The method of phase trajectories in system diagnostics of economic protectability of industrial enterprise

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Abstract. The article demonstrates the applied use of the method of phase trajectories for refinement of results of system-complex diagnostics of economic protectability of industrial enterprise. System of a kind “expenses-risk” with absolute speed of changes of its constituent elements is chosen as the adjustable parameter. On the basis of real dynamics of the specified parameters of the system there was revealed an inter-relation with current protectability of entrepreneurial activity of business entity that gives an opportunity to make definitely right decision on the prognostic fluctuation of diagnosed his level of economic protectability in the short term.

Key words: the method of phase trajectories, diagnostics, economic protectability, expenses, risk, enterprise.

INTRODUCTION

Unfavorable market conditions of management that are prevailing at the current moment in the post-crisis period at most industrial enterprises of different countries of the world, aggravated the main problem of the present day – the search and implementation of optimal methods of diagnostics, assessment and control of the condition of current protective functions of leading production and economic structures in order to accelerate the adoption towards them of effective decisions on stabilization of the situation that has emerged. In this regard, we more and more need to clarify the system diagnostics of their condition of economic protectability that can combine both system-complex and structurally functional diagnostics. As system-complex diagnostics of economic protectability of enterprise is not necessarily the quantitative diagnostics of the condition of protectability of financial-economic and production activity of business entity from the consequences of the actions of destabilizing factors of external and internal environments, but can be only qualitative, that is manifested through weighed check of implementation or non-implementation of system of criteria or principles of integrated economic protection and is not always thorough in terms of profound functional analysis of all economic potential of enterprise on the basis of entered check indices-indicators, this kind of diagnostics needs obligatory refinement of the results through applied use of a number of economic and mathematical methods with a prevalence of the method of phase trajectories to confirm the objectivity of condition of protectability of enterprise in consequence of the dynamics of the value of expenses of different categories in combination with the value of allowed financial risk.

ANALYTICAL INSTRUMENTS

In general the condition of economic protectability of industrial enterprise is an integrated value that reflects the level of protection and simultaneously of condition of its competitiveness, liquidity, solvency, and creditworthiness fixing a performance of properties of efficiency, reliability, flexibility, capacity, stability and sustainability that are correlated by systematic and nonsystematic kinds of risks of arrival of threats, the total magnitude of which characterizes the quantitative measurement of possible deviations from expected result - permissible level of economic protection on the basis of conformity of performance of above mentioned properties of business entity considering controlled and uncontrolled factors that act continuously on the part of the main spheres of activity of enterprise. In its turn, the condition of economic protectability is correlated with the satisfactory or unsatisfactory financial condition of enterprise that is reflected in the degree or level of its economic protection.

Category “economic protectability”, being dynamic in time, needs necessary diagnostics, that is the elaboration of the system of appraisal measures aimed at determination of the value of deviation of the fixed current functional protection of enterprise from the permitted level
of the general condition of economic security first of all to maintain its normal continued existence.

Many scholars such as O. Dobykina, A. Herasymov, O. Hetman, L. Ivanets, S. Kasyanyuk, A. Kiriyenko, T. Kostenko, L. Kostyrko, O. Kuzmin, V. Luk’yanova, A. Maryuta, O. Melnyk, O. Oleksyk, V. Ryzyhkov, V. Shapoval, H. Shvydanenko, I. Sokyrynyska, Yu. Tocheyev, V. Tszunov, A. Voronkova, O. Yelisieyeva, N. Yev dokymova, T. Zahorna, et al. [1, 7-21] were engaged in the issues of diagnostics of broad direction in the system of assessment of entrepreneurial activity. Each of the authors individually applied the appropriate mechanism or system of diagnostics for a current assessment of economic phenomena in the general system of functioning of enterprise having suggested diagnostics of bankruptcy, diagnostics of financial and business condition, diagnostics of financial and economic sustainability, diagnostics of economic (production) potential, diagnostics of competitiveness, diagnostics of creditworthiness, diagnostics of the market value of the property, diagnostics of antirecessionary management, diagnostics of management of production and economic systems, diagnostics of financial and economic activity of enterprise both in general and in the system of process-structured management, diagnostics of risks and economic security and so on. However, no one of them applied to the constricted category such as “economic protectability” the process of recognition of its quantitative value through refinement of its measurement, involving application of economic and mathematical methods.

