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Methodological Aspects in Problem Solution of the Determined Factor Analysis

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ABSTRACT

The urgency of the analyzed problem is due to the fact that the need to study the relationship of economic phenomena and the comparative analysis of the factor ratings not only in time but also in space requires the development of determined factor analysis. The purpose of the article is to develop a generalized method of determined factor analysis, which increases the accuracy of its results, and it will broaden and deepen its scope. The leading approach to solve the problems of determined factor analysis is a systematic approach that allows establishing a more precise assessment of multiplicative component. Results: The proposed generalized integral method of determined factor analysis has a high precision of factorial assessment, and the ground construction allows carrying out a comparative analysis of the impact of factors on a productive indicator of the surveyed economic system of any level. The data of this article may be useful for the analysis of economic activity of organizations, as well as for the development of the economic development strategy.

KEYWORDS
Determined factor analysis; Index method; Integral method; The rates of growth

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Introduction

Establishing a context

At present the determined factor analysis (DFA) to define interrelations of economic development indicators of any objects and territories is the most popular and widely spread on the final stage of statistic research and analysis of the enterprise economic activities. The methods are the basis of text-books on statistics and analysis of economic activities and are often used in scientific research. The results of DFA are used by administrative bodies at all levels to develop decisions in tactic and strategic planning, control and coordination of

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production development. The need to study the relationship of economic phenomena and the comparative analysis of the factor ratings not only in time but also in space, which allows ensuring the accuracy of its results, requires the development of determined factor analysis.

Reviewing the literature

The traditional method of DFA, a familiar method to students, researchers and practitioners, is the index method that has in its basis the order of changing factors from quantitative to qualitative or any other conditional premise of the order of changes, not continuous, smooth but intermittent which is hardly ever observed in reality (Lebedev, 2012; Safonov, 2014). Instead of the traditional approach there were repeatedly offered different approaches to the possible types of changes in the factors and the extent of their participation in results assessment (Artemenko & Anisimova, 2011; Lubushin, 2010), but they were rejected by different opponents because of the identified shortcomings of their theoretical justification except the integral methods of DFA oriented opposed to the index (traditional) method towards simultaneous changes of factor indicators (Bagautdinova, Markov & Jashin, 2013). However, integral methods were not fully recognized by the traditional apologists due to the inability to specify (estimate) the level of dynamic series at any point in time (date) of the analyzed interval, comparable with the levels of calendar periods, although this reproach could be attributed to all other DFA methods.

Establishing a research gap

All the above-mentioned data defines the problems of DFA which obstacle to its development and imperfection:

1. The absence of the universal and scientifically-grounded DFA method.

2. Simplification of DFA by way of chain substitutions in many cases leads to distortion of the reality and causes unpredictable errors and contradictions up to opposite interpretation of the factors' influence - one - in the direction of increasing the result, not the decline in real life, and the other - on the contrary - in the direction of reducing rather than increasing the result.

3. The absence of the possible level interpretation of dynamics series at any date of the analyzed interval.

4. The discrepancy between the aggregation assessment results of the factor productive indicator assessment for sub-periods with its factor assessment for the period as a whole.

Stating the purpose

The purpose of the article is to develop a generalized method of determined factor analysis, which increases the accuracy of its results, and it will broaden and deepen the scope of the DFA.

Materials and methods

Methods of research

In the course of the research, the following methods were used: theoretical (analysis, synthesis, dialectical method, scientific generalizations); statistics (method of averages (arithmetic and geometric), the index method, integral

methods of DFA - decomposition of the absolute growth index and productive indicator on factors; analysis methods of dynamics); methods of mathematical statistics and graphic results.

Experimental research base

Experimental research base is the kind of economic activity - "manufacturing enterprises" in the Saratov region in terms of their average salary.

Stages of research

The research was conducted at three stages:

- at the first stage was carried out a theoretical analysis of the existing methodological approaches to the philosophical, mathematical, and economic literature, as well as the theory and methodology of statistical research: were emphasized problems, the purpose and methods of research, and was made up the pilot plan of the study.

