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Modified Method of Chain Substitutions as an Alternative to the Integral Method of Economic Analysis

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ABSTRACT

The **aim** is to present the results of the development of a modified method of chain substitutions, which is based on the use of the arithmetic mean sum of the results of the influence of each factor on the indicator of interest, taking into account the priority of each factor in all possible variants. At the same time, from the point of view of accuracy, the results obtained using the modified technique practically do not differ from the results of the integral method, however, they exceed it in terms of using a simpler mathematical apparatus. The **relevance** of the work is determined by the fact that in modern economic conditions (noticeably increased inflation, problems with energy prices), the issue of applying methods of deterministic factor analysis of expenses and incomes becomes especially significant in order to determine the size of the impact of each factor on a specific economic indicator as accurately as possible. However, the chain substitution method used in the vast majority of cases for deterministic factor analysis is inferior in accuracy to the integral method. The **scientific novelty** of the work lies in the fact that the author uses strict mathematical proofs of the coincidence of the accuracy of the results of the modified methodology and the integral method for various types of deterministic factor models (additive, multiplicative, multiple), which are supported by real practical calculations. **Conclusions**: the proposed modified method of chain substitutions, due to its mathematical simplicity and proven accuracy of the results obtained, can be widely used in real practical calculations using methods of economic analysis, especially taking into account the computer implementation of algorithms developed in this technique.

Keywords: factor analysis; the method of chain substitutions; integral method; modified methodology

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INTRODUCTION

Recent political events, the conflict with Ukraine, numerous Western sanctions against Russia, problems in the energy sector have already caused and, most likely, will still cause serious changes in the economic life of not only individual countries, but also entire continents.

The inevitable increase in prices due to a lack of resources, rapidly growing inflation cause a completely natural desire not so much to reduce expenses, but to determine by changing which factors the largest share of the increase in the expenditure part of the economic indicator of interest occurs [1–11].

All these examples show that of all the methods of economic analysis, the method of deterministic factor analysis is now gaining the most importance, which will make it possible to quantify the influence of individual factors on the performance indicator of interest. It is obvious that the desire to determine the influence of factors on the result as accurately as possible is completely justified, especially in the current difficult conditions. That is why you should carefully consider the choice of factor analysis method, which will allow you to achieve your goal: accurately determine the influence of each factor on the economic indicator [12–19].

Most often in practice, the chain substitution method (further — CSM) is used. This is explained by its mathematical simplicity and accessibility. However, the CSM also has a significant drawback: the size of the influence of each factor on the result will largely depend, in fact, on the chosen order of changing the arguments in the factor model of the indicator [20]. From a theoretical point of view, an accurate quantitative determination of the influence of factors on the result can be obtained using the integral method (further —IM) [20], however, from a mathematical point of view it is quite complex.

This is where the idea of setting the task in this paper arises — to develop a method of factor analysis that:

1) on the one hand, would have sufficient accuracy in assessing the influence of a factor on the result;

2) on the other hand, it would be quite simple from the point of view of its mathematical tools.

It should be noted that in the works of V. Mitev [21, 22] an attempt was made to solve such a problem, however, from our point of view, it lacks a mathematically rigorous assessment of the accuracy of the results obtained in comparison with classical IM.

PROBLEM STATEMENT

In the practice of applying economic analysis, additive, multiplicative and multiple factor models are most often used. This is most clearly manifested in the financial analysis of accounting reporting forms. For example, expression:

$$R - C = P_g.$$

or

$$R - C - SE - AE = P_s,$$

where P_g и P_s — gross profit and from sales, a R, C, SE, AE — revenue, cost, selling and administrative expenses are additive models.

In turn, the expression for revenue

$$R = p \cdot Q,$$

where p — is the product price, a Q — is its volume — an example of a multiplicative model.

Expressions for different types of profitability (P_R):

$$P_R = P/R,$$

where P — various types of profit, provide examples of multiple factor models.

Thus, in order to achieve the goals set in the work, it is necessary to compare the results of factor analysis for all the above-mentioned models for CSM with similar results for IM in terms of the accuracy obtained.

THEORETICAL ANALYSIS

1. Consider an additive model for a two-factor indicator

$$F_1 = f_1(A,B) = A + B. \quad (1)$$

We applied CSM factor analysis with *factor priority, i.e. when the change in factor A is used first in the chain of substitutions in model (1)*. Then the change in the indicator F_1 will be determined as

$$\Delta F_{1\,CSM}^{A} = \Delta F_{1\,CSM}^{A}(\Delta A) + \Delta F_{1\,CSM}^{A}(\Delta B),$$

where $\Delta F_{1\,CSM}^{A}$ — общее изменение показателя F_1 with priority of indicator A;

$\Delta F_{1\,CSM}^{A}(\Delta A)$ — change in indicator F_1 due to change in factor A;

$\Delta F_{1\,CSM}^{A}(\Delta B)$ — change in indicator F_1 change in indicator B.

Then, according to the rules of the CSM method [20], we obtain:

$$\Delta F_{1\,CSM}^{A}(\Delta A) = (A_1 - B_0) - (A_0 - B_0) = A_1 - A_0, \quad (2)$$

$$\Delta F_{1\,CSM}^{A}(\Delta B) = (A_1 - B_1) - (A_1 - B_0) = B_0 - B_1, \quad (3)$$

where index 0 determines the value of the factor in the base period, and index 1 — in the current one.

