

Obaeva, Alma; Zaitsev, Vladimir

**Conference Paper**

## Dynamic analysis and program formalization of regional banks activity in catastrophe theory conception

41st Congress of the European Regional Science Association: "European Regional Development Issues in the New Millennium and their Impact on Economic Policy", 29 August - 1 September 2001, Zagreb, Croatia

**Provided in Cooperation with:**

European Regional Science Association (ERSA)

*Suggested Citation:* Obaeva, Alma; Zaitsev, Vladimir (2001) : Dynamic analysis and program formalization of regional banks activity in catastrophe theory conception, 41st Congress of the European Regional Science Association: "European Regional Development Issues in the New Millennium and their Impact on Economic Policy", 29 August - 1 September 2001, Zagreb, Croatia, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

<https://hdl.handle.net/10419/115193>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

**Dynamic analysis and program formalization of regional banks activity in catastrophe theory conception.**

**Vladimir V. Zaitsev, Alma S. Obaeva**

Ivanovo State University of Chemistry and Technology,  
Institution of Management, Finance and Informational Systems  
Sacco 3-60, Ivanovo, 153000, Russia  
E-mail: [zaitsev@com.ivanovo.ru](mailto:zaitsev@com.ivanovo.ru)

**ABSTRACT** Present researches in the framework of catastrophe theory aimed to describe in formalized form the dynamics of regional banks activity in transitive economics. For this purpose the system of differential equations was algorithmically solved and the decision with approximation error in 9.4% gives reliable description of the real statistics of banks activity. Certain managing parameters, establishing the dynamics of money input components interaction and output producing in banks activity were defined and theoretical approach to functional dependencies finding of above mentioned parameters was made. The integral activity curve of the bank was build and it showed the exact time  $T_x$  of bifurcation appearance, bringing about the misbalance in banks production with consequence in banks catastrophe. It was found that since the bank integral activity curve had fallen below the zero the bank experienced the "fold" bifurcation, assuming the catastrophe( bankruptcy) and this situation couldn't be diagnosed in time by means of traditional methods of bank analysis. The ways of planning and crisis management in regional politics conception were offered by varying of initial banks inputs and managing parameters.

**Keywords:** Regional banks; Integral and differential program formalization; stable dynamics.

## 1. INTRODUCTION

Development of Russian economics in post-crisis period characterized by deep economic problems in industrial sector of the regions opens a subject that significant consideration should be given to the strategy of financial resources management and their distribution by means of regional financial flows (Pavlenko, a.o., 1999). Thus particular interest of regional authorities concerns the stable and effective activity of regional banks establishing mutual relations with industrial customers in parameters of costs and incomes.

It is a well-known fact that in the frameworks of modern financial intermediary theory strategic approach for financial organizations management is based on the principles of flexible inside-firm planning. That means rejecting the rigid administrating of risks in the temporal distribution of money flows in the banks creating value added. Usually to select an effective strategy the methods DFA, SFA, DEA (Dietsch, a.o., 2000) are used when we have to agree with so-called stationary assumption. Thus the effectiveness is the politics of effective costs found as statistical evaluation of each cost component or factor contribution into production of banks product. Above mentioned methods being statical in their nature allow neither to formalize precisely the production process in the bank nor to come nearer to market-oriented principles of supervision in order to make profits and reduce the probability of production catastrophes.

In the articles (Zaitsev 1999a, Zaitsev 1999b) the method was proposed for financial flows' management which can be named as putting in order the information about financial flows hereafter in the form of the system of differential equations. The method presents numerical economic experiment using the added value method (Berger, a.o., 1992) and program formalization of bifurcation theory equations (Arnold, 1990). Where usually the bounds of stability are considered in catastrophe theory with equations

$$dy_i / dt = f_i(y_k, c), \quad (1)$$

where -  $y_{i,k}$  - parameters, describing system conditions,  $c$  - managing parameters.

The base models for equations (1) describing changes of resources: goods, money etc., can be equations of kinetic type (Lisichkin, a.o., 1997). So, for speed of change of resources  $Y$  in the time, it is possible to write down differential equations in usual derivatives as following:

$$dy / dt = \sum_i Q_i - \sum_j \beta_j N_j \quad (2)$$

where  $\sum_i Q_i$  - resources resumption;  $\sum_j \beta_j N_j$  - resources consumption.