- at the second stage were presented methods for improving the accuracy of the results of DFA; were given mathematically reasonable classification of categories in absolute and relative rate changes of economic indicators depending on the method of comparing the distance and the time of their levels; was introduced the concept of trend levels measured for "astronomical" periods that allowed recognizing the legitimate application of higher mathematics for continuous functions in the development and improvement of methods of DFA, was conducted experimental work, were analyzed and refined the findings obtained in the course of experimental work.

- at the third stage was concluded experimental work, were clarified theoretical and practical conclusions and systematized the received results.

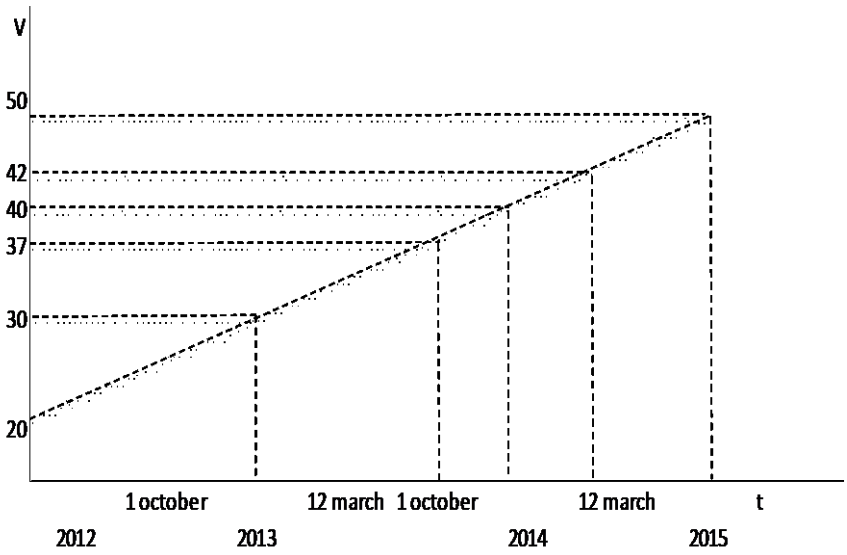
Results

Methods to increase the results accuracy of determined factor analysis

While conducting a critical analysis of the vast majority of statistical methods, techniques and methods of DFA there was formed the most important prerequisite for a clear interpretation of the original continuity of changes in economic indicators which are given in practice by discrete levels, and fixed only at the beginning and end of the respective periods related necessarily to the calendar and documentary fixed length (month, quarter, year).

In order to reduce the discrete level of social and economic phenomena, in other words - its oncoming to continuity, it is necessary to enhance the levels of calendar periods by the levels of “astronomical” periods of the same duration, starting and ending at the same date of the related calendar periods.

Figure 1 shows the nature of points location in astronomical and calendar periods and marks the linear trend levels of the conditional indicator: 20, 30, 40, 50 for the calendar years: 2012, 2013, 2014, 2015 at the end of each of them and, as an example, there are only two additional levels of astronomical years: 37 - from October, 2012 to October 1, 2013 and 42 - from March 12, 2013 to March 12, 2014 (Fig.1).



Figere1. The points (dates) location at the beginning and end of the year periods on the X-axis and the levels of the indicator υ in corresponding units on the Y-axis

Such astronomical levels can be defined for the moment as well as for the interval primary and derivative dynamics series at any point of the reported period (five years, year, half a year, quarter, month), if not exactly, then approximately, on the assumption that their value corresponds to the trend of changes in the calendar levels.

Thus, the proposed assessment methods (exact or approximate) of astronomical period levels at time points (dates) of calendar periods negate the third problem of the real existence and determination of indicator values in continuous economic processes.

The mathematically grounded inequality interpretation of the growth rate of productive indicator for each factor for the period to multiplicative factor assessment of the result for sub-periods that is calculated by the method of chain substitutions allowed to develop a number of important provisions to obtain estimates of most adequate DFA results to simultaneous and continuous development of interrelated economic phenomena, leveling the second and the fourth problems of improving DFA.

