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ENTERPRISE SUSTAINABILITY FORECASTING IN THE CONTEXT OF ECONOMIC SECURITY MANAGEMENT

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Abstract. A model of stability of the equilibrium of the enterprise in the context of ensuring economic security is proposed, which allows predicting the nature of the particular point of equilibrium of the enterprise and the type of attractor. The model has been tested at the VOLKSWAGEN plant (Wroclaw, Poland) and it has been revealed that after 3 years the saddle-focus of the first kind, which is an unstable equilibrium, will be a singular equilibrium point. Therefore, structural changes at the plant should be expected. However, this is not a bad condition for the enterprise, it only indicates the upcoming choice between the opposite trajectories of its development. Therefore, it is imperative to develop in advance measures to manage the economic security of the enterprise on the basis of changing management parameters, namely: increasing the profitability of the assets of the enterprise, finding a loan with a lower percentage and reducing the share of expenses of the company per employee, the joint implementation of which will help the company in the future to fall into the field of sustainable limit attractor and avoid the chaotic attractor, that is, bankruptcy. The author has developed an information base for calculating the model in accordance with financial statements with a view to its application in the practical activities of enterprises. The model results are presented visually in the form of phase portraits based on the use of the Maple package.

Keywords: safety; enterprise sustainability; phase portrait; development trajectories; attractor

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JEL Classifications: F35; F42

1. Introduction

The strategic European integration course of Ukraine before joining the European community requires the protection of national interests of the country. From the content of Art. 17 of the 1996 Constitution of Ukraine: ensuring economic security is one of the most important functions of the state (Constitution of Ukraine, 1996). The activities of state bodies to protect the economic interests and economic security of the country are an integral part of ensuring national security. The emergence of external threats to the national security of the state requires not only rapid response, but also existence of effective mechanisms to counteract the possible causes of these phenomena of negative consequences.

Protection requires the vital values and interests of both societies in particular and the state on the whole. In this context, an important area is to ensure the customs security of the state, which provides the protection of society from prohibited, dangerous and substandard products, formation of the adequate level of competitiveness of the country in the world market, promotion of investment attractiveness of Ukraine and its regions, protection of interests of business entities, etc. The implementation of customs security functions rests with the relevant state structures - customs authorities. Based on the above, it is relevant to study the concept of customs security, legal status and features of the functioning of customs authorities in the context of ensuring national security of the country.

2. Literature Survey

Today, the security problem causes a wide response and the reason for its appearance is very transparent - the growth of threats to humanity and their multi-vector nature. Among the modern threats, the following ones can be distinguished (Stewart, A. (2018)): destabilization of the system of international economic relations, a high degree of uncertainty in the actions of participants in the economic space, disintegration trends, the escalation of international tension, the permanent emergence of global and local crises, limited world resources, and their high cost.

Recently, state security, enterprise security, and personal security are not considered separately - they are interconnected and interdependent (Behei, M. (2017), Plėta, T. et al. (2020)). If any objective or subjective reason (for example, war) poses a threat to national security, then it poses a threat to both the enterprise and the individual (Hilorme, T., et al. (2019)). All this determines the relevance of studying world experience in solving the complex problems of ensuring the economic security of any business entity and its institutionalization (the historical process of transition from a phenomenon, which is self- self-managed and self-organized to managed and organized) (Adekanye, MO, & Rahman, SS (2018)). Thus, international institutions manage global economic security and generate international economic law, which is an important means of supporting it, and state institutions manage national economic security and are the main repeaters of the norms and laws that ensure it (Drobyazko, S., et al. (2019), Drobyazko, S., et al. (2020)). An enterprise should have a certain information and management structure that would neutralize the negative variety of environmental influences (Bernus, P., et al. (2016)). Neutralization may consist in the fact that the structure blocks external threats, or hides from them in areas safe for itself, or launches futurization (proactive) measures of its self-preservation (Ştefănescu, C., Comănescu, LE, Buhuşi, C., & Bilcan, GA (2019)). In turn, an enterprise as an open system can use a wide variety of environmental resources and safety strategies depending on its internal information content (Lai, F. W., & Shad, M. K. (2017)). Therefore, the solution to this conceptual question must be sought in the integration of the dialectical contradictions of self-organization and management (Wu, G., & Wang, J. (2020)). Self-organization differs from management in that its essence is explained by the nature of the system, which, by itself, spontaneously finds a certain spatial, temporal, or functional structure without additional impact from the outside (this is a property of all open systems) (Sulphey, MM, & Alkahtani, N. (2017)).The management is a phenomenon of only human rational systems (this property of socio-technical systems) (Tetiana, H., et al. (2019)). On the one hand, management limits the diversity of the state of the enterprise, and on the other hand, accelerates its development and achievement of goals. The economic security of an enterprise as a complex system consists of two elements: managed and managed systems (Harrer, J., & Wald, A. (2016)). The management system belongs to the management of the enterprise, including the head of the security service, in the managed system in the context of this study we understand the economic security of the enterprise as its business process. Feedback can be both positive and negative. Thus, with positive feedback, the management system converts the deviations of the output parameter of the signal (fluctuation) into a management solution and transmits it to the input of the managed system in order to increase this deviation (Kang, Y. (2016 May)). It can be said that positive feedback "accelerates" the deviations of the output parameter.