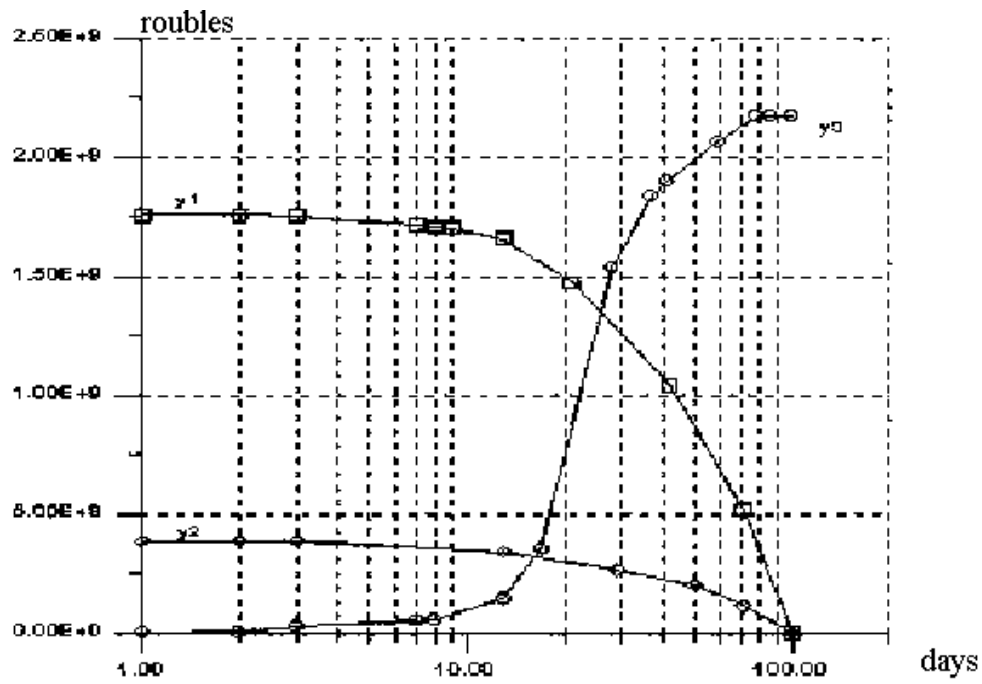
Computer formalization allows to bring the number of variables  $y_i$ , defining cost components, to dozens as well as the same can be made with managing parameters  $c$  (Zaitsev, 2000).

The aims of present researches were the following: (1) to formalize the dynamics of regional bank's activity, comparing the modeled results with real statistical data; (2) to estimate differentially the intensity of interaction between money inputs' components by means of invariant unique significances of managing parameters in banks production cycle; (3) to create the annual "integral activity curve" and analyze it in the catastrophe theory framework; (4) to consider the possibility of crisis management in the regional banking by varying initial inputs and managing parameters to make bank dynamics stable.

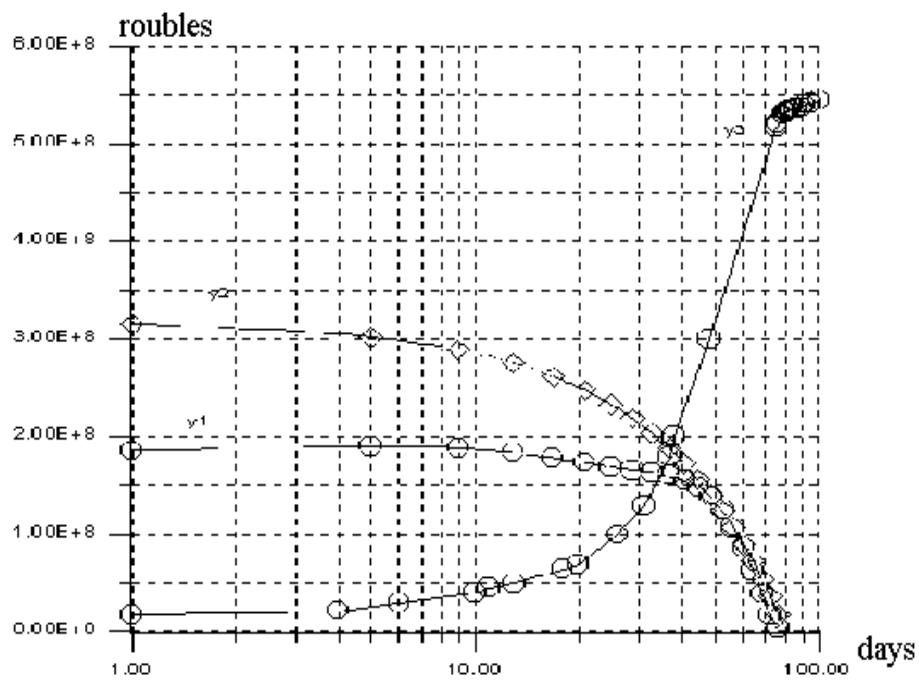
## **2. DIFFERENTIAL DYNAMIC PROGRAM FORAMLIZATION OF REGIONAL BANK ACTIVITY.**

In present researches the case of regional bank's activity from homogenous sample of 52 banks from Central region is considered. The banks have been producing mainly crediting services and experienced in 1996-97 the catastrophe, some of them although continue working today. Initial information source included the statistical data of everyday balance-sheets. Data of bank inputs(operational costs and costs for wages) and outputs( total incomes) were processed by the sliding average and polynomial fitting in order to obtain the main tendency (Shmoilova,2000). The example of typical bank production dynamics in the sample of 52 regional banks in 1996-97 is shown in Figures 1-2.

In all figures at the beginning of each quarter total incomes equal zero. Operational costs and costs on wages were taken in the volume how they would have appeared at the end of each quarter. Thus, everyday balance-sheets were showing the speed of their consumption. The character of curves' behavior in Fig. 1-2 agrees with dynamics of growth of the sizes of compulsory reserves of financial organisations (Kugaev, 2000) in conditions of their relative stabilization.