Recommendations to increase the DFA results accuracy

The useful result of the research is the following conclusion: It is impossible to develop a universal method of DFA to calculate the absolutely exact factor assessment for any system of interrelated economic indicators of any consequent calendar period. That is why, to obtain the desired factor assessment it is advisable to do the following:

1) fill up the original data base of calendar levels of economic indicators by astronomical ones,

2) define the tendencies of changing interrelated economic indicators,

3) use the integral DFA methods oriented towards these tendencies,

4) implement the second and the third terms in adjacent sub-periods of the analyzed period and then to aggregate factor decomposition assessment of the growth rate and (or) absolute growth of the result obtained for sub-periods in generalized for the whole period.

Economic and mathematical grounds of categories in rate changes of economic indicators and generalized DFA method

The implementation of the third and the fourth conditions recommended in Section 1 should base on the clear interpretation of categories in rate changes of the continuous economic process which does not contradict to the provisions of higher mathematics on the one hand and to its analogues in the theory of statistics (absolute growth and the rate of increase) on the other hand. The authors suggest the following explanations to the interpretation of categories in rate changes of economic indicators.

Absolute rate definition

As you know, the numerator of the average speed is identical to the basic absolute growth during the interval spanning the full dynamic series equal to the sum of chain growth for adjacent sub-intervals, and the denominator is equal to the duration of the whole interval measured by the unit of time by which the average speed is calculated. For example, let us calculate the average rate change of employee's annual wage who is engaged in manufacturing in the Saratov region: 234 000; 210 000 rubles at the end of December, 2015 and 2014: 234-210=24 (thousand rubles) in 2015; quarterly 24/4 = 6 (thousand rubles); monthly 6/3=2 (thousand rubles), daily 2000/30=66,7 (rubles).

Defining a linear trend for two reference levels: $y = 210000 + 66 \cdot t$ where $t = 0,1,2,...,365$, we calculated the average daily rate change of the year levels: during randomly selected first three days of February ($t_H = 31$, $t_K = 34$): $y_H = 210000 + 66 \cdot 31 = 212046$ (rubles); $y_K = 210000 + 66 \cdot 34 = 212244$ (rubles) и $\bar{h} = \frac{y_K - y_H}{t_K - t_H} = \frac{212244 - 212046}{34 - 31} = 66$ (rubles).

Decreasing the length of period $(t_K - t_H)$ from 3 days to 1 day, to0,1; to 0,01; …, shares of the day, we obtained the same values of the average daily rate change of the annual level of wage: 66 rubles equal to the parameter a_1 of the trend $y = a_0 + a_1 t$ where $y'_t = a_1$ is its first derivative.

In general case it is convenient to call y' moment average absolute rate change of the trend level, to call $dy = y'dt$ differential absolute rate and to call absolute growth of the level during the interval (a, b) equal to the integral sum of differentials of the trend interval absolute rate and to estimate it by the value of the definite integral $\int_a^b y'dt$

Relative rate definition

In conditions of the given example the rate change of employees' annual wage for the year 2014 was $\frac{234}{210}=1{,}114$ (111.4 %). Then the average rate changes of the annual levels for the year 2014 will be equal: quarterly $(1{,}114)^{\frac{1}{4}}=1{,}0274$, monthly $(1{,}114)^{\frac{1}{12}}=(1{,}0274)^{\frac{1}{3}}=1{,}0089$, daily $(1{,}0089)^{\frac{1}{30}}=1{,}0003$. It means that in 2014 the annual size of the employee's average wage increased every quarter 1.0003 times or by 0.03%.

The average daily relative rate change of the annual levels of wages for small periods of time in February 2014 $\left(T=\sqrt[t_K-t_H]{\frac{y_K}{y_H}}\right)$ is: for the first three days of February $\sqrt[34-31]{\frac{212244}{212046}}\approx 1{,}00031$; for 0.1of a day; for 0.01 of a day $\approx 1{,}00031$.

In the limit transition in general case, if $h\to 0$ we have $T\to e^{\frac{y'}{y}}$.

The value $y^T=e^{\frac{y'}{y}}$ will be called the moment rate change of the trend level and will be marked as y^T.

In our example $y^T_{(364)}=e^{\frac{66}{210000+66\cdot 1364}}\approx 1{,}00028$, i.e. at the end December 30 the average daily rate of salary increase was 100.028%.