Next, we applied factor analysis (1) using the same method (CSM) *with the priority of factor B, when the change in factor B is used first in the chain of substitutions in model (1)*. Then the change in the indicator will be determined as

$$\Delta F_{1\,CSM}^{B} = \Delta F_{1\,CSM}^{B}(\Delta B) + \Delta F_{1\,CSM}^{B}(\Delta A),$$

where

$$\Delta F_{1\,CSM}^{B}(\Delta B) = (A_0 - B_1) - (A_0 - B_0) = B_0 - B_1, \quad (4)$$

$$\Delta F_{1\,CSM}^{B}(\Delta A) = (A_1 - B_1) - (A_0 - B_1) = A_1 - A_0. \quad (5)$$

Comparing (2) and (5), as well as (3) and (4), it is obvious that the results obtained using CSM for both factors in both options are absolutely the same, so the use of IM is not required here.

2. Let us now consider the multiplicative model for a two-factor indicator. Application of CSM for such a model:

$$F_2 = f_2(A,B) = A \cdot B \quad (6)$$

with priority of the factor A leads to the result:

$$\Delta F_{2\,CSM}^{A} = \Delta F_{2\,CSM}^{A}(\Delta A) + \Delta F_{2\,CSM}^{A}(\Delta B),$$

$$\Delta F_{2\,CSM}^{A}(\Delta A) = (A_1 \cdot B_0) - (A_0 \cdot B_0) = (A_1 - A_0) \cdot B_0, \quad (7)$$

$$\Delta F_{2\,CSM}^{\,A}(\Delta B) = (A_1 \cdot B_1) - (A_1 \cdot B_0) = A_1 \cdot (B_1 - B_0). \tag{8}$$

However, applying the CSM to model (6) with factor priority B gives a completely different result:

$$\Delta F_{2\,CSM}^{\,B} = \Delta F_{2\,CSM}^{\,B}(\Delta B) + \Delta F_{2\,CSM}^{\,B}(\Delta A),$$

$$\Delta F_{2\,CSM}^{\,B}(\Delta B) = (B_1 \cdot A_0) - (B_0 \cdot A_0) = (B_1 - B_0) \cdot A_0, \tag{9}$$

$$\Delta F_{2\,CSM}^{\,B}(\Delta A) = (B_1 \cdot A_1) - (B_1 \cdot A_0) = B_1 \cdot (A_1 - A_0). \tag{10}$$

Comparison of (7) and (10), (8) and (9) reflects the very significant drawback of CSM, which was mentioned above — the size of the factor's influence on the indicator will greatly depend on the *chosen priority (in fact, the order of change) of the factor in the indicator model.*

The size of the influence of each factor on the indicator, calculated according to the IM rules [20] applied to model (6), gives the following result:

$$\Delta F_{2\,IM}(\Delta A) = B_0 \cdot (A_1 - A_0) + \frac{(A_1 - A_0) \cdot (B_1 - B_0)}{2} = \frac{(A_1 - A_0) \cdot (B_0 + B_1)}{2}, \tag{11}$$

$$\Delta F_{2\,IM}(\Delta B) = A_0 \cdot (B_1 - B_0) + \frac{(A_1 - A_0) \cdot (B_1 - B_0)}{2} = \frac{(B_1 - B_0) \cdot (A_0 + A_1)}{2}. \tag{12}$$

Let us prove that the results obtained using IM coincide with the arithmetic average of the results obtained using CSM using the priority of both factors. Then

$$\left[\Delta F_{2\,CSM}^{\,A}(\Delta A) + \Delta F_{2\,CSM}^{\,B}(\Delta A)\right] \cdot \frac{1}{2} = \frac{(A_1 - A_0) \cdot B_0 + B_1 \cdot (A_1 - A_0)}{2} = \frac{(A_1 - A_0) \cdot (B_0 + B_1)}{2}. \tag{13}$$

When comparing (11) and (13), we can clearly conclude that

$$\Delta F_{2\,IM}(\Delta A) = \left[\Delta F_{2\,CSM}^{\,A}(\Delta A) + \Delta F_{2\,CSM}^{\,B}(\Delta A)\right] \cdot \frac{1}{2}.$$

In a similar way it can be determined that

$$\left[\Delta F_{2\,CSM}^{\,A}(\Delta B) + \Delta F_{2\,CSM}^{\,B}(\Delta B)\right] \cdot \frac{1}{2} = \frac{A_1 \cdot (B_1 - B_0) + (B_1 - B_0) \cdot A_0}{2} = \frac{(B_1 - B_0) \cdot (A_0 + A_1)}{2}. \tag{14}$$

Then, comparing (12) and (14), we can make the same unambiguous conclusion that

$$\Delta F_{2\,IM}(\Delta B) = \left[\Delta F_{2\,CSM}^{\,A}(\Delta B) + \Delta F_{2\,CSM}^{\,B}(\Delta B)\right] \cdot \frac{1}{2}.$$

Thus, the results of factor analysis of a two-factor multiplicative model obtained using IM coincide with the arithmetic mean sum of the results obtained for the same model using CSM in both versions of economic analysis, each of which uses the priority of a certain factor.

3. Let us further consider the use of both methods of economic analysis (CSM and IM) for factor analysis of a three-factor multiplicative model

$$F_3 = f_3(A, B, C) = A \cdot B \cdot C. \tag{15}$$

Obviously, the number of priority options that determine the order of influence of factors *A, B* and *C* on the F_3 indicator will be equal to the number of permutations of factors in the model record (15). where *n* — is the number of factors, so the number of priority options for model (15) will be $3! = 6$. Then

$$F_3 = A \cdot B \cdot C = A \cdot C \cdot B = B \cdot A \cdot C = B \cdot C \cdot A = C \cdot A \cdot B = C \cdot B \cdot A. \tag{16}$$

The methodology for comparing the results obtained from CSM and IM will be as follow:

1) first, we will conduct a factor analysis of model (15) according to CSM for each of the six options with priority, for example, factor *A*, in order to determine the arithmetic mean sum of the results of the influence of changes in factor *A* on the F_3 indicator

$$\overline{\Delta F_{3\,CSM}(\Delta A)} = \left[\Delta F_{3\,CSM}^{\,A}(A,B,C) + \Delta F_{3\,CSM}^{\,A}(A,C,B) + \Delta F_{3\,CSM}^{\,A}(B,A,C) + \right.$$
$$\left. + \Delta F_{3\,CSM}^{\,A}(B,C,A) + \Delta F_{3\,CSM}^{\,A}(C,A,B) + \Delta F_{3\,CSM}^{\,A}(C,B,A)\right] \cdot \frac{1}{6}; \tag{17}$$

2) we will conduct a factor analysis of model (15) according to IM to determine the result: the change in the F_3 indicator when the same changes factor *A*: $\Delta F_{3\,IM}(\Delta A)$;

3) the obtained result must be compared with $\overline{\Delta F_{3\,CSM}(\Delta A)}$ and the equality

$$\Delta F_{3\,IM}(\Delta A) = \overline{\Delta F_{3\,CSM}(\Delta A)} \text{ checked.}$$

Let us determine the influence of factor *A* on the F_3 indicator in each of the options (16):

$$\Delta F_{3\,CSM}^{\,A}(A,B,C) = A_1 \cdot B_0 \cdot C_0 - A_0 \cdot B_0 \cdot C_0 = (A_1 - A_0) \cdot B_0 \cdot C_0 = \Delta A \cdot B_0 \cdot C_0,$$

$$\Delta F_{3\,CSM}^{\,A}(A,C,B) = A_1 \cdot C_0 \cdot B_0 - A_0 \cdot C_0 \cdot B_0 = (A_1 - A_0) \cdot C_0 \cdot B_0 = \Delta A \cdot C_0 \cdot B_0,$$

$$\Delta F_{3\,CSM}^{\,A}(B,A,C) = B_1 \cdot A_1 \cdot C_0 - B_1 \cdot A_0 \cdot C_0 = (A_1 - A_0) \cdot B_1 \cdot C_0 = \Delta A \cdot B_1 \cdot C_0,$$

$$\Delta F_{3\,CSM}^{\,A}(B,C,A) = B_1 \cdot C_1 \cdot A_1 - B_1 \cdot C_1 \cdot A_0 = (A_1 - A_0) \cdot B_1 \cdot C_1 = \Delta A \cdot B_1 \cdot C_1,$$

$$\Delta F_{3\,CSM}^{\,A}(C,A,B) = C_1 \cdot A_1 \cdot B_0 - C_1 \cdot A_0 \cdot B_0 = (A_1 - A_0) \cdot C_1 \cdot B_0 = \Delta A \cdot C_1 \cdot B_0,$$

$$\Delta F_{3\,CSM}^{\,A}(C,B,A) = C_1 \cdot B_1 \cdot A_1 - C_1 \cdot B_1 \cdot A_0 = (A_1 - A_0) \cdot C_1 \cdot B_1 = \Delta A \cdot C_1 \cdot B_1.$$

Simple transformations when using the results obtained in (17) lead to the determination of the arithmetic mean sum of the results of the influence of changes in factor *A* on the F_3 indicator in all options (16) with the priority of factor *A*:

$$\overline{\Delta F_{3\,CSM}(\Delta A)} = \left[\Delta A \cdot B_0 \cdot C_0 + \Delta A \cdot C_0 \cdot B_0 + \Delta A \cdot B_1 \cdot C_0 + \Delta A \cdot B_1 \cdot C_1 + \right.$$
$$\left. + \Delta A \cdot C_1 \cdot B_0 + \Delta A \cdot C_1 \cdot B_1 \right] \cdot \frac{1}{6} = \tag{18}$$
$$= \frac{1}{6} \cdot \Delta A \cdot B_1 \cdot C_0 + \frac{1}{6} \cdot \Delta A \cdot C_1 \cdot B_0 + \frac{1}{3} \cdot \Delta A \cdot C_1 \cdot B_1 + \frac{1}{3} \cdot \Delta A \cdot B_0 \cdot C_0 .$$

Let us now determine the change in indicator F_3 when the same factor A changes using IM, using the rules of factor analysis of this method [20] applied to model (15):

$$\Delta F_{3\,IM}(\Delta A) = \frac{1}{2} \cdot \Delta A \cdot \left(B_1 \cdot C_0 + B_0 \cdot C_1\right) + \frac{1}{3} \cdot \Delta A \cdot \Delta B \cdot \Delta C .$$

Using the substitutions in the last equality

$$\Delta A = A_1 - A_0; \quad \Delta B = B_1 - B_0; \quad \Delta C = C_1 - C_0; \tag{19}$$

opening the brackets in it and bringing similar ones, we get the final result:

$$\Delta F_{3\,IM}(\Delta A) = \frac{1}{6} \cdot \Delta A \cdot B_1 \cdot C_0 + \frac{1}{6} \cdot \Delta A \cdot C_1 \cdot B_0 + \frac{1}{3} \cdot \Delta A \cdot C_1 \cdot B_1 + \frac{1}{3} \cdot \Delta A \cdot B_0 \cdot C_0 , \tag{20}$$

which completely coincides with the result (18).