**Figure 1.** Dynamics of incomes and costs in the bank in the 1st quarter, 1996 (roubles.):  $y_1$ - operational costs;  $y_2$ - costs on wages;  $y_3$ - total incomes.



**Figure 2.** Dynamics of incomes and costs in the bank in the 1st quarter, 1997 (roubles.):  $y_1$ - operational costs;  $y_2$ - costs on wages;  $y_3$ - total incomes.

For model description of the results of regional bank activity (see Fig. 1-2) the equations (Zaitsev, 1999 a) are written down in the form of production system (3).

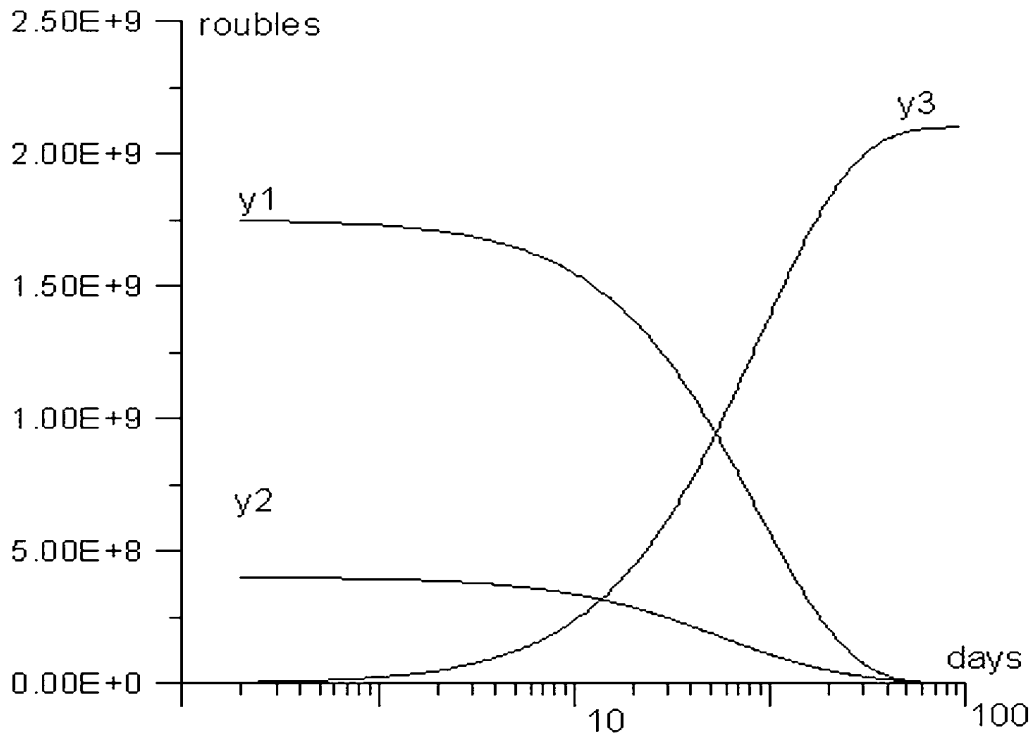
$$\left\{ \begin{array}{l} y_1 \xrightarrow{k_1} y_3 \\ y_2 \xrightarrow{k_2} y_3 \\ y_1 + y_2 \xrightarrow{k_3} y_3 \\ y_3 \xrightarrow{k_4} y_1 + y_2 \end{array} \right. \quad (3),$$

where:  $y_1, y_2, y_3$  - operational costs, costs on wages and incomes accordingly;  $k_1$  and  $k_2$  - correlation coefficients;  $k_3$  and  $k_4$  - restriction coefficients.

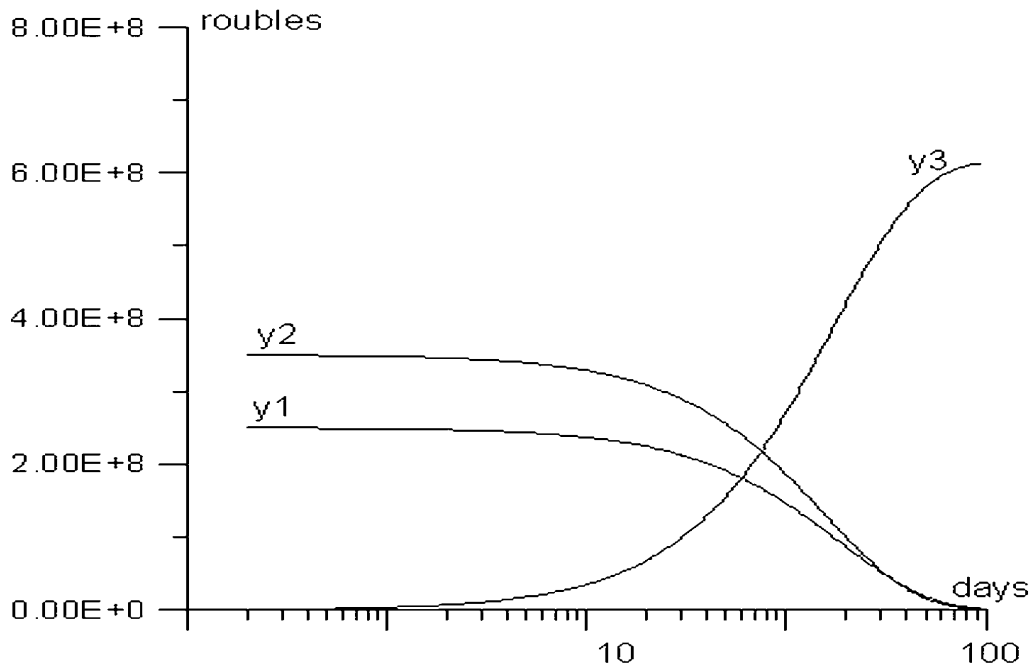
For decision of the problem by (3) the system of differential equations in the form of functions is written down:

$$\left\{ \begin{array}{l} f_1 = \frac{dy_1}{dt} = -k_1 \times y_1 - k_3 \times y_1 \times y_2 + k_4 \times y_1 \times y_2 \\ f_2 = \frac{dy_2}{dt} = -k_1 \times y_2 - k_3 \times y_1 \times y_2 + k_4 \times y_1 \times y_2 \\ f_3 = \frac{dy_3}{dt} = k_1 \times y_1 + k_2 \times y_2 + k_3 \times y_1 \times y_2 - k_4 \times y_1 \times y_2 \end{array} \right. \quad (4)$$

Unlike reproduction system of enterprises-banks clients (Zaitsev, 1999a) in system (3) two new equations with correlation coefficients  $k_1$  and  $k_2$  are brought in, because it is impossible to define certainly the order of enterprise-client's costs inclusion into reproduction of bank capital. Nevertheless the formation of incomes is a result of interaction between different combinations of inputs (cost units) (Schumpeter, 1934). Besides, reproduction equation inherent to specific character of banking is written down with restrictive coefficients  $k_3$  and  $k_4$ , specifying by the ratio  $k_3/k_4$  the restriction on spending of the advanced costs. Thus the ratio means a bias of equilibrium towards the inputs or outputs in the production system (3).



**Figure 3.** The decision of system of differential equations (3) at significances of managing parameters:  $y_{10}=1.75 \cdot 10^9$ ,  $y_{20}=3.9 \cdot 10^8$ ,  $y_{30}=0$ ;  $k_1=9.4 \cdot 10^{-2}$ ,  $k_2=5.6 \cdot 10^{-2}$ ,  $k_3=7.2 \cdot 10^{-11}$ ,  $k_4=9 \cdot 10^{-11}$ ; variables  $y_1, y_2, y_3$  - operational costs, costs on wages, total incomes in roubles.;  $t$ - time, days.



**Figure 4.** The decision of system of differential equations (3) at significances of managing parameters:  $y_{10}=2.5 \cdot 10^8$ ,  $y_{20}=359 \cdot 10^8$ ,  $y_{30}=0$ ;  $k_1=5.1 \cdot 10^{-2}$ ,  $k_2=6.1 \cdot 10^{-2}$ ,  $k_3=1.1 \cdot 10^{-11}$ ,  $k_4=1.33 \cdot 10^{-11}$ ; variables  $y_1, y_2, y_3$  - operational costs, costs on wages, total incomes in roubles.;  $t$ - time, days.

In Figures 3-4 the results of the decision of the program formalized system of differential equations (4) are presented. During decision the program algorithm for Euler's circuit by Newton's method (Kuboniva, 1991) was being used.

Absolute values of variables  $y_1, y_2, y_3$  and their dependencies on the time are repeating with sufficient reliability real statistical data in Figures 1-2 with correlation coefficient  $R^2=0,99$  and mean approximation error  $\bar{\varepsilon} = \frac{1}{n} \sum \frac{|y_{\text{fig.1-2}} - y_{\text{fig.3-4}}|}{y_{\text{fig.1-2}}} = 9,4\%$  which matches admissible interval of models' adequacy in 12-15% (Shmoilova, a.o. 2000).

The consent of offered model results (Figures 3-4) with real statistical data of regional bank's activity (Figures 1-2) confirms the reliability of the model and the possibility to use it for putting in order the information about regional financial organizations' activity.

In the model (3,4) we can find confirmation of the Leontief-based (Leontief, 1986) approaches about uniformity and interaction of dynamic production cycles in creation and realization of cost by the enterprises of various branches of economy. The enterprises of traditional industries, agriculture and trade in our case interact with regional financial intermediary. Besides, regional commercial bank with classical structure of activity and functions of means saving on accounts, crediting and cash service, is executing own reproduction cycle, produces and sells bank services, provides wages and employment, redistributes profits. For example, credit as one of the bank services, becomes the initial element of the costs of enterprise in "input-output" system, replacing its own means, and again created cost of the enterprises, deposited on bank's current account becomes the base element of the costs of the bank. This circumstances are responsible for banks' activity dynamics.

However, balance methods and linear models as their consequence do not permit to reproduce the real activity of regional commercial bank as good as the model (3,4) does (see Fig. 3-4). The uniformity of received laws for enterprises in the articles (Zaitsev 1999a; Zaitsev 1999b) and in present researches (Figures 3-4) characterizes normal situation of production, i.e. real economic interaction of the financial intermediary and enterprises-clients in Russian Federation.