SOURCE MATERIALS AND METHODS

Further development of market relations at the present stage increases the responsibility and independence of strategically important enterprises and of other market entities in the preparation and acceptance of administrative decisions, efficiency and economic security of which depends on comprehensiveness and objectivity of diagnostic assessment of their financial condition, in estimation of investors that are interested in profit earning and in an acceptable riskiness of investing their money in enterprise, in the relationship with creditors and suppliers who want to be convinced of the solvency of enterprise. Since the essence of market economy lies in the fact that all entities are free in their economic activity and should act at their discretion, on the basis of present conditions, the set rules and market regulators, such as interest rates, prices, taxes, customs tariffs, the amount of expenses, the magnitude of risk etcetera, that are formed according to the results of competition of producers, sellers, buyers and consumers and should look for any innovative approaches to intensify and rationalize their activity for further survival in the market and diagnosing in the higher level perspective of their economic security.

Selection of effective innovative solutions at industrial enterprise can be long-term and, therefore, impossible without comprehensive dynamic analysis of complex interconnected factors, determination and comparative estimation of possible alternatives and admissible plans of action for a given business entity. In this connection, in practice, diagnosed value of allowed level of economic protectability plays an important role for assessment of procedures of acceptance or non-acceptance of certain management decisions at an enterprise. It can be periodically subjected to recommended narrowly differentiated control with an application of variety of economic and mathematical methods that give an opportunity with the largest absolute precision in time to estimate the final financial and economic result of enterprise regarding the condition of implementation at it of such main properties as economic stability, independence, solvency, profitability, etc. It generally affects the completeness of correctness of urgent management decision making and holistically integrates objective procedure of diagnostics of the condition of economic protectability of enterprise.

Majority of elaborations concerning this problem are based on such economic and mathematical toolkit that consists of six basic stages: 1. Determination of problem situation of enterprise that currently has the most significant effect on the change of condition of its economic protectability under market conditions, and building of its formalized description. 2. Development of economic and mathematical model concerning the problem. 3. Selection of method and performance of calculations in a simulated situation. 4. Preparation of output information and simulation on real data. 5. Search for alternative variants and selection of the optimal one. 6. Adoption of an innovative approach concerning this problem with the use of economic and mathematical modeling [5].

Although these stages are reduced to six major ones, in real conditions their quality content can be changed. It especially concerns the third stage with the desirable conceptual combination of several economic and mathematical methods, namely the stage of selection of the method and performance of calculations in simulated situations that promotes building of a more accurate system of management according to components of condition of economic protectability of business entity, primarily affected by more factors from the external environment of enterprise. First of all it is a condition of financial and credit and investment activity of business entity, which, before all affects the diagnostics of condition of its economic protection, taking into account financial risks and elements of the losses.

In this regard, there is a need for simulation search for data for the investigated enterprise that would directly influence its financial stability and would allow to additionally conduct in-depth estimation of its key economic parameters such as: expenses, risk, loan size, expected income, the probability of successful realization of the investment project that can be the basis for innovative approaches of system-complex diagnostics of its level of economic protectability.

Experience shows that for the visual analysis of the dynamics of financial-economic activity and its impact
on the diagnosed value of the condition of economic protectability of production and business entity, it is best to use a graphical method - the method of phase trajectories. This method is based on the image of such changes in the form of the trajectory of motion of the point (of selected financial and economic parameter) that reflects it in the phase space [2, 3].

If a system of second order is chosen (dependence only between two parameters, for example the size of expenses of enterprise on time interval or dependence of expenses and risk of appropriate business entity), this movement will be provided on the phase plane. It is recommended to take an adjustable parameter expenses-risk (y) and speed (or value) of their changes (Δy) at enterprise [2, 4] as axis of coordinates. Weighed conclusions about entrepreneurial activity of production and economic structure in general can be done by the character of possible changes of parameters of the system.

During various economic processes that take place at the industrial enterprise which directly or indirectly affect the condition of its economic protectability, a point with specified coordinates (y, Δy), when moving on phase plane will define the phase trajectory. A complex of phase trajectories that reflect dynamic properties of the system is called the phase portrait of the system. The method of isolines is most frequently used for their construction [6]. The more times the trajectory crosses the x-axis in the area of the II and III quadrant of the coordinate system, the less stable is the condition of enterprise considered to be, first of all on the part of the control of the level of expenses if actual expenses exceed the planned ones.

