the shift in lending policy towards low risk assets (eg bonds), due to the depreciation of the quality of loan portfolios. As regards the dynamics of structure indicators for bank assets, two phenomena can be noticed:

a) strong growth of the **Claims on government sector** indicator (from 5% to 12.7%);

b) breaking the tandem consisting of the two cyclical evolution indicators **Claims on households** and **Claims on the central bank and credit institutions**, as in 2009 they became pro-cyclical (both have decreased). This could be the end of an unfortunate evolutionary cycle.

Ternary diagrams do not reflect anything other than the disappearance of mechanism consists of two outbreaks of intense activity and countercyclical, spread over several years and an outbreak of intense activity in the area of indicator **claims on government**. The images of diagrams presents a good situation in terms of banking assets structure (similar to image of diagram for 2005). Changing the asset portfolio (eg purchase of government securities/bonds) at the expense of lending the segment of the highest risk level (population) is an important step to restore the normal banking system [5]. The most important risk, however, could be the excessive growth of the government sector lending.

Observation 9 Although the effect of the combined action of the two anticyclical indicators **Claims on households** and **Claims on the central bank and credit institutions** ceased, there is danger of formation of new tandems. Possible pairs could be:

a) **Claims on credit institutions and central bank** and **Claims on government** (the first drops, the second increases) - unlikely to be achieved as the first indicator could decrease but not much. Secondly, their share of the total assets is currently about 31% (far from the sum of the first tandem, 40 16.4 = 56.4 in 2005), although not important enough, as a share in total bank assets.

b) **Claims on government** and **Claims on households** (the first increase and the second falls) - unlikely to be achieved even if their share in total assets is significant at this time (approximately 42%). Although the first indicator could increase and the second could decrease even more, the decrease of the second will be a slow, low intensity process, the loans to the population being due in a long term. Last but not least, both population and government need money, and the natural tendency would be that both indicators grow, the decreasing in lending to the population being the result of tougher lending conditions rather than a lower demand.
5. Conclusions
The crisis hit in late 2008 and early 2009 is the result of combined action of the two indicators of anticyclical development in the period 2005-2008. **Claims on households** and **Claims on central bank and credit institutions**.

Year 2009 represents for the Romanian banking system a turning point, a shift in the lending policy towards lower risk assets (eg bonds), because of the depreciation of the loan portfolios quality.

The occurrence of a tandem-type mechanism consisting of two significant bank indicators (share in total assets of at least 50%), with activity of close intensity and cyclical, spread over several years, is a potential source of turbulence in the banking sector.

Ternary diagrams for 2009 reflect the disappearance of the mechanism consisting of two intense activity and cyclical outbreaks, spread over several years, and an outbreak of intense activity in the indicator **Claims on government asset** Changing the asset portfolio (eg purchase of securities states/bonds) at the expense of lending to the segment with the highest risk level (population) is an important step to restore the normal banking system.

The greatest danger for the banking sector might be even stop the lending (their object of work). Government sector lending is a positive thing for the quality portfolio of assets of credit institutions; A possible solution for the recovery of banking activity might be shift to companies (those that generate added value) and not the population (those who consume resources).

The most important risk for the banking system might be the excessive growth of government sector lending. Plotting ternary diagrams for the assets of the credit institutions enables anticipation (prediction) of the time of a major event, such as the financial crisis which started in 2007.

**Future research directions** will pursue a predictive mathematical model for the dynamics of the structural indicators of the bank assets and carrying out simulations using predictive values, and finally, by comparing the results obtained from the database to find answers to these questions:

When will the Romanian banking system reach a situation of equilibrium?
On which indicator should one intervene with measures of adjustment or stabilizing policies?

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