The decision of the system (4) assumed the definition of the coefficients  $k_1, k_2, k_3, k_4$ , from deciding of simple algebraic system (4) for particular significances of first derivatives on sectors of time  $t$  in days and acceptance of appropriate significances  $y_1,$



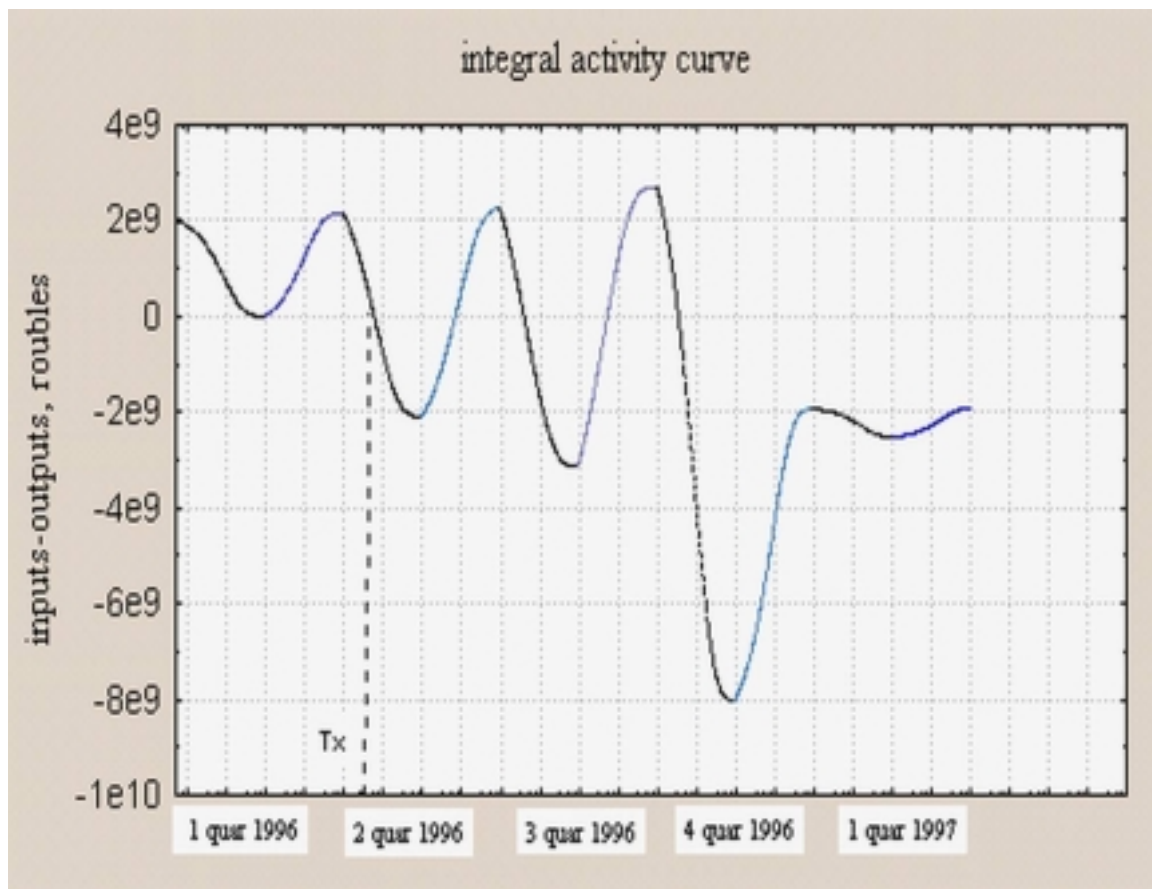
$y_2, y_3$  (Figures. 1-2). In particular, for time  $t=5$ ,  $y_2=3.25 * 10^8$ ,  $y_1=1.67 * 10^9$ ,  $y_3=7 * 10^7$  (Figure 1) graphic differentiation and simple decision of system (4) as system of three equations with three unknown gives the following significances:  $k_1=9.4 * 10^{-2}$ ,  $k_2=5.6 * 10^{-2}$ ,  $k_3=7.2 * 10^{-11}$ . Thus, three variables  $k_1, k_2, k_3$ , have been calculated and  $k_4$  was found from restriction  $k_3/k_4=0.8$ . Restriction means that equilibrium in the system moves towards the returns in proportion 0,8 to 1. Managing parameters over the 1st quarter 1997 have been found by use of the same procedure.

Model (3,4) permits to come through factors  $k_i, a, b, c$ , (which could be added to the model (3-4) to specify the ratio of the costs combinations) to significances of parameters determining the structure of regional bank's activity. Considering interaction of initial cost units on the entrance of the system of a bank, the proposed model solves rather old economic dynamics problem which was pointed by Schumpeter, it is the describing of growth, created by new combinations of factors being spent with certain speed and intensity. Each new interaction is unique in this moment of time due to economic conditions. Though if  $a, b, c$  etc., by analogy to Leontief's matrixes (Leontief, 1986) could be set from economic essence of considered objects, the factors  $k_1, k_2$  and  $k_i$  can be defined by deciding the system of algebraic equations (as it was showed above). Nevertheless, for particular economic situations the managing parameters  $k_i$  are possible to present in the form of simple exponential (Tsarkov, 2000) or combined analytical dependencies  $k_i = A_i(M) * \exp(-m/M)$ , where  $M$  is fixed capital,  $m$ - current periodic financing which can act as stabilizing monetary factor.