Using the same methodology, we will determine the influence of factor B on the F_3 indicator using CSM in each of the options (16):

$$\Delta F_{3\,CSM}^{\;B}(A,B,C) = (B_1 - B_0) \cdot A_1 \cdot C_0 = \Delta B \cdot A_1 \cdot C_0 ,$$

$$\Delta F_{3\,CSM}^{\;B}(A,C,B) = (B_1 - B_0) \cdot A_1 \cdot C_1 = \Delta B \cdot A_1 \cdot C_1 ,$$

$$\Delta F_{3\,CSM}^{\;B}(B,A,C) = (B_1 - B_0) \cdot A_0 \cdot C_0 = \Delta B \cdot A_0 \cdot C_0 ,$$

$$\Delta F_{3\,CSM}^{\;B}(B,C,A) = (B_1 - B_0) \cdot C_0 \cdot A_0 = \Delta B \cdot C_0 \cdot A_0 ,$$

$$\Delta F_{3\,CSM}^{\;B}(C,A,B) = (B_1 - B_0) \cdot C_1 \cdot A_1 = \Delta B \cdot C_1 \cdot A_1 ,$$

$$\Delta F_{3\,CSM}^{\;B}(C,B,A) = (B_1 - B_0) \cdot C_1 \cdot A_0 = \Delta B \cdot C_1 \cdot A_0 .$$

Then the arithmetic mean sum of the influence of changes in factor B on the F_3:

$$\overline{\Delta F_{3\,CSM}(\Delta B)} = \frac{1}{6} \cdot \Delta B \cdot A_1 \cdot C_0 + \frac{1}{6} \cdot \Delta B \cdot C_1 \cdot A_0 + \frac{1}{3} \cdot \Delta B \cdot A_1 \cdot C_1 + \frac{1}{3} \cdot \Delta B \cdot A_0 \cdot C_0 . \tag{21}$$

Change in F_3 when changing the same factor B with IM:

$$\Delta F_{3\,IM}(\Delta B) = \frac{1}{2} \cdot \Delta B \cdot \left(A_0 \cdot C_1 + A_1 \cdot C_0\right) + \frac{1}{3} \cdot \Delta A \cdot \Delta B \cdot \Delta C .$$

Using substitutions (19) and corresponding transformations in the last equality, we obtain:

$$\Delta F_{3\ IM}(\Delta B) = \frac{1}{6}\cdot\Delta B\cdot A_1\cdot C_0 + \frac{1}{6}\cdot\Delta B\cdot C_1\cdot A_0 + \frac{1}{3}\cdot\Delta B\cdot A_1\cdot C_1 + \frac{1}{3}\cdot\Delta B\cdot A_0\cdot C_0\,, \tag{22}$$

which completely coincides with the result (21).

In the same way, the influence of factor C on the F_3 with indicator is determined using CSM in each of the options (16):

$$\Delta F_{3\ CSM}^{\ C}(A,B,C) = \Delta C\cdot A_1\cdot B_1\,;\ \Delta F_{3\ CSM}^{\ C}(A,C,B) = \Delta C\cdot A_1\cdot B_0\,;\ \Delta F_{3\ CSM}^{\ C}(B,A,C) = \Delta C\cdot B_1\cdot A_1\,;$$

$$\Delta F_{3\ CSM}^{\ C}(B,C,A) = \Delta C\cdot B_1\cdot A_0\,;\ \Delta F_{3\ CSM}^{\ C}(C,A,B) = \Delta C\cdot A_0\cdot B_0\,;\ \Delta F_{3\ CSM}^{\ C}(C,A,B) = \Delta C\cdot B_0\cdot A_0$$

and the arithmetic mean sum of the influence of changes in factor C on the F_3:

$$\overline{\Delta F_{3\ CSM}(\Delta C)} = \frac{1}{6}\cdot\Delta C\cdot A_1\cdot B_0 + \frac{1}{6}\cdot\Delta C\cdot B_1\cdot A_0 + \frac{1}{3}\cdot\Delta C\cdot A_1\cdot B_1 + \frac{1}{3}\cdot\Delta C\cdot A_0\cdot B_0\,. \tag{23}$$

Change in F_3 when changing the same factor C with IM:

$$\Delta F_{3\ IM}(\Delta C) = \frac{1}{2}\cdot\Delta C\cdot\left(A_0\cdot B_1 + A_1\cdot B_0\right) + \frac{1}{3}\cdot\Delta A\cdot\Delta B\cdot\Delta C\,,$$

using replacement (19) and the corresponding transformations is reduced to the form:

$$\Delta F_{3\ IM}(\Delta C) = \frac{1}{6}\cdot\Delta C\cdot A_1\cdot B_0 + \frac{1}{6}\cdot\Delta C\cdot B_1\cdot A_0 + \frac{1}{3}\cdot\Delta C\cdot A_1\cdot B_1 + \frac{1}{3}\cdot\Delta C\cdot A_0\cdot B_0\,, \tag{24}$$

which completely coincides with the result (23).

Comparing the results (18) and (20), (21) and (22), (23) and (24) we can draw an unambiguous conclusion. For a three-factor multiplicative model we obtain the same result as for a two-factor model: the arithmetic mean sum of the results of the influence of changes of a certain factor by the F_3 indicator in all priority options using CSM coincides with the change in the F_3 indicator when changing the same factor using IM.

Using a similar technique for multiplicative models with 4 or more factors, we obviously come to the same conclusion as made above. This means that in practical calculations of economic analysis of multiplicative models, the complex algorithm of the integral method can be successfully replaced by the much simpler, modified method of chain substitutions discussed above.

4. Let us further consider the use of the methodology given in paragraph 3 of this work to compare the results of the influence of factors on the indicator using both methods, obtained by analyzing a two-factor multiple model. Typically, such a model is used to assess the effectiveness of financial and economic activities using the profitability indicator.