By analogy with the differential absolute velocity the authors introduce the concept of differential rate change of the trend (function) for an infinitesimal period of time dt which is marked as $dTy(t)$; $dTy(t)=y^{T^{dt}}$.

Differential rate change is equal to the moment rate change in the degree dt and it is a necessary link of multiplicative integration of the private rate change for the infinitesimal adjacent intervals in the interval rate change:

$$\overset{b}{\underset{a}{T}}y(t)=\prod_a^b y^T(t)^{dt}=\prod_a^b dTy(t). \quad (1)$$

Generalized method DFA of the relative rate change of economic indicators

Given by the formula (1) the interrelation of the moment, differential and interval rate changes of the function $y = y(t)$ allowed establishing the important thing: the interval rate change in the sum of the end number of functions is equal to the end product of multiplications of differential rate changes in the degree of specific values weight of each function in the total number of items. Thus, the attraction of higher mathematics methods in the theory of DFA assures that when assessing the degree of influence of each additive factor on the relative rate change of their overall result we should consider the rate change value of this factor as well as its contribution (share) in the total amount, and it is sensible as from two factors with similar rate changes the greater impact of the sum on the dynamics will be made by the factor that has a bigger share in this sum.

The theoretical researches accompanied by numerical examples give grounds to assert that diversified expansion ways of the rate change of the productive indicator for various cases of changing factors can be approximated by the formula of the integral DFA method, and the accuracy of the results will steadily increase with the degree of fragmentation of the analyzed period in equal time periods and involvement of additional astronomical levels (Prokofyev, Nosov & Salomatina, 2014):

$$I_{\sum U} = \frac{\sum_{1}^{r_m} \cdots \sum_{1}^{r_2} \sum_{1}^{r_1} U_n}{\sum_{1}^{r_m} \cdots \sum_{1}^{r_2} \sum_{1}^{r_1} U_0} = \prod_{1}^{r_m} \cdots \prod_{1}^{r_2} \prod_{1}^{r_1} \prod_{l=1}^{s} \prod_{j=1}^{n} i_{\upsilon_j^l}^{\overline{f_U^1} \cdot \overline{f_U^2} \cdots \overline{f_U^m}} \quad (2)$$

where $r_1, r_2, \ldots, r_m$ is the number of totality parts (for example, r_1 is the number of enterprises in the complex, r_2 -is the number of complexes in the corporation, etc.);

n is the number of time segments that the analyzed period is divided in;

$U = \prod_{l=1}^{s} \upsilon^l$ -additive factors;

υ^l - multiplicative factors $\left(l = \overline{1,s}\right)$;

s - the number of multiplicative factors making corresponding additive factor U;

$i_{\upsilon_j^l}$ - the individual index of the factor υ^l during the period $[j-1, j]$;

$\overline{f_U^1} \cdot \overline{f_U^2} \cdots \overline{f_U^m}$ - average shares U for the intervals $[j-1, j]$ of the corresponding structural subdivision in the total value of this factor in the production formation (for example, $\overline{f_U^1}$ is the average share of the factor U of

the enterprise in the total value of this factor in the complex; $\overline{f_U^2}$ is the average share of the factor U of the enterprise in the summary value of this factor in the corporation; ..., $\overline{f_U^m}$ is the average share of the factor U of the structural subdivision of the level m of the hierarchy in the total value of this factor in the production formation, for example, the average share of the factor U in the group of corporations in their totality in the region.

To calculate the indicators of the degree $\overline{f_U}$, indexes $i_{\upsilon_j^l}$ we can only use three different methods described in scientific works and text-books on statistics to define the average chronological value of the moment series of dynamics in the following situations: piece-linear changes f_U; in case of small changes f_U half-sum of its levels at the beginning and at the end of the period; assuming exponential changes f_U.

Using a simple numerical example the authors illustrate the assessment behavior of the factors impact (T - labor costs, W - productivity) on the dynamics of the productive indicator (Q - volume of output) of two enterprises defined by different methods and ways of DFA on the assumption of the following alternatives: 1) simultaneous change or single-stage sequence of factors during the whole period; 2) quarterly refined dynamics of simultaneous or step-by-step factors development (Table 1).