There are two situations, when  $m/M \ll 1$ , and  $\exp$  according to known rule  $e^x = 1 + (m/M)/1! + (m/M)^2/2! + \dots \approx 1$  and empirical function  $A_i(M)$  will be the managing parameter in system of differential equations. In all other cases the managing parameters  $k_i$  will be found as combination of empirical functions  $A_i(M)$  and exponents determined by the relation of current periodic financing and base financing. The dimensions of  $k_i$  will be defined by number of multipliers - variables  $y$  in the base system of equations (3) and this dimension should be incorporated in empirical functions  $A_i(M)$ . The values for  $k_{1-4}$  that have been obtained in this experiment from statistics are to be of complex functional nature and to be found as functions of bank's money funds ratios.

### 3. INTEGRAL DESCRIPTION OF PRODUCTION CYCLE DYNAMICS OF REGIONAL BANK AND CATASTROPHE DIAGNOSTICS.

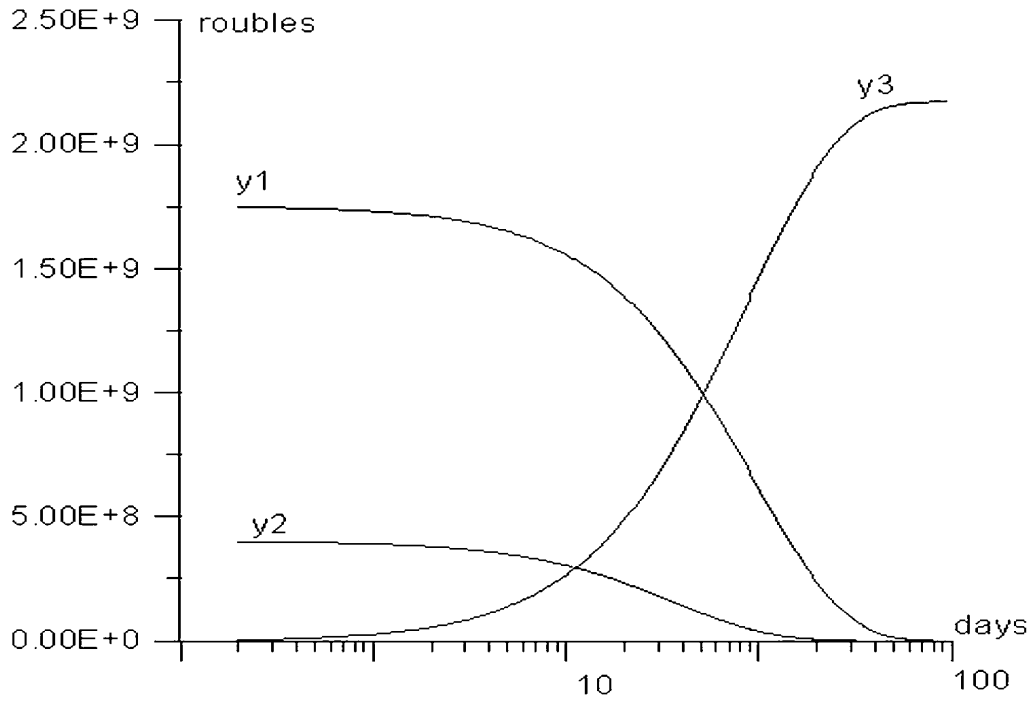
It may be said that the character of interaction that has been received agrees with economic cycles theory (Kondratiev, 1991) outgoing from repeatability of cycles of economic conjuncture, however, with new significances of managing parameters specifying the condition of economic system at new stages of development. The modeled situations shown in Figures 3-4 represent the decomposition of initial costs, having decided the question of effective ratio, i.e. the situation when the combination brings active balance of inputs and outputs. Nevertheless the decomposition itself seems to be out of the context of continuous bank dynamics, because could not be answered why, for example, the volume of inputs in 1997 has fallen though the production seems effective (Figure 3-4). New production cycle supposes and deep changes of managing parameters that may result in business catastrophe. In order to define the reasons, why the initial costs have fallen at the beginning of 1997, the integral activity curve was created by adding up the curves which were calculated, using the procedure of paragraph 2.



