Development of an indicator for assessing the reproductive process

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Abstract. The reproduction process in agriculture is complex and multifaceted, requiring new assessment methods, and a system of indicators that takes into account its dynamics. The uncertainty caused by inaccurate knowledge of the boundaries of the permissible state of agricultural activities can be eliminated by using status indicators. Parameters of activities of agricultural enterprises with known values were used as indicators. It helped develop an indicator of integrated assessment of reproduction, beyond which an unstable state and transition to another qualitative state can occur. Based on the indicator of integrated assessment of reproduction, agricultural enterprises were classified into the following groups: highly performing with positive average annual rates of development (expanded reproduction), highly performing with negative rates of development (simple reproduction), low-performing with positive rates of development (narrowed reproduction).

1. Introduction
The comparative analysis of existing methods for assessing the economic status and software for implementing these methods allowed us to identify the following problems: interpretation of analysis results, uniqueness of assessment of analysis results, challenges of spatio-temporal comparison, forecasting of future results. Multivariate statistical methods allowed us to compare agricultural enterprises, rank them by their financial stability indicators, classify them into groups by their status, and predict the status level for the nearest period.

2. Problem statement
Instrumental assessment of ongoing processes on the basis of retrospective analysis requires appropriate quantitative indicators. Indicators for assessing the reproductive process should serve as a barometer of the state of activities, processes and development trends for various power structures, decision-makers, and society. The developed method for assessing the reproduction process of agricultural enterprises on the basis of multivariate statistical analysis and the developed indicator allowed us to determine capabilities of the enterprise to narrowed, simple or expanded reproduction in statics and dynamics, to outline priorities for further development of an individual enterprise, a group of enterprises, and the industry as a whole.
3. Research questions
To identify industrial characteristics, the following indicators were used: the current liquidity ratio (given that the correlation analysis of this indicator has a high relationship, and the ratio of sufficiency of own working capital is excluded from further calculations); the autonomy ratio taking into account peculiarities of the agricultural industry and characterizing different phases of the crisis; the cost recovery ratio [1]; the capital return ratio taking into account the efficiency of resources; the market share ratio reflecting the level of competitiveness [2]. All the indicators have a low relationship, since the pair ratios of correlation between them do not exceed 0.3. Thus, the main drawback of the ranking systems – the unjustified use of the Euclidean metric to measure the relations between highly correlated features – was eliminated.

4. Purpose of the study
The article aims to develop an indicator of integrated assessment of reproduction taking into account the state of enterprises on the basis of the multivariate analysis.

5. Research methods
The theoretical and methodological basis of the study was the works on multivariate analysis by Hidalgo, Goodman [3], Anderson [4], Sen Pranab Kumar, Anderson, Arnold, Eaton, Giri, Gnanadesikan, Kendall, Kshirsagar [5], Schervish [6], Tyapkina, Ilyina [7].

The main stages of the reproduction-cyclic model are based on the use of methods of multidimensional classification, sustainable assessment and forecasting [8]:

1. Creation of an information database of agricultural enterprises and accumulation of data for the retrospective analysis.

2. Correlation analysis where for each compared agricultural enterprises n indicators are calculated, where: \( i = 1, 2, 3, ..., m \); \( j = 1, 2, 3, ..., n \). All the indicators were checked for multicollinearity (the correlation between them), and indicators which do not influence each other were selected: current liquidity, investment, capital productivity and market share. For each indicator, the best and worst values were determined and assigned to the best (m+1) and worst (m+2) reference enterprise, respectively. The data obtained were standardized in relation to the difference between the best and worst values of the corresponding indicators, where \( D_{i,j} \) – standardized indicators of the i-th enterprise \([0 \leq D_{i,j} \leq 1]\), which determine the deviation of the j-th indicator from the reference (best) value expressed in shares of the difference between the best and worst values in the group of compared enterprises; \( P_{i,j} \) – are the j-th financial indicators characterizing the results of the i-th enterprises. For each (i-th) enterprise, the value of its deviation from the reference one was determined, where \( R_{di} \) is the value of the deviation of the i-th enterprise from the reference one.

3. The third stage involves the classification of enterprises by cluster analysis methods, where the set of enterprises is divided into groups depending on the type of reproduction; determination of the average values of indicators for each group; ranking of the compared enterprises and assignment of the highest rank to the enterprise with the maximum value, where \( R_{i} \) is the indicator of integrated assessment of reproduction, \( R_{d_{max}} \) and \( R_{d_{min}} \) are the best and worst estimates of the deviation in the group of compared enterprises.