Table 1. The indicators of the enterprise activities for the calendar reported year and astronomic years at the beginning and at the end of every quarter of the reported year

Enterprise	Indicators	Year levels at the beginning and at the end of the quarters of the reported year				
		1.01	1.04	1.07	1.10	31.12
A	**B**	**1**	**2**	**3**	**4**	**5**
1	*Q* -the volume of output, thousand rubles	17664	15789	14372	13991	13721
	f - the share in association	0,62770	0,54825	0,50005	0,50201	0,47925
	T - the number of workers	369	366	352	340	342
	W -output/worker, thousand rubles	47,87	43,14	40,83	41,15	40,12
2	*Q* - the volume of output, thousand rubles	10477	13010	14369	13879	14909
	f - the share in association	0,32230	0,45175	0,49995	0,49799	0,52075
	T - the number of workers	223	225	243	249	257
	W - output/worker, thousand rubles	46,98	57,82	59,13	55,74	58,01

Totally in association	*Q* - the volume of output, thousand rubles	28141	28799	28741	28870	28630
	T - the number of workers	592	591	595	589	599
	W - output/worker, thousand rubles	47,54	48,73	48,30	47,32	47,80

With the data from Table 1 the formula will be:

$$I_Q = \frac{\sum_{r=1}^{2} Q_4^r}{\sum_{r=1}^{2} Q_0^r} = \prod_{r=1}^{2}\prod_{j=1}^{4}\left(\frac{Q_j^r}{Q_{j-1}^r}\right)^{\overline{f_j^r}} = \prod_{r=1}^{2}\prod_{j=1}^{4} i_{T_j^r}^{\overline{f_j^r}} \cdot i_{W_j^r}^{\overline{f_j^r}}, \quad (3)$$

where r is the number of the enterprise;

$\overline{f_j^r} = \frac{1}{2}\left(\frac{Q_{j-1}^r}{\sum_{r=1}^{2} Q_{j-1}^r} + \frac{Q_j^r}{\sum_{r=1}^{2} Q_j^r}\right)$ - the average share of the enterprise output r in the association in j-quarter $[j-1, j]$;

$i_{T_j^r}$, $i_{W_j^r}$ or i_{T^r}, i_{W^r} are individual indexes of the number of the workers and the efficiency of labour for the dynamics of the result Q of the enterprise r for the quarter $[j-1, j]$ or the whole reported year;

$\prod_{r=1}^{2} i_{T_j^r}^{\overline{f_j^r}}$ и $\prod_{r=1}^{2} i_{W_j^r}^{\overline{f_j^r}}$ - assessment of the changes influence of labour costs and productivity of two enterprises on the value of the output index of the complex for the quarter of a year $[j-1, j]$;

$\prod_{r=1}^{2}\prod_{j=1}^{4} i_{T_j^r}^{\overline{f_j^r}}$ и $\prod_{r=1}^{2}\prod_{j=1}^{4} i_{W_j^r}^{\overline{f_j^r}}$ - assessment of the changes influence of each factor T and W on the value of the output index of the complex for a year.

You can see the single and total values of the changes influence of the factors on the dynamics of the productive indicator in Table 2.

Table 2. The values of the influence of the factors *T* and *W* enterprises on the dynamics of the output obtained by integral method

Enterprises	Indicators	At the end of quarters of the reported year				During the whole period
		I	II	III	IV	(1.01 - 31.12)

A	B	1	2	3	4	$5=1\cdot2\cdot3\cdot4$
1	*T*	0,9952	0,9798	0,9828	1,0029	0,961
	W	0,9407	0,9716	1,0039	0,9876	0,906
	Q	0,9361	0,9519	0,9866	0,9905	0,871
2	*T*	1,0037	1,0373	1,0122	1,0162	1,071
	W	1,0893	1,0107	0,9710	1,0205	1,091
	Q	1,0933	1,0484	0,9828	1,0371	1,168
Totally in association	*T*	0,9989	1,0163	0,9948	1,0192	1,0291
	W	1,0247	0,9820	0,9748	1,0079	0,9882
	Q	1,0234	0,9980	0,9697	1,0273	1,017

Final assessments of the influence of factors on the dynamics of the productive indicator are located in the intersection of the column 5 with the last three of its lines.