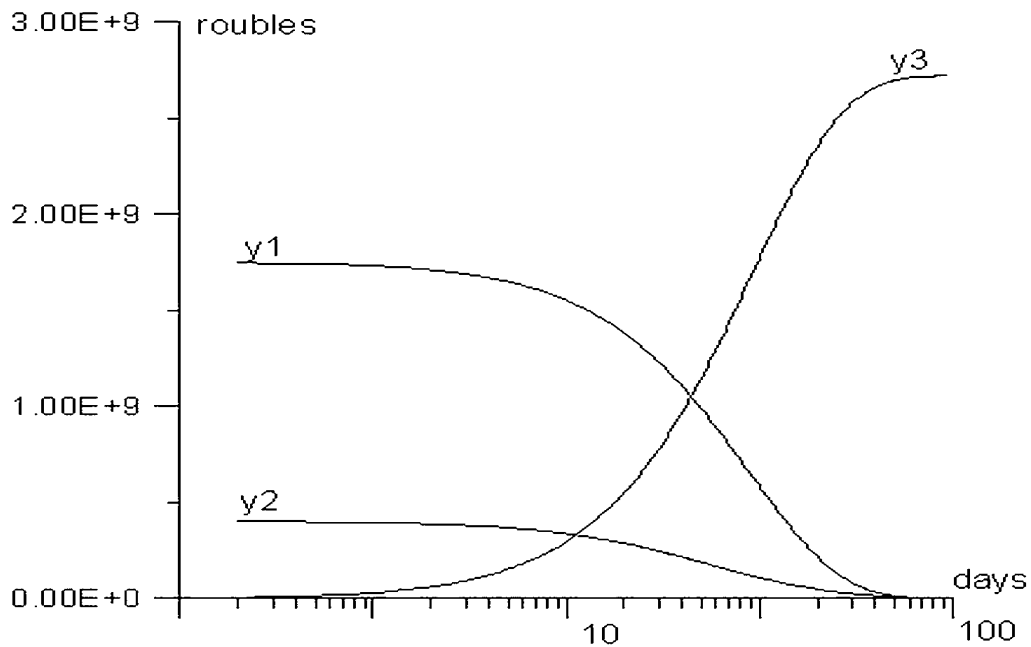
**Figure 5.** Integral activity curve of the regional bank in 1996-1997.

First quarter in 1996 was taken as a starting-point when initial expenditures were made and the total incomes would have been received at the end of the quarter (peculiarity of accounting in Russian Federation). Following cycles are being corrected by the inflation rate of 46 % per year<sup>1</sup>. Effective dynamics of banks' production is to be theoretically characterized by the mounting "wave" as a result influence of both financial and technological effects (Berger, a.o., 2000). However, as it can be seen in Figure 5, the misbalance appeared in bank activity, having its expression in increasing amplitude of interaction between inputs and outputs, which is free from external macroeconomic factors (inflation, taxation, etc.). That means riskness or in mathematical terms "fold" bifurcation (Arnold, 1991) has begun which is of internal, managerial nature. The necessity of overcoming the negative zone (see Figure 5) at each new stage (second, third...quarters) has begun at the point  $T_x$  and the bank eventually stands before the disability to restore the costs made in advance. Taking into consideration similar features of all regional banks in Central region of Russian Federation (there have been observed 52 banks, 30 of them were closed, having experienced the same bifurcation) where own funds can't cover all risks and refinancing is impossible, the described situation had ended in the work with negative capital and as a consequence for them in bankruptcy. Such outcome could not be seen by carrying out traditional analysis. Well-known integral methods (Lvov, a.o., 1996, Proscurin, 1997) were estimating the bank's state as positive for 8 months. Thus, bank's management has lost time since the  $T_x$  point for overcoming the crisis that had already begun.

The analysis of possible decisions to be taken for crisis management in regional banking politics includes, first of all, non-admission of misbalance in production cycle of a bank by control of effective costs in the past and planning. The last betokens the varying of scenarios by changing managing parameters to make dynamics stable as it is shown in Figures 6-7. Secondly, and it is the most frequent case, the correction of the situation that has been happened takes place (see Figure 5). Obviously, the first one is optimal, because it excludes the appearance of the bifurcations leading to the business catastrophe by accumulating the unfavorable conditions. In Figures 6-7 one can see variants of change the integral curve's behavior by varying managing parameters responsible for volume and speed of resources consumption in the form of costs and as well gaining the incomes.



**Figure 6.** The decision of system of differential equations (4) with increase of consumption speed of money funds for wages at significances of managing parameters:  $y_{10}=1.75*10^9$ ,  $y_{20}=3.9*10^8$ ,  $y_{30}=0$ ;  $k_1=9.4*10^{-2}$ ,  $k_2=15.8*10^{-2}$ ,  $k_3=7.2*10^{-11}$ ,  $k_4=9*10^{-11}$ ; variables  $y_1, y_2, y_3$  - operating costs, costs for wages, total incomes in roubles.;  $t$ - time, days.



**Figure 7.** The decision of system of differential equations (4) with increase of investments efficiency on 50% at significances of managing parameters:  $y_{10}=1.75*10^9$ ,  $y_{20}=3.9*10^8$ ,  $y_{30}=0$ ;  $k_1=9.4*10^{-2}$ ,  $k_2=5.6*10^{-2}$ ,  $k_3=7.2*10^{-11}$ ,  $k_4=9*10^{-11}$ ; variables  $y_1, y_2, y_3$  - operating costs, costs for wages, total incomes in roubles.;  $t$ - time, days.

The situation in Figure 6 describes modeled in future activity of regional commercial bank with the change managing parameters consisting in increase of consumption speed of money fund on wages in 3 times which results in premature exhaustion of the corresponding fund, brings the reducing in efficiency and the high probability of the bifurcation appearance.