Let us compare the planned expenses of the investigated enterprise regarding execution of works and their change with the actual service provided or volume of sold production displayed under continuous linear part. The output value V will be the risk of non-reimbursement of expenses of business entity. Level of expenses is monitored, as a rule, by the planning department of enterprise that adjusts the rate of change of the size of the actual expenses in comparison with the planned ones. The value of the existing level is compared with the set one and the risk is assessed according to the sign of this in coordination.

The transfer function of the linear part of the system, according to [6], has the form:

\[ W(p) = \frac{k}{p \times (T_p + 1)} \]  \tag{1}

where: k – is a constant, equal to 1 if there is the signal about the study of the economic system of enterprise and otherwise − 0, T – the specific weight of expenses of enterprise; p – number of partners in this enterprise.

Output information is the fact that the financial risk that can be one of the identifiers of economic protectability of production and economic structure is constantly changing, and its value is determined by the sign of mismatch +1 or −1. Then the equation of the system in general form can be written as follows:

\[ Ty'' + y' + k \operatorname{sgn}(x - y) = 0, \]  \tag{2}

where: \( x \) and \( y \) – are coordinate values of regulated economic parameters that affect the condition of enterprise activity.

Having taken \( x = 0 \) and taking into account that \( \operatorname{sgn}(-y) = -\operatorname{sgn}(y) \), we get:

\[ Ty'' + y' + kU \operatorname{sgn}y = 0. \]  \tag{3}

In dimensionless coordinates they set \( T = 1, k = 1 \) and denote \( \operatorname{sgn}y = -d \) and therefore, \( d = 1 \) at \( Dy < 0 \) and \( d = -1 \) at \( Dy > 0 \).

Then \( V' + V = \delta \), where: \( y' = V \) or \( \frac{dV}{dy} = \frac{\delta - V}{V} \).  \tag{4}

The equation of phase trajectories is received by integration of this equation provided that \( t = 0 \) and denoting \( V_0 = \Delta y_0 \):

\[ y = y_0 + \Delta y_0 - V + \delta \ln \Delta y_0 - \delta; \]  \tag{5}

where: \( y_0 \) – is the actual value of expenses of enterprise; \( y_0 - \) is the planned value of expenses of enterprise; \( \Delta y_0 - \) is the change of expenses; \( V \) – is the risk; \( d \) – is the value of the identifier +1 or −1.

If the value of identifier is set \( d = 1 \), the equation of the phase trajectory will look like:

\[ y = y_0 + \Delta y_0 - V + \ln(1 - \Delta y_0). \]  \tag{6}

If \( d = -1 \) the equation of the phase trajectory will look like:

\[ y = y_0 + \Delta y_0 - V + \ln(1 + \Delta y_0). \]  \tag{7}

Transition of trajectory from \( d = 1 \) to \( d = -1 \) on phase plane takes place on y-axis. Herewith a transition zone is formed, that reflects the change of values of the actual expenses of enterprise in comparison with the planned ones, respectively, located sequentially according to the growing tendency from the coordinate origin. There is also a change of signs on V-axis, respectively, clearly according to the change of values of d from +1 to −1 and vice versa.

RESULTS AND DISCUSSION

Let us consider economic-mathematical method of the phase trajectories on the basis of data on the dynamics of expenses as a result of a generalized financial and production activity of N-th industrial enterprise given in Table 1.

When studying the real industrial entity its business activity covers the results of expenses simultaneously as a result of operating, financing and investing activities.
Number of crossings of zones of I, IV quadrants characterizes positive dynamics of decrease of actual expenses as to planned values within acceptable risks. Number of crossings of zones II, III characterizes the negative dynamics of growth of actual expenses of enterprise as to planned values fixing the negative value of risks. If the amount of crossings of I and IV zones exceeds the number of crossings of II and III quadrants, the positive tendency of economic stability at enterprise prevails and thus business entity keeps under control all the actual expenses and even has reserve funds and can lend them the similar enterprises of certain sector acting now as a creditor. However, this does not always correspond to the dynamics of the expected increase of level of economic protectability of real industrial enterprise and only if its incomes of the reporting period exceed actual expenses (Table 1), moreover, in the next time period this tendency not only persists but also has a corresponding predicted rate of growth of incomes according to a linear, logarithmic, exponential and polynomial trend dependencies at diagnosing absolute or at least normal financial sustainability of business entity.