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However, the action of positive feedback can have side effects (Hong, J., Zhang, Y., & Ding, M. (2018)):
1) the appearance of the hysteresis loop, which is characterized by the phenomenon of "saturation";
2) the emergence of a "vicious circle", which leads to undesirable results. Positive feedback destabilizes the system, disturbs its state of stable equilibrium, which can lead to an increase in the efficiency of the system and to its destruction.

In the case of negative feedback, the deviation of the output parameter signal (fluctuation) is transmitted to the input of the managed system in such a way as to attenuate ("cancel") this deviation (Jiang, B., Muzhikyan, A., Farid, AM, & Youcef-Toumi, K (2017). That is, the negative feedback "keeps" the output parameter unchanged or reduces its negative consequences. Negative feedback stabilizes the system and maintains its stable equilibrium state by adapting to threats and counteracting potential degradation (Soomro, Z. A., Shah, M. H., & Ahmed, J. (2016)). The system can self-regulate if it has a standard for correction and self-improvement on the way to the attractor.

3. Methods

It is possible to distinguish specific methods of research: statistical methods - to study the state and dynamics of activity of enterprises; Internet analysis - to evaluate the popularity and relevance of the definition of "economic security of the enterprise"; taxonomic method and fuzzy logic method - to determine the resulting parameter of economic security of the enterprise; iterative analysis - for in-depth study of the structure, functions, processes, and goals of economic security of the enterprise; black box method - to study the connection between the managing system of the enterprise's economic security and the managed one; gold section method - to determine ranges of economic security level; IDEFO functional modeling method - for modeling of the business process taking into account entropy and synergy; nonlinear dynamics methods - to improve the synergistic model of enterprise stability; phase space method - to predict the state of stable equilibrium of an enterprise.

4. Results

In the conditions of increasing turbulence of the external environment, it is important to predict the state of stable equilibrium of the enterprise. Predicting the dynamics of events and owning a scenario of development allows effectively managing the enterprise's economic security, which requires the development of an adequate mathematical model, which would be based on fundamental laws and a priori knowledge of the processes of system functioning, taking into account the causality of factors of influence.

Mathematical modeling of stability of the enterprise provides an opportunity to predict the state of stable equilibrium, which allows developing appropriate measures to manage the enterprise's economic security. Sustainability of production activity of the enterprise is determined by such parameters of the order as: number of highly organized personnel, availability of equity capital, and volume of investments (credit).

The mathematical model of stability of a medium-sized enterprise is presented as a system of three differential equations:

$$\begin{cases} \hat{F}_1 = -bF_1 + aF_2 + aF_2F_3 = f_1(F_1, F_2, F_3) \\ \hat{F}_2 = cF_2 - dF_1 + cF_3 - dF_1F_3 = f_2(F_1, F_2, F_3) \\ \hat{F}_3 = -hF_3 + gF_2 = f_3(F_1, F_2, F_3) \end{cases} \quad (1)$$

where $F_1 = F_1(t)$ - the number of employees of the enterprise at time t, persons;

$F_2 = F_2(t)$ – the amount of equity capital at time t, US dollars;

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$F_3 = F_3(t)$ – the amount of borrowed capital, that is, the loan at time t, US dollars.