Checking the index equality of the productive indicator $\left(\frac{28630}{28141}=1{,}017\right)$ to the product of the multiplicative components of its factor decomposition confirms the correctness of calculations made by all four methods specified in the columns of Table 3: the first and the second $(1{,}011\cdot1{,}006=1{,}017)$; the third and the fourth $(1{,}021\cdot0{,}996=1{,}017)$; the fifth and the sixth $(1{,}027\cdot0{,}990=1{,}017)$; the seventh and the eighth $(1{,}029\cdot0{,}988=1{,}017)$.

As Table 3 contains information on quarterly simultaneous (parallel) changes of the year levels of the factor indicators but not on step-by-step changes, the results obtained with the help of the integral method in the graphs 3, 4 of Table 3 show the results of the multidirectional impact of the factors: T – towards the increase and W towards the decrease of the productive indicator Q more exactly than the factor assessments of the index method in the graphs 1, 2 provoking the false impression of the unidirectional impact of the factors T and W towards the increase of Q.

The results obtained after implementing astronomical quarterly annual levels in DFA using the index method - in columns 5, 6, and – the integral one in columns 7, 8, are significantly different from the previous ones, while maintaining the priority opinion that the influence of the factors is multidirectional: T - towards the increase of Q and W – towards its decrease.

Both methods even with a small split of the reported period (in quarters) rather than the more significant (in months, decades) gave very similar and more accurate multiplicative components assessment results of the factor decomposition in the index of the productive indicator.

Discussions

The study of literature allows the authors to conclude that the analysis methods of the relationship of socio-economic phenomena and processes are widely applied to any object in the final stage of the study (Arjomand, Emami & Salimi, 2016; Procházka & Čermáková, 2015; Savić & Zubović, 2015; Mahlberg et al., 2013; Moskowitz, Yao & Pedersen, 2012).

In the traditional method of determined factor analysis is the premise of the conditional order of influence factors (Artemenko & Anisimova, 2011; Lebedev, 2012; Prokofyev, Nosov & Salomatina, 2014). K.N. Lebedev (2012) and N.P. Lubushin (2010) offered a different approach, characterizing the degree of participation of the considered factors in the assessment of the result. However, integral methods, focused on the simultaneous change of factorial indicators, along with the traditional have a theoretical disadvantage - take into account the intermittent nature of the change factors.

The paper proposes a generalized method of determined factor analysis (DPA) in the study of the relationship of economic phenomena. The authors illustrate ways to improve the accuracy of the results of DFA, and a mathematically reasonable classification of categories in absolute and relative rate changes of economic indicators depending on the method of comparing the distance and the time of their levels. The concept of trend levels measured for "astronomical" periods allows recognizing the legitimate application of higher mathematics for continuous functions in the development and improvement of methods of DFA. The authors also highlight useful features of the generalized method of DFA to broaden and deepen the scope of its application

The article represents methodological aspects in solving development problems of determined factor analysis, which have not been considered in previous studies.

Conclusion

The research showed that the generalized integral DFA method is characterized not only by high accuracy of factor values but also by other positive qualities, which make it possible to develop and widen the sphere of its use. Because of its construction containing the product of factor values for the periods of time of the reported period it is possible to make comparative analysis of the factors influence on the productive indicator of any level of the studied economic system for sub-periods of the same and different duration.

The next peculiarity is the availability of the determining factors influence assessment of structural unit at any level of the hierarchy in complex production formation on a productive indicator. At the same time factor assessment forms the system of interrelated variables which allows obtaining assessment for the industrial formations of higher level (enterprises, complexes, definite economic activities) from assessment of the factors for the structural divisions of lower level. This ensures the possibility of deepening the comparative analysis of factorial assessment not only in time but also in space, exploring the effect of similar factors for different departments within the same productive formation.

The principal assumptions and the generalized DFA method are free of conservatism and subjectivity inherent in the traditional method, and therefore it has a high degree of improvement, modernization and adaptation in relation to determined modeling of the relationship of economic indicators having any complexity.

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