When the correlation coefficient is 1, the value of total incomes and expenses of enterprise is connected with linear functional dependence. However, the presence of absolute financial sustainability of enterprise at the reporting date does not always give a full guarantee for a rather high level of economic protectability. In addition, having set the speed of resizing expenses at an industrial enterprise, the predicted value of risk can be achieved that will be important for saving the appropriate condition of economic protectability (Table 2).

Let us apply the method of phase trajectories to the control of dynamics of expenses of enterprise (Table 3).

### Table 1. Control values of inspection of excess of total incomes over total expenses in the system of ensuring economic protectability of enterprise for years 2010-2011 (thousand hrn)

<table>
<thead>
<tr>
<th>№</th>
<th>Parameter name</th>
<th>Planned value</th>
<th>Actual value</th>
<th>Deviation of planned incomes from planned expenses (+,-)</th>
<th>Deviation of actual incomes from actual expenses (+,-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Total incomes</td>
<td>173576</td>
<td>187274</td>
<td>4310</td>
<td>4325</td>
</tr>
<tr>
<td>2.</td>
<td>Total expenses</td>
<td>169266</td>
<td>182949</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The correlation coefficient 1

### Table 2. Control of actual expenses of industrial enterprise in accordance with the implementation of the financial plan for years 2010-2011 (thousand hrn)

<table>
<thead>
<tr>
<th>№</th>
<th>Name of kind of expenses</th>
<th>Plan</th>
<th>Actual</th>
<th>Deviation (+,-)</th>
<th>Percentage of implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cost of sales (goods, works and services)</td>
<td>141269</td>
<td>154248</td>
<td>12979</td>
<td>109,19</td>
</tr>
<tr>
<td>2.</td>
<td>Administrative expenses, Total</td>
<td>18538</td>
<td>18965</td>
<td>427</td>
<td>102,3</td>
</tr>
<tr>
<td>3.</td>
<td>Including:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Expenses connected with the use of official cars</td>
<td>371</td>
<td>328</td>
<td>-43</td>
<td>88,41</td>
</tr>
<tr>
<td>5.</td>
<td>Expenses for consulting services</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6.</td>
<td>Expenses for insurance services</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7.</td>
<td>Expenses for auditing services</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>8.</td>
<td>Other administrative expenses</td>
<td>18160</td>
<td>18630</td>
<td>470</td>
<td>102,59</td>
</tr>
<tr>
<td>9.</td>
<td>Selling expenses</td>
<td>480</td>
<td>417</td>
<td>-63</td>
<td>86,88</td>
</tr>
<tr>
<td>10.</td>
<td>Other operational expenses</td>
<td>5200</td>
<td>5225</td>
<td>25</td>
<td>100,48</td>
</tr>
<tr>
<td>11.</td>
<td>Financial expenses</td>
<td>939</td>
<td>246</td>
<td>-693</td>
<td>26,2</td>
</tr>
</tbody>
</table>
### Table 3. Practical implementation of the method of phase trajectories in the system of control of expenses of industrial enterprise for years 2010-2011

<table>
<thead>
<tr>
<th>№</th>
<th>Planned values of expenses $\phi$, thousand hrn</th>
<th>Actual values of expenses $\psi$, thousand hrn.</th>
<th>Setting of identifier $d$</th>
<th>Design formula for calculation of risk $V$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>141269</td>
<td>154248</td>
<td>$d = -1$</td>
<td>$154248 = 141269 + 12979 - \ln(1 + 12979) \Rightarrow V_1 = -9,4%$</td>
</tr>
<tr>
<td>2</td>
<td>18538</td>
<td>18965</td>
<td>$d = -1$</td>
<td>$18965 = 18538 + 427 - \ln(1 + 427) \Rightarrow V_2 = -6,1%$</td>
</tr>
<tr>
<td>3</td>
<td>480</td>
<td>417</td>
<td>$d = 1$</td>
<td>$417 = 480 + (-36) + \ln(1+36) \Rightarrow V_3 = 4,2%$</td>
</tr>
<tr>
<td>4</td>
<td>5200</td>
<td>5225</td>
<td>$d = -1$</td>
<td>$5225 = 5200 + 25 - V_4 - \ln(1+25) \Rightarrow V_4 = -3,3%$</td>
</tr>
<tr>
<td>5</td>
<td>939</td>
<td>246</td>
<td>$d = 1$</td>
<td>$246 = 939 + (-693) - V_5 + \ln(1+693) \Rightarrow V_5 = 6,3%$</td>
</tr>
<tr>
<td>6</td>
<td>665</td>
<td>547</td>
<td>$d = 1$</td>
<td>$547 = 665 + (-118) - V_6 - \ln(1+118) \Rightarrow V_6 = 4,8%$</td>
</tr>
<tr>
<td>7</td>
<td>2175</td>
<td>3301</td>
<td>$d = -1$</td>
<td>$3301 = 2175 + 1126 - V_7 - \ln(1+1126) \Rightarrow V_7 = -7,0%$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The correlation coefficient 0,999927</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Year 2010**