$\hat{F}_1, \hat{F}_2, \hat{F}_3$ - derivatives of independent variable t;

a - a proportionality coefficient, which shows how much of the capital an enterprise can allocate to attract new employees;

b - a proportionality coefficient, which summarizes the various reasons why the employee may be fired or he or she will be released;

c - a proportionality coefficient, which shows the efficiency of the enterprise's investment (taking into account the influence of various taxes, payments, fees - they have a dissipative influence on the "energy" of the enterprise and threaten to reduce profitability)

d - a proportionality coefficient, which characterizes the value of the enterprise costs per employee;

g - a proportionality coefficient, which affects the availability of equity capital;

h - a proportionality coefficient, which indicates difficulties in obtaining a loan. For example, a high percentage of credit increases the risk of default, which threatens bankruptcy.

For an average firm, the coefficients *a* and *d* must be relatively large since they both relate to employee costs, and the coefficient *c* and *b*, on the contrary, should not be large because, first (in case of *b*), the firm's profit from operations in the market is not too high, otherwise the firm would be rich rather than average; and secondly (in case of *b*), in a civilized society, the staff turnover is low in an average firm.

In the model F_1, F_2, F_3 - replaceable factors or they are called order parameters in the thesaurus of synergetics; a, b, c, d, g, h are constant factors (proportionality coefficients) or control parameters.

Based on the developed mathematical model of the behavior of the object of management, the possibility of forecasting the state of stable equilibrium of the enterprise appears. There are several types of forecasting that require an understanding of the laws of development:

1) Inertial forecasting or extrapolation lies in the fact that the process continues the trajectory that was before it began, that is, the future parameters of the system are determined on the basis of previous development trends.

2) The design scenario consists in certain probabilities of possible alternatives of development or desired state in the conditions of future turbulent macro environment. The scenarios depend on the resources invested in the future.

3) Management design consists in forecasting the consequences of the decisions made. The researcher does not have information about the inertia of the process but knows an instant "snapshot" of certain parameters that affect the development. The scientific challenge lies in the fact that the knowledge of the instantaneous distribution of parameters of a complex socio-economic system and their connection in the future allows obtaining a predictive temporal reversal of what will happen. Later, this type of forecasting is applied.

As noted above, nonlinear dynamics studies the properties of dynamic systems, which are systems that describe a process in time, namely the transition from a state of stable equilibrium to an unstable equilibrium and vice versa.

The main tasks are: first, the search and classification of a singular equilibrium point, and second, the identification of sets, which attract (attractors) or repel (repellers). To perform a qualitative analysis of the dynamic system, what the enterprise is, the method of phase space is used. It is based on the geometry of time and gives the opportunity to visualize the behavior of the enterprise. The advantages of this method are a significant simplification of the description of the state of the dynamic system.

The phase space of the system is an abstract multidimensional space, in which the change of the coordinates of a point (ie its movement) over time forms curves (phase trajectories) that clearly describe the evolution of a nonlinear, "chaotic" system in a geometric form (phase portrait). The main characteristic of a space is its dimension, that is, the number of order parameters that must be specified to determine the state of the system.

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The phase portrait is a collection of all phase trajectories describing all its possible modes. On this basis, it is possible to determine a particular equilibrium point of the system as a benchmark to which it will come over time.

The singular point of the phase space is the equilibrium point at which the process is established and the order parameters do not change, so why the derivatives are zero. At this point, different phase trajectories are attracted or repel (divergent) (solutions may branch out). In the first case, an attractor is formed, in the second - a repeller. The singular point of the phase space is a mathematical category, and within the framework of economics, it is proposed to call it a state of stable equilibrium.

The classification of singular equilibrium points is presented in Table 1.

Table 1. Classification of singular equilibrium points

Feature	Stability			Instability			
1. By the nature of the singular point of equilibrium	Stable node	Stable focus	Stable center	Unstable node	Unstable focus	Unstable center	Saddle instability
2. In the direction of the phase trajectories relative to the equilibrium point	Attractor - Phase trajectories are attracted to the equilibrium point which is stable			Repeller - phase trajectories repel an equilibrium point that is unstable			
3. By the number of equilibrium states	Multistable		Bistable		Monostable		

Source: Designed by the authors

In the economic context, the phase trajectories are the trajectories of economic development of the economic entity or the trajectories of individual (main and supporting) business processes and interests of stakeholders. If they are all within the area of attraction of the attractor, then there is no need to make instant management decisions to change the situation. Conversely, if they are not within the area of attraction of the attractor, then there is a need to make instant management decisions.