4. The fourth stage involves the ranking of enterprises depending on the type of reproduction, where \( R_{ai} \) is the removal of results of the i-th year from the reference (best) period.

5. The fifth stage involves the forecasting of an enterprise’s rank. Knowing the dynamics of the auto-ranking, it can be described by the first order regression equation, where \( R_{a} \) is the auto-rank of the enterprise for each year when comparing the results of only one enterprise for several years, K is the regression coefficient characterizing the average rate of growth of the enterprise’s status, T is the ordinal number of the period, C is the the initial ordinate of the regression equation. The stability of the growth rate is estimated taking into account the entire set of indicators based on the residual variance of the auto-ranking, where \( R_{ari} \) is the value of auto-ranking for the i-th year calculated by the regression equation, \( R_{ari} = KTi+C \), T is the number of years of observation.
Following the above conditions, we have a mathematical model for estimating the type of reproduction \((1)\). The stability of the estimated variance of indicators is calculated for several years. The smaller the variance, the greater the sustainability of the enterprise's performance.

\[
\begin{align*}
D_{i,j} &= (P_{m+1,j} - P_{i,j})/(P_{m+1,j} - P_{m+2,j}) \\
Rd_i &= \sqrt{D_{i1^2} + D_{i2^2} + \cdots + D_{in^2}} \\
R_i &= (Rd_w - Rd_d)/(Rd_w - Rd_b) \times 100 \\
Ra_i &= (1 - Rd_i/100) \\
D &= \sum_{i=1}^{N}(Ra_i - Ra_i[KT + C])^2/N \\
\text{[(m + 1) max and (m + 2) min]} \\
P_{i,j}, \text{ where } i = 1, 2, 3, \ldots, n \\
[0 \leq D_{i,j} \leq 1]
\end{align*}
\]

Table 1 presents indicators for different groups of enterprises in their respective octants.

**Table 1.** The boundaries of the indicator values for different groups of agricultural enterprises depending on the type of reproduction.

| Criterion | Groups of enterprise | 1 | 2 | 3 | 4 |
|-----------|----------------------|---|---|---|---|
| Type of reproduction | expanded reproduction | simple reproduction | simple reproduction | narrowed reproduction |
| \(R\) | > Rz | > Rz | < Rz | < Rz |
| \(K\) | > 0 | < 0 | > 0 | < 0 |

\(R = Rz; K = 0,\)

where \(Rz\) is the indicator of integrated assessment of the reproduction process for a group of agricultural enterprises.

**Table 2.** The indicators for the reference enterprise (m+3).

| Indicator | Current liquidity ratio | Autonomy ratio | Cost recovery ratio | Capital productivity ratio | Market share ratio |
|-----------|------------------------|----------------|--------------------|---------------------------|-------------------|
| Parameter indicator | 2 | 0.5 | 1.25 | 0.6 | 0.01 |

The model of assessment of the reproduction process was tested on agricultural enterprises of Irkutsk region for 2000-2002, 2003-2008, 2009-2012, 2013-2017.

The indicator of integrated assessment of the reference enterprise for the first cycle of the model was 60.6 (\(R_{z1}\)), for the second cycle 44.7 (\(R_{z2}\)), for the third cycle 38.6 (\(R_{z3}\)), for the fourth cycle 34.8 (\(R_{z4}\)) (table 3).

By reducing the standard indicators of the reference enterprise, the value \(Rd\) (deviation) increased. If the cost-recovery levels decreased by 5 % (120% rather than 125 %), the criterion was 34.3 rather than 34.8 (table 4). If the standard indicator of the cost recovery level increases up to 130 %, the indicator of integrated assessment of reproduction is 35.2.
Table 3. Characteristics of the indicator of integrated assessment of the reproduction process for a group of agricultural enterprises compared.

| Name                                      | Cycles               | 1      | 2      | 3      | 4      |
|-------------------------------------------|----------------------|--------|--------|--------|--------|
|                                           | 2000-2002           | 2003-2007 | 2009-2012 | 2013-2017 |
| 2000–2002                                 |                      |        |        |        |        |
| 2007–2012                                 |                      |        |        |        |        |
| 2012–2017                                 |                      |        |        |        |        |
| 2017–2017                                 |                      |        |        |        |        |
| $Rd_{m+3}$ – deviation of the enterprise $m+3$ from the reference one | 11.6 | 11.1 | 10.8 | 17.1 |
| Best values $Rd$ in total                  | 7.1 | 3.2 | 3.1 | 7.1 |
| Worst values $Rd$ in total                 | 18.3 | 17.3 | 15.5 | 22.5 |
| $R_{m+3}$ - the indicator of reproduction assessment $m+3$ | 60.6 | 44.7 | 38.6 | 34.8 |

The indicator allowed us to classify agricultural enterprises into types of reproduction; the higher the indicator, the higher the $R_{di}$ requirements to the value of the deviation of the i-th enterprise from the reference one.