1. $V_1 = -9,4\%$
2. $V_2 = -6,1\%$
3. $V_3 = 4,2\%$
4. $V_4 = -3,3\%$
5. $V_5 = 6,3\%$
6. $V_6 = 4,8\%$
7. $V_7 = -7,0\%$

**Year 2011**

1. $V_1 = -0,1\%$
2. $V_2 = -7,8\%$
3. $V_3 = -7,8\%$
4. $V_4 = -7,9\%$
Graphical interpretation of the phase trajectories of the system expenses-risk at enterprise for the period of years 2010-2011, is shown in figures 1-2.

Number of crossings of I and IV quadrants (Figure 1) is less than the number of crossings of II and III quadrants (6 <8), meaning that enterprise could not reduce the number of planned expenses in the reporting period. However, as the total incomes still exceeded total expenses of the period, it did not negatively affect the process of ensuring economic protectability.

Number of crossings of I and IV quadrants (Figure 2) is much lower than the number of crossings of II and III quadrants (4 <10), meaning that enterprise could not reduce the number of planned expenses in the reporting year 2011; there is a high probability of fall in level of economic protectability in relation to the previous year 2010, although still within the allowable values as total incomes exceeded total expenses of the period (Table 1). However, this can negatively affect the process of ensuring economic security in the case if business entity has

<table>
<thead>
<tr>
<th>№</th>
<th>Planned values of expenses $\phi_0$, thousand hrn</th>
<th>Actual values of expenses $\gamma$, thousand hrn</th>
<th>Setting of identifier d</th>
<th>Design formula for calculation of risk $V$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>1100</td>
<td>459</td>
<td>d = 1</td>
<td>$459 = 1100 + (-641) – V5 + \ln(1+641) \rightarrow V5 = 6,5%$</td>
</tr>
<tr>
<td>6.</td>
<td>123</td>
<td>129</td>
<td>d = – 1</td>
<td>$129 = 123 + 6 – V6 – \ln(1+6) \rightarrow V6 = –1,9%$</td>
</tr>
<tr>
<td>7.</td>
<td>2800</td>
<td>2446</td>
<td>d = 1</td>
<td>$2446 = 2800 + (-354) – V7 + \ln(1+354) \rightarrow V7 = 5,9%$</td>
</tr>
</tbody>
</table>

The correlation coefficient 0,999937

![Graphical interpretation of the method of phase trajectories (expenses - risk) for enterprise according to investigated data of year 2010](image)

**Fig. 1.** Graphical interpretation of the method of phase trajectories (expenses - risk) for enterprise according to investigated data of year 2010
outstanding debt on the credit line or overdraft at the end of the reporting period, if the enterprise is officially self-financing.

CONCLUSIONS

Analysis of the method of phase trajectories demonstrated the possible applied use for refinement of the results of the system-complex diagnostics of economic protectability of industrial enterprise as an economic phenomenon, which at the appropriate entity characterizes a certain property that is based on the degree of absence of consequences of threats of influence of destabilizing factors of internal and external environments on the economic potential, on the overall production and economic activity of enterprise engaged in financial, production and business activity, including both positive and negative dynamics of risk and current expenses which is accurately fixed graphically as a result of crossing of isoclines of all categories of quadrants of the coordinate axes.

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Fig. 2. Graphical interpretation of the method of phase trajectories (expenses - risk) for enterprise according to investigated data of year 2011
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