A visualization of the phase portrait of such special points as "center", "saddle", and "saddle center" in 3D is shown in Figure 1-3.

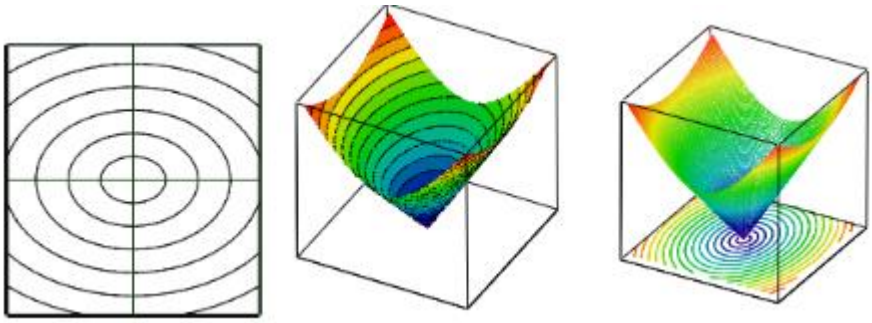

Figure 1. Phase portrait of a singular equilibrium point of “center” type
Source: Designed by the authors

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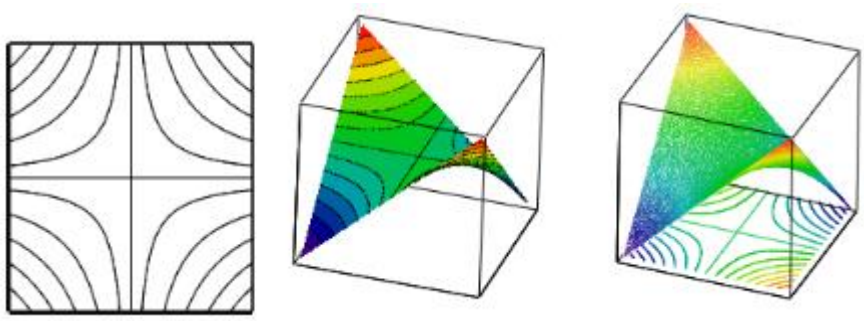

Figure 2. Phase portrait of a singular equilibrium point of "saddle" type
Source: Designed by the authors

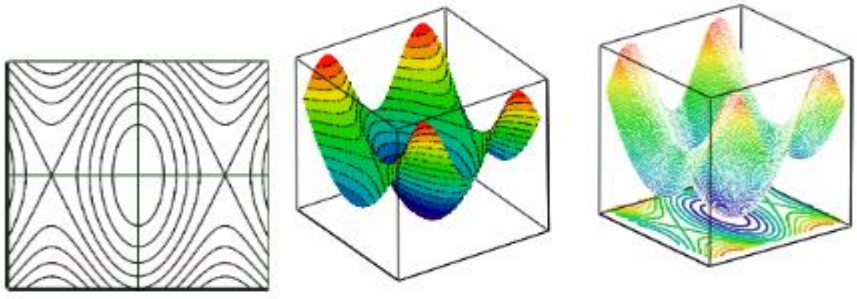

Figure 3. Phase portrait of a singular equilibrium point of "center-saddle" type
Source: Designed by the authors

A dynamic system can have several attractors (alternative paths of development) at the same values of control parameters. For example, the movement of a ball on the surface of a complex descending relief, on which there are a number of holes and tubercles. Of course, each local well has an area of attraction to which the ball rolls. If it goes beyond these limits, it will slide into another hole. The choice of the further path of development occurs at the point of bifurcation (fork).

The activity of an enterprise with a lot of cross-business processes, many relationships with different stakeholders seems chaotic at first glance but, in reality, it follows a hidden order. We can distinguish four nonlinear functions, four forces, and four types of attractors that exaggerate order from disorder, among which there are point, periodic, quasiperiodic, strange attractors.

The model was tested at the VOLKSWAGEN plant (Wroclaw, Poland). Based on the formula 1, the author defined control parameters (proportionality coefficients) in accordance with the statistical and financial statements of the enterprise and developed an information base for the calculation of the mathematical model.