Table 4. The dependence of the indicator of integrated assessment of reproduction on cost recovery.

| Cost recovery, % | Cycles               | First | Second | Third | Fourth |
|------------------|----------------------|-------|--------|-------|--------|
| 105              |                      | 57.5  | 41.2   | 35.2  | 32.6   |
| 110              |                      | 58.4  | 42.7   | 36.1  | 33.2   |
| 115              |                      | 59.2  | 43.4   | 37.0  | 33.8   |
| 120              |                      | 59.9  | 44.0   | 37.8  | 34.3   |
| 125              |                      | 60.6  | 44.7   | 38.6  | 34.8   |
| 130              |                      | 61.3  | 45.2   | 39.2  | 35.2   |

It should be noted that the value of integrated assessment varied from 0 to 100, while its average value varied from 60.6 ($R_{1}$) for the first cycle and 44.7 ($R_{2}$) for the second cycle, which is 73.1% and 93.1% of the $R_{z}$. For the third cycle, the average value was higher by 12 % (38.6), which indicates an increase in the number of agricultural enterprises with above average values of integrated assessment. For the fourth cycle, the average value was higher by 12.7 % (34.8) (table 5).

Table 5. Deviations of the average value of integrated assessment of the reproduction process from the indicator.

| Cycles | Mean value $\bar{W}$ of the integrated assessment of the reproduction process | The indicator of integrated assessment of the reproductive process $R_a$ (according to the reference enterprise) | Deviation of the average value from the indicator, % |
|--------|--------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| 1      | 44.3                                                                     | 60.6                                                                                                                            | 73.1                                             |
| 2      | 41.6                                                                     | 44.7                                                                                                                            | 93.1                                             |
| 3      | 43.2                                                                     | 38.6                                                                                                                            | 112.0                                            |
| 4      | 39.2                                                                     | 34.8                                                                                                                            | 112.7                                            |

The indicator of integrated assessment was $R_z = 34.8$ for the last cycle, and the regression coefficient characterizing average annual growth rates was $K= 0.001$. Agricultural enterprises with $R_z$ above 34.8 were referred to the first and second groups, and below 34.8 - to the third and fourth groups. Agricultural enterprises that have a regression coefficient characterizing the average annual growth rates
growth rate above \( K = 0.001 \) were referred to the first and third groups, and below \( K = 0.001 \) were referred to the second and fourth groups.

6. Findings
The first group (expanded reproduction): highly performing enterprises - 43.4% of the total number of enterprises, with a cost recovery ratio of 113.8%; they have a relatively high financial performance index and an average annual growth rate. In 2017, these enterprises received revenues in the amount of 14674 million rubles, their profit was 1784 million rubles which is 65.3% and 84.5% of the total value for all agricultural enterprises.

The second group included 23.2% of highly performing enterprises with negative rates of development. They may have high declining results and remain highly performing with a payback rate of 106.4%. In 2017, these enterprises received revenues in the amount of 6444 million rubles, their profit was 390 million rubles which is 28.7% and 18.5% of the total value for all agricultural enterprises.

The third group included 17.2% of low-performing, developing agricultural enterprises of Irkutsk region which have relatively low indicators and an average annual growth rate with a cost recovery index of 97.6%. In 2017, these enterprises received revenues in the amount of 1075 million rubles (4.8% of all revenues in the industry), the loss on sales was 27 million rubles.

The fourth group included 16.2% of low-performing enterprises with negative rates. They have relatively low economic indicators and a declining rate with a cost recovery index of 89.2%. In 2017, these enterprises received revenues in the amount of 300 million rubles, the loss on sales was 36 million rubles.

7. Conclusion
Thus, the development of the indicator of integrated assessment of reproduction allows us to identify differences between high-performing agricultural enterprises and low-performing agricultural enterprises. It will allow for the development of a reasonable and targeted regional public policy aimed at supporting agricultural enterprises.
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