We wrote the gross profitability indicator (PR_g) in the form:

$$PR_g = \frac{P_g}{R} = \frac{R-C}{R} = 1-\frac{C}{R} = PR_g = f\,(C,R)\,, \tag{25}$$

to use only independent factors. Let's determine the influence of factor C the PR_g on CSM with the priority of factor C:

$$\Delta PR^{C}_{g.CSM}(\Delta C) = \left(1-\frac{C_1}{R_0}\right)-\left(1-\frac{C_0}{R_0}\right) = \frac{C_0-C_1}{R_0}$$

and with the priority of factor R

$$\Delta PR^{R}_{g.CSM}(\Delta C) = \left(1-\frac{C_1}{R_1}\right)-\left(1-\frac{C_0}{R_1}\right) = \frac{C_0-C_1}{R_1}.$$

Let us now determine the influence of factor C on the PR_g according to the rules of IM [20] as applied to model (25):

$$\Delta PR_{g.IM}(\Delta C) = \frac{C_0-C_1}{R_1-R_0}\cdot Ln\left|\frac{R_1}{R_0}\right|. \tag{26}$$

Following the above methodology, it is necessary to compare the arithmetic mean sum of the impact of changes in factor C the PR_g on the indicator for both priority CSM options

$$\overline{\Delta PR_{g.CSM}(\Delta C)} = \left[\Delta PR^{C}_{g.CSM}(\Delta C)+\Delta PR^{R}_{g.CSM}(\Delta C)\right]\cdot\frac{1}{2} = \left(\frac{C_0-C_1}{R_0}+\frac{C_0-C_1}{R_1}\right)\cdot\frac{1}{2} \tag{27}$$

with results (26).

Let us transform (27) as follows:

$$\overline{\Delta PR_{g.CSM}} = \left(\frac{C_0-C_1}{R_0}+\frac{C_0-C_1}{R_1}\right)\cdot\frac{1}{2} = \frac{C_0-C_1}{R_1-R_0}\cdot\left(\frac{R_1-R_0}{R_0}+\frac{R_1-R_0}{R_1}\right)\cdot\frac{1}{2} = \tag{28}$$
$$= \frac{C_0-C_1}{R_1-R_0}\cdot\frac{1}{2}\cdot\left(\frac{R_1}{R_0}-\frac{R_0}{R_1}\right).$$

Comparing expressions (26) and (28), it is obvious that the difference in their values will be determined by the difference in the values of the two functions: $f_1(x,y) = \frac{1}{2}\cdot\left(\frac{y}{x}-\frac{x}{y}\right)$ and $f_2(x,y) = Ln\frac{y}{x}$, where $x = R_0$, but $y = R_1$. Thus, from a mathematical point of view, the difference in values $\overline{\Delta PR_{g.CSM}(\Delta C)}$ and $\Delta PR_{g.IM}(\Delta C)$ will depend on the behavior of the function $f_1(x,y)$ and the function $f_2(x,y)$ in the certain points.

Let us denote $\frac{y}{x} = t$ and expand the function $f_1(t) = \frac{1}{2}\cdot\left(t-\frac{1}{t}\right)$ and the function $f_2(t) = Ln\,t$ in a Taylor series in the points. While $t_0 = \frac{y_0}{x_0} = 1$. $y_0 = R_1$ and $x_0 = R_0$ determine the values of revenue in the current and base periods, then the point $t_0 = 1$ will be determined by the proximity of the values R_0 and R_1, which is quite possible in most practical cases of implementing Form 2 of financial statements. Then, according to the rules for expanding a function into a Taylor series [23]:

$$f(t) = f(t_0-1)+\frac{f'(t_0)}{1!}\cdot(t-1)+\frac{f''(t_0)}{2!}\cdot(t-1)^2+\frac{f'''(t_0)}{3!}\cdot(t-1)^3+\frac{f^{(4)}(t_0)}{4!}\cdot(t-1)^4+\ldots,$$

after calculating the derivatives we obtain a series for the function $f_1(t)$:

$$f_1(t) = 0 + 1\cdot(t-1) - \frac{1}{2!}\cdot(t-1)^2 + \frac{3}{3!}\cdot(t-1)^3 - \frac{12}{4!}\cdot(t-1)^4 + \ldots \quad (29)$$

We also expand the function $f_2(t) = Ln\,t$ into a Taylor series in point $t_0 = 1$, as a result for the function $f_2(t)$ we get:

$$f_2(t) = 0 + 1\cdot(t-1) - \frac{1}{2!}\cdot(t-1)^2 + \frac{2}{3!}\cdot(t-1)^3 - \frac{6}{4!}\cdot(t-1)^4 + \ldots \quad (30)$$

Comparing expressions (29) and (30) we can clearly say that a slight difference in the values of $f_1(t)$ and $f_2(t)$ will occur only in the fourth and fifth terms of series (29) and (30). From here, returning to the comparison of expressions (26) and (28), an important economic conclusion follows: in practical problems, the value $\Delta PR_{g.IM}(\Delta C)$ м can be replaced with a sufficient degree of accuracy by the value $\overline{\Delta PR_{g.CSM}(\Delta C)}$:

$$\Delta PR_{g.IM}(\Delta C) \cong \overline{\Delta PR_{g.CSM}(\Delta C)} = \left[\Delta PR^{C}_{g.CSM}(\Delta C) + \Delta PR^{R}_{g.CSM}(\Delta C)\right]\cdot\frac{1}{2}.$$

Since, within the meaning of factor analysis, the total change in the indicator (in this case PR_g) is defined as the sum of changes in both factors (regardless of their priority).

$$\Delta PR_g = \Delta PR_g(\Delta C) + \Delta PR_g(\Delta R) = \Delta PR_g(\Delta R) + \Delta PR_g(\Delta C),$$

when $\Delta PR_g(\Delta C) = \overline{\Delta PR_{g.CSM}(\Delta C)} = \Delta PR_{g.IM}(\Delta C)$, as proven above, the result of the influence of factor R on the PR_g determined with IM — $\Delta PR_{g.IM}(\Delta R)$, can in the same way be replaced in practical calculations by $\overline{\Delta PR_{g.CSM}(\Delta R)}$ — the arithmetic mean sum of changes in the PR_g when factor R changes for both priority CSM options

$$\Delta PR_{g.CSM}(\Delta R) = \overline{\Delta PR_{g.CSM}(\Delta R)} = \frac{1}{2}\cdot\left[\Delta PR^{R}_{g.CSM}(\Delta R) + \Delta PR^{C}_{g.CSM}(\Delta R)\right].$$