Unlike others, this study is supplemented by statistical analysis. And for this purpose, it is introduced into the model in the initial data for 2014-2018, which are presented in one-dimensional form based on the mathematical standardization procedure according to formula 2:

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$$k_{il} = \frac{m_{il} - \overline{m}_l}{P_l} \quad (2)$$

where k_{il} - the standardized value of the *l*-th separate parameter for the *i*-th period;

P_l - the mean square deviation of the *l*-th individual parameter;

$\overline{m}_l$ - the arithmetic mean of the *l*-th individual parameter;

m_{il} - the value of the *l*-th parameter for the *i*-th period.

Generally, standardization of the order parameters (dependent variables) does not affect the stability study procedure. Moreover, the values of the variables are not important at all. Only the relationship between them and the values of the control parameters (constant coefficients) in the evolution equations are important.

The end of observations, namely 2018, is the beginning of the forecast, so constant factors (proportionality coefficients) are included in the model for this year.
Using the Maple package, the system of differential equations (1) for the values of the proportionality coefficients is: a = 5,15; d = 10,17; b = 1,73; g = 34,46; c = 4,24; h = 22,50, numerically integrated with the Runge-Kutta method with a constant step on a time interval [0,5].

The roots of the characteristic equation at the aforementioned numerical values of the proportionality coefficients determine the existence of only a trivial singular point as justified objectively, that is, one real and two complex conjugates with a negative real part.

Visually, the results of the model of stability of the studied enterprise are reflected in Figure 4, where the following designations are adopted: $k_{l,1} = F_1$ - the number of employees of the enterprise; $k_{l,2} = F_2$ - the volume of equity capital; $k_{l,3} = F_3$ - the volume of credit. However, unfortunately, in Maple, the drawings are presented in two-dimensional space.

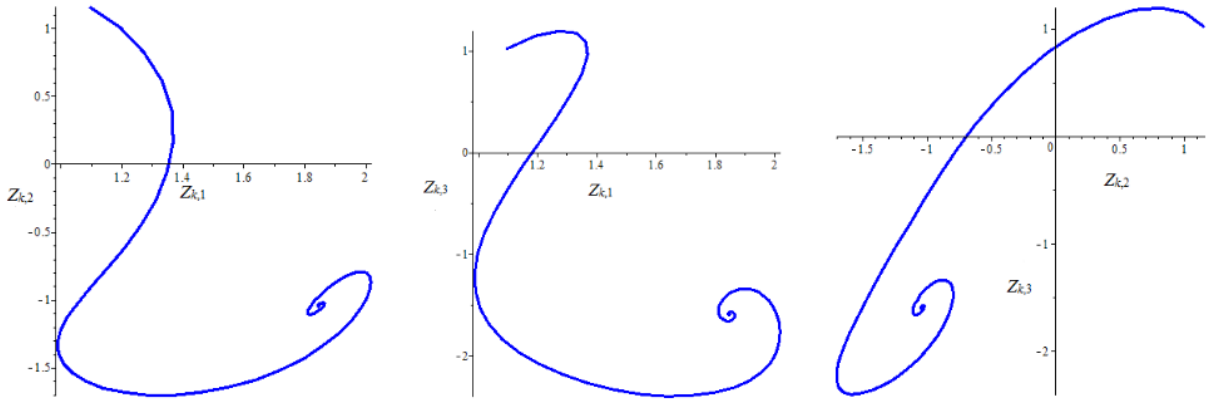

Figure 4. Forecast of the state of stable equilibrium before implementation of measures for management of economic security of the enterprise
Source: Designed by the authors

Since the VOLKSWAGEN plant is in a saddle instability, at the point of bifurcation, which is the moment of choice between different attractors (in our case, between chaotic and limiting), the manager of the enterprise needs to change the value of some control parameters so that the plant is in a stable equilibrium for example, in a stable limit cycle.

It is proved that only by changing the values of the control parameters, it is possible to direct the enterprise in the area of attraction of the desired attractor in order to avoid bankruptcy. Therefore, measures have been developed to manage the economic security of the enterprise, namely:

1. Increase in profit from operations on the market, ie increase in profitability of assets of the enterprise (for example, 4,24% to 9%).
2. Search for credit with a smaller percentage. The attraction of credit can protect the company from bankruptcy and allow it to develop: to increase production volumes much faster than in its absence, not to reduce staff, and to pay decent wages.
3. Reduction of the share of expenses of the enterprise on one worker, that is wages, social expenses and expenses on the maintenance of labor, which are not a part of the payroll fund (for example, 10.17% to 5%).