Modeled situation in Figure 7 describes the increase of the effect of means invested into assets. It may be an alternative source of profits (other asset) having been found that is being reflected in the increase in 2 times of the coefficient at the first member of the third equation in system (4). Thus, efficiency of resources' investments of the bank in active operations (for example, crediting) is seen in curve's ( $y_3$ ) growth at the end of the quarter.

The answer to the question about stable dynamics in regional banking raised in (Zaitsev, 2000b) may be considered as not to allow the negative circumstances affecting managing parameters to move situation from bifurcation point into business catastrophe/ Thus the necessary steps should be undertaken. These corrections, managerial in their nature, will appear as new significances of managing parameters in the model (3-4), as well as through the managing parameters, since they can be found as functional dependencies of bank money funds, it will be transparent what managerial steps for stability in banking are to be made.

#### 4. CONCLUSION

The investigations resulted in the basic conclusions: 1. The system of differential equations was algorithmically solved. The decision with approximation error in 9.4% gives the reliable description of the real statistics of banks activity. 2. The managing parameters establishing the dynamics of interaction between the money input components producing outputs in banks' activity were defined. The theoretical approach to functional dependencies of finding of above mentioned parameters was made. 3. In the framework of catastrophe theory the integral activity curve of the bank was created which showed the exact time  $T_x$  of bifurcation appearance, bringing the misbalance in the bank's production with consequence in banks catastrophe. 4. It was shown that as soon as the bank integral activity curve had fallen below the zero the bank experienced the "fold" bifurcation entailing the catastrophe( bankruptcy) and this situation couldn't be diagnosed in time by means of traditional methods of bank analysis. 5. The ways to

make regional banking dynamics stable were considered in the banks' crisis management by varying of initial inputs and managing parameters.

## REFERENCES.

1. Arnold, V.N., 1990, Teorija katastrof (Nauka, Moscow).
2. Belykh, V., 1998, Elementary introduction to the qualitative theory and theory of bifurcations of the dynamical systems, Soros Educational Journal, 1, 115-122.
3. Berger, A.N., Humphrey, D.B., 1992, Measurement and efficiency issues in commercial banking. In: Griliches, Z. (Ed.), Output Measurement in the Service Sectors. The University of Chicago. ( Press, Chicago).
4. Berger Allen N., Bonime Seth D., Covitz Daniel M., Hancock Diana, 2000, Why are bank profits so persistent? The role of product market competition, informational opacity, and regional/macroeconomic shocks, Journal of Banking and Finance 24, 1203-1235.
5. Dietsch, Michel, Lozano-Vivas, Ana, 2000, How the environment determines banking efficiency: A comparison between French and Spanish industries, Journal of Banking And Finance, 24, 985-1004.
6. Kugaev, S.V., Kaltirin, A.V., 2000, Inconsistent character of functioning of regional bank system, Business and banks, 10, 1-2.
7. Kondratiev, N., 1991 The basic problems of economic statics and dynamics ( preliminary version) (Nauka, Moscow).
8. Leontief, W., 1986, Input-output economics( Oxford Univ. Press, Inc).
9. Pavlenko, F., Novitskiy, V. (1999) Tendencies of structural changes in industrial policy in CIS countries, Questions of Economy, 1, 105-124.
10. Tsarkov, V.A, 2000, Modeling of bank economic dynamics, Journal Bankovskoe delo 6, 25-30.
11. Kuboniva, M., 1991, Mathematical economy on PC (Finansi i statistika, Moscow).
12. Lisichkin, V.A., Shelepin L.A., a.o., 1997, Zakat civilizacii ili dvijenie k noocfere( IC-Garant, Moscow).
13. Lvov, V.S., Ivanov, V.V, 1996, Financial analysis in commercial banks: descriptive model ( Jahtsmen, Moscow).
14. Proscurin, A.M., 1997, Bankovskiy reiting doljen polnee otrajat ego sostjanie, Journal Bankovskoe delo 11, 18-22.
15. Shmoilova, R.A., 2000, Theory of statistics( Finansi i statastika, Moscow ).

16. Schumpeter, J., 1934, The Theory of Economic Development. Translated by Redvers Opie (Harvard University Press, Cambridge, MA).
17. Zaitsev, V.V., 1999a, Elements of economic kinetics, Problems of regional economy study 2, 203-206.
18. Zaitsev, V.V., 1999b, K voprosy o modelirovanii finansovogo polosenija regionov v usloviyakh chastichnoy liberalisacii ekonomiki. Problems of regional economy studies 2, 207-210.
19. Zaitsev, V.V., 2000a, Informational systems and numerical economic experiment over management by financial flows in quantitative theory of money. Proceedings of the 6-th international conference 'High technology in Russian industry' ( Central Research Technological Institute, Moscow), 227-230.
20. Zaitsev, V.V., 2000b, Control, Diagnostics, Ordering Of Information About Regional Banks Activity And Planning In The Form Of The System Of Differential Equations, Paper presented at 40<sup>th</sup> European Regional Science Association Conference, 29 August-1 September, Barcelona, Spain.