Thus, the total change in the PR_g indicator in the two-factor model (25) will be determined by the sum

$$\Delta PR_g = \overline{\Delta PR_{g.CSM}(\Delta C)} + \overline{\Delta PR_{g.CSM}(\Delta R)}.$$

5. The three-factor multiple model, which is most often used in practice, is an expression for return on sales (PR_s)

$$PR_s = \frac{R - C - CAE}{R}, \quad (31)$$

when CAE — the amount of commercial and administrative expenses. Then (31) can be written in the form

$$PR_s = 1 - \frac{C}{R} - \frac{CAE}{R}. \quad (32)$$

Then $1 - \frac{C}{R} = PR_g(C, R)$, a $\left(-\frac{CAE}{R}\right) = f\,(CAE, R)$ — a function of independent variables CAE and R, then the indicator PR_s can be written as the sum of two terms

$$PR_s = PR_g(C,R) + f\,(CAE,R),$$

where each term is a two-factor multiple model, the economic analysis of which was discussed in detail in paragraph 4 of the section "Theoretical analysis" of this work. Therefore, the result of factor analysis of the indicator P_s will be determined by the amount:

$$\Delta PR_s = \Delta PR_g + \Delta f\,(CAE,R), \tag{33}$$

moreover, each of the terms (33) represents the arithmetic average sum of changes in indicators $PR_g(C,R)$ and $f\,(CAE,R)$ when both factors change for both priority CSM options:

$$\Delta PR_s = \overline{\Delta PR_{g.CSM}(\Delta C)} + \overline{\Delta PR_{g.CSM}(\Delta R)} + \overline{\Delta f_{CSM}(\Delta CAE)} + \overline{\Delta f_{CSM}(\Delta R)},$$

where

$$\overline{\Delta f_{CSM}(\Delta CAE)} = \left[\Delta f_{CSM}^{CAE}(\Delta CAE) + \Delta f_{CSM}^{R}(\Delta CAE)\right]\cdot\frac{1}{2},$$

but

$$\overline{\Delta f_{CSM}(\Delta R)} = \left[\Delta f_{CSM}^{R}(\Delta R) + \Delta f_{CSM}^{CAE}(\Delta R)\right]\cdot\frac{1}{2},$$

as was proven in paragraph 4 of section "Theoretical analysis".

In a similar way, it is obviously possible to conduct a factor analysis of economic models of other types of profitability, using mathematical expressions of the corresponding indicators of Form 2 of the financial statements:

1) accounting profitability PR_{BIT} (profitability before interest and tax):

$$PR_{BIT} = \frac{R - C - CAE + S_{ext}}{R};$$

2) net profitability:

$$PR_{BITDA} = \frac{R - C - CAE + S_{ext} + S_{tax}}{R};$$

where S_{ext} and S_{tax} — balance of external transactions, as well as tax deductions and assets, respectively.

Thus, the method of using the arithmetic mean sum of the influence of each factor on the resulting indicator using a modified method of chain substitutions instead of using the integral method, especially in the case of multifactor models, proves its validity in the case of multiple economic models.

RESULTS

1. We will begin to consider the practical results of numerical calculations, which confirm the theoretical conclusions made in the previous section, with a two-factor multiplicative model of revenue (R), obtained from the sale of products in volume Q at a market price p

$$R = p \cdot Q.$$

The numerical data of this operation, performed in the base (0) and current (1) periods, are presented in *Table 1*.

Table 1

Numeric Data

Parameter \ Period	1	0
p, rubles	20	14
Q, things	60	50

Source: Compiled by the author.

The change in indicator *R* when both factors *p* and *Q* change in both priority options using CSM is represented by the following calculations:

$$\Delta R^{p}_{CSM}(\Delta p) = p_1 \cdot Q_0 - p_0 \cdot Q_0 = 20 \cdot 50 - 14 \cdot 50 = 300,$$

$$\Delta R^{p}_{CSM}(\Delta Q) = p_1 \cdot Q_1 - p_1 \cdot Q_0 = 20 \cdot 60 - 20 \cdot 50 = 200,$$

$$\Delta R^{p}_{CSM}(\Delta Q) = Q_1 \cdot p_0 - Q_0 \cdot p_0 = 60 \cdot 14 - 5 \cdot 14 = 140,$$

$$\Delta R^{p}_{CSM}(\Delta p) = Q_1 \cdot p_1 - Q_1 \cdot p_0 = 60 \cdot 20 - 60 \cdot 14 = 360.$$

The change in indicator *R* when each factor changes as the arithmetic mean sum of the CSM results in each priority option according to the methodology presented in paragraph 2 of the "Theoretical analysis" section:

$$\overline{\Delta R_{CSM}(\Delta p)} = \left[\Delta R^{p}_{CSM}(\Delta p) + \Delta R^{Q}_{CSM}(\Delta p)\right] \cdot \frac{1}{2} = (300 + 360) \cdot \frac{1}{2} = 330, \quad (34)$$

$$\overline{\Delta R_{CSM}(\Delta Q)} = \left[\Delta R^{p}_{CSM}(\Delta Q) + \Delta R^{Q}_{CSM}(\Delta Q)\right] \cdot \frac{1}{2} = (200 + 140) \cdot \frac{1}{2} = 170. \quad (35)$$