Reduction of the share of expenses of the enterprise on one worker threatens with a decrease of own capital of the enterprise (lack of profit). Because of this, there is a reduction in the number of workers, a decrease in the quality of the work of execution, which will lead to a decrease in production volumes and a decrease in the amount of equity capital. However, over time, the trend will change with the decline in profits and the massive layoff of employees, the company will start to make a profit, which will again attract highly qualified staff. In turn, attracting more qualified staff will reduce the need for credit due to increased profits. Although then there will be costs associated with training new workers, which will cover their content with their own resources.

Thus, a kind of repetition generates a stable limit cycle (in this case, the order parameters fluctuate around the optimal values). Until the system makes a choice between possible directions of further evolution, it is impossible to unambiguously determine the fate of the system. The arsenal of synergetics has the concept of a cone or funnel of an attractor, which seems to draw on itself different trajectories and causes the "fate" of the enterprise. Without changing the management parameters, the enterprise has no chance to get into the "desired" attractor or the "desired" future.

Based on the above, it can be argued that the sense of synergistic management of the economic security of the enterprise is to achieve a state of stable equilibrium, which is the main criterion for the quality of all management decisions.

5. Discussion

One of the main conclusions of chaos theory is that the three order parameters change so that the state of the system (enterprise) cannot be predicted for a long period of time, only within the forecast horizon. At the same time, the inability to know all the initial conditions and factors of influence does not make it possible to predict the future. It can only be described with a certain amount of probability since the real activity of the enterprise is much more diverse, which is also created by the employees themselves.

In turn, the instability of the trajectories of chaotic systems makes them extremely sensitive to control. Therefore, firstly, it is important for the leader and chief of the security service to “flap wings” at the right time in the right

place, and secondly, given that small mistakes can lead to big consequences, to realize the full measure of responsibility for what happens.

Consequently, if the enterprise is in the field of attraction of stable equilibrium, which can be called a "channel", then fluctuation processes will not violate its stable state and the behavior of the system will be predictable. However, if the enterprise is in the "pool" of unstable equilibrium or in the "joker" area, then even a slight deviation can lead to its destruction ("butterfly effect"). In this case, the behavior of the system is unpredictable and random. At an unstable equilibrium point, solutions can branch out (bifurcation).

Conclusions

The enterprise's sustainability model has been improved in the context of ensuring economic security based on the phase portrait method, which allows predicting the nature of a particular equilibrium point of an enterprise and the type of attractor, and early development of measures for managing economic security of the enterprise, the implementation of which will allow the enterprise to be in the field of a stable limit attractor in the future to avoid the biggest threat - to be in the field of attraction of a chaotic attractor, which for the enterprise is tantamount to bankruptcy.

The author developed an information base for calculating the model, adapted it to the financial statements of the enterprise and tested it at the factory VOLKSWAGEN (Wroclaw, Poland). It was revealed that after 3 years at the plant (the end of observations, namely 2018 is the beginning of the forecast), the saddle-focus of the first kind will be a singular equilibrium point, which is an unstable (bifurcation) point and at which a choice between opposite attractors (simple and chaotic) will take place. This means that structural changes are expected, a greater threat to it is a hit in the future in the field of attraction of a chaotic attractor, that is, bankruptcy.

It is proved that only by changing the values of the control parameters, it is possible to direct the enterprise in the field of attraction of the desired attractor in order to avoid bankruptcy. Therefore, measures have been developed to manage the economic security of the enterprise, namely: increasing the return on assets of the enterprise (from 4.24% to 9%); search for a loan with a lower percentage; reduction in the share of enterprise expenses per employee (from 10.17% to 5%). The early joint implementation of measures will allow the enterprise in the future to fall into the field of a simple limit attractor, that is, to achieve a state of stable equilibrium.

Perspectives for further research is the development of strategies to ensure the economic security of the enterprise, taking into account the constructed model. As a primary need, the economic security of the enterprise should be justified from the point of view of strategic management, that is, for the effective management of the enterprise today the priority is to ensure the economic security of the enterprise, for which an important problem is to develop a strategy as the main guideline in this direction.

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