Changing indicator *R* when changing each factor using IM gives the following result:

$$\Delta R_{IM}(\Delta p) = (p_1 - p_0) \cdot Q_0 + \frac{(p_1 - p_0) \cdot (Q_1 - Q_0)}{2} = (20 - 14) \cdot 50 + \frac{(20 - 14) \cdot (60 - 50)}{2} = 330, \quad (36)$$

$$\Delta R_{IM}(\Delta Q) = (Q_1 - Q_0) \cdot p_0 + \frac{(p_1 - p_0) \cdot (Q_1 - Q_0)}{2} = (60 - 50) \times 14 + \frac{(20 \cdot 14) \cdot (60 - 50)}{2} = 170. \quad (37)$$

Comparison of results (34) and (35) with results (36) and (37), respectively, allows us to conclude that

$$\overline{\Delta R_{CSM}(\Delta p)} = \Delta R_{IM}(\Delta p) \text{ and } \overline{\Delta R_{CSM}(\Delta Q)} = \Delta R_{IM}(\Delta Q),$$

and this fact fully confirms the conclusions of paragraph 2 of the "Theoretical Analysis" section.

2. For a three-factor multiplicative model

$$F = A \cdot B \cdot C$$

the corresponding numerical data are presented in *Table 2*.

Table 2

Numeric Data

Parameter \ Period	1	0
A	15	10
B	25	20
C	35	30

Source: Compiled by the author.

The change in the F indicator when factor A changes in all options with priority A according to CSM is represented by the following calculations:

$$F(A,B,C):\ \Delta F_1^A(\Delta A) = (A_1 - A_0)\cdot B_0 \cdot C_0 = (15-10)\cdot 20\cdot 30 = 3000,$$

$$F(A,C,B): \Delta F_2^A(\Delta A) = (A_1 - A_0)\cdot C_0 \cdot B_0 = (15-10)\cdot 30\cdot 20 = 3000,$$

$$F(B,A,C): \Delta F_1^B(\Delta A) = B_1 \cdot (A_1 - A_0)\cdot C_1 = 25\cdot(15-10)\cdot 30 = 3750,$$

$$F(B,C,A): \Delta F_2^B(\Delta A) = B_1 \cdot C_1 \cdot (A_1 - A_0) = 25\cdot 35\cdot(15-10) = 4375,$$

$$F(C,A,B): \Delta F_1^C(\Delta A) = C_1 \cdot (A_1 - A_0)\cdot B_0 = 35\cdot(15-10)\cdot 20 = 3500,$$

$$F(C,B,A): \Delta F_2^C(\Delta A) = C_1 \cdot B_1 \cdot (A_1 - A_0) = 35\cdot 25\cdot(15\text{-}10) = 4375.$$

Change in the F indicator when factor A changes as the arithmetic mean sum of the CSM results in each priority option according to the methodology presented in paragraph 3 of the “Theoretical Analysis” section:

$$\overline{\Delta F_{CSM}(\Delta A)} = \frac{\Delta F_1^A(\Delta A) + \Delta F_2^A(\Delta A) + \Delta F_1^B(\Delta A) + \Delta F_2^B(\Delta A) + \Delta F_1^C(\Delta A) + \Delta F_2^C(\Delta A)}{6} = \\ = \frac{3000+3000+3750+4375+3500+4375}{6} = 3666{,}6(6). \quad (38)$$

Changing the F indicator when changing factor A using IM gives the result:

$$\Delta F_{IM}(\Delta A) = \frac{1}{2}\cdot(A_1 - A_0)\cdot(B_0\cdot C_1 + B_1\cdot C_0) + \frac{1}{3}\cdot(A_1 - A_0)\cdot(B_1 - B_0)\cdot(C_1 - C_0) = \\ = \frac{1}{2}\cdot(15-10)(20\cdot 35 + 25\cdot 30) + \frac{1}{3}\cdot(15-10)(25-20)(35-30) = 3666{,}6(6). \quad (39)$$

Similar calculations for changes in indicator F when factor B changes in all options with priority B according to CSM give the results:

$$\Delta F_1^A(\Delta B) = A_1 \cdot (B_1 - B_0)\cdot C_0 = 2250,$$

$$\Delta F_2^A(\Delta B) = A_1 \cdot C_1 \cdot (B_1 - B_0) = 2625,$$

$$\Delta F_1^B(\Delta B) = (B_1 - B_0)\cdot A_0 \cdot C_0 = 1500,$$

$$\Delta F_2^B(\Delta B) = (B_1 - B_0)\cdot C_0 \cdot A_0 = 1500,$$

$$\Delta F_1^C(\Delta B) = C_1 \cdot A_1 \cdot (B_1 - B_0) = 2625,$$

$$\Delta F_2^C(\Delta B) = C_1 \cdot (B_1 - B_0)\cdot A_0 = 1750.$$

Change in indicator F when factor B changes as the arithmetic mean sum of the CSM results in each priority option according to the methodology presented in paragraph 3 of the "Theoretical Analysis" section:

$$\overline{\Delta F_{CSM}(\Delta B)} = \frac{\Delta F_1^A(\Delta B)+\Delta F_2^A(\Delta B)+\Delta F_1^B(\Delta B)+\Delta F_2^B(\Delta B)+\Delta F_1^C(\Delta B)+\Delta F_2^C(\Delta B)}{6} = \\ = 2041{,}6(6). \quad (40)$$

Changing the F indicator when changing factor B using IM gives the result:

$$\Delta F_{IM}(\Delta B) = \frac{1}{2}\cdot(B_1 - B_0)\cdot(A_0\cdot C_1 + A_1\cdot C_0) + \frac{1}{3}\cdot(A_1 - A_0)\cdot(B_1 - B_0)\cdot(C_1 - C_0) = \\ = 2041{,}6(6). \quad (41)$$

Similar calculations for changes in indicator F when factor C changes in all options with priority B according to CSM give the results:

$$\Delta F_1^A(\Delta C) = A_1 \cdot B_1 \cdot (C_1 - C_0) = 1875,$$

$$\Delta F_2^A(\Delta C) = A_1 \cdot (C_1 - C_0)\cdot B_0 = 1500,$$

$$\Delta F_1^B(\Delta C) = B_1 \cdot A_1 \cdot (C_1 - C_0) = 1875,$$

$$\Delta F_2^B(\Delta C) = B_1 \cdot (C_1 - C_0)\cdot A_0 = 1250,$$

$$\Delta F_1^C(\Delta C) = (C_1 - C_0)\cdot A_0 \cdot B_0 = 1000,$$

$$\Delta F_2^C(\Delta C) = (C_1 - C_0)\cdot B_0 \cdot A_0 = 1000.$$

Change in indicator F when factor C changes as the arithmetic mean sum of the CSM results in each priority option according to the methodology presented in paragraph 3 of the "Theoretical Analysis" section:

$$\overline{\Delta F_{CSM}(\Delta C)} = \frac{\Delta F_1^A(\Delta C)+\Delta F_2^A(\Delta C)+\Delta F_1^B(\Delta C)+\Delta F_2^B(\Delta C)+\Delta F_1^C(\Delta C)+\Delta F_2^C(\Delta C)}{6} = \\ = 1416{,}6(6). \quad (42)$$

Changing the F score when changing factor C using IM gives the result:

$$\Delta F_{IM}(\Delta C) = \frac{1}{2}\cdot(C_1 - C_0)\cdot(A_0\cdot B_1 + A_1\cdot B_0) + \frac{1}{3}\cdot(A_1 - A_0)\cdot(B_1 - B_0)\cdot(C_1 - C_0) = \\ = 1416{,}6(6). \quad (43)$$

Comparing results (38), (40) and (42) with results (39), (41) and (43), respectively, allows us to conclude that

$$\overline{\Delta F_{CSM}(\Delta B)} = \Delta F_{IM}(\Delta A); \ \overline{\Delta F_{CSM}(\Delta A)} = \Delta F_{IM}(\Delta B); \ \overline{\Delta F_{CSM}(\Delta C)} = \Delta F_{IM}(\Delta C);$$

and this fact fully confirms the conclusions of paragraph 3 of section "Theoretical Analysis".

3. For practical calculations to test the methodology discussed in paragraph 4 of the "Theoretical Analysis" section, consider a two-factor multiple model in the form of an expression of gross profitability:

$$PR_g = \frac{R-C}{R} = 1-\frac{C}{R} = PR_g = f(C, R)$$

with numerical data in *Table 3*.

Table 3

Numeric Data

Parameter \ Period	1	0
R, thous. rubles	1000	910
C, thous. rubles	720	750

Source: Compiled by the author.

The change in the indicator when both factors *R* and *C* change in both priority options using CSM is represented by the following calculations (accurate to the sixth before dot):

$$\Delta PR^{C}_{g.CSM}(\Delta C) = \frac{C_0 - C_1}{B_0} = \frac{750-720}{910} = 0,03296\ldots,$$

$$\Delta PR^{C}_{g.CSM}(\Delta C) = \frac{C_0 - C_1}{B_1} = \frac{750-720}{1000} = 0,03,$$

$$\Delta PR^{C}_{g.CSM}(\Delta C) = \frac{C_1}{B_0} - \frac{C_1}{B_1} = \frac{720}{910} - \frac{720}{1000} = 0,07120\ldots,$$

$$\Delta PR^{C}_{g.CSM}(\Delta C) = \frac{C_0}{B_0} - \frac{C_0}{B_1} = \frac{750}{910} - \frac{750}{1000} = 0,07417\ldots.$$

Change in the PR_g indicator when each factor changes as the arithmetic mean sum of the CSM results in each priority option according to the methodology presented in paragraph 4 of the "Theoretical Analysis" section:

$$\overline{\Delta PR_{g.CSM}(\Delta C)} = \left[\Delta PR^{C}_{g.CSM}(\Delta C) + \Delta PR^{R}_{g.CSM}(\Delta C)\right]\cdot\frac{1}{2} = \frac{0.03296\ldots+0.03}{2} = 0.03148\ldots, \quad (44)$$

$$\overline{\Delta PR_{g.CSM}(\Delta R)} = \left[\Delta PR^{C}_{g.CSM}(\Delta R) + \Delta PR^{R}_{g.CSM}(\Delta R)\right]\cdot\frac{1}{2} = \frac{0.07417\ldots+0.07120}{2} = 0.07268\ldots \quad (45)$$

Changing the PR_g indicator when changing each factor using IM gives the following results:

$$\Delta PR_{g.IM}(\Delta C) = \left|\frac{C_1 - C_0}{R_1 - R_0}\right| \cdot Ln\left|\frac{R_1}{R_0}\right| = 0.03143\ldots, \quad (46)$$

$$\Delta PR_{g.IM}(\Delta R) = \Delta PR_g - \Delta PR_{g\,IM}(\Delta C) = \left(1 - \frac{C_1}{R_1}\right) - \left(1 - \frac{C_0}{R_0}\right) - \Delta PR_{g.IM}(\Delta C) =$$
$$= \left(\frac{C_0}{R_0} - \frac{C_1}{R_1}\right) - \Delta PR_{g.IM}(\Delta C) = 0.10417 - 0.03148... = 0.07269... \quad (47)$$

Comparison of results (44) and (45) with results (46) and (47), respectively, allows us to conclude that

$$\overline{\Delta PR_{g.CSM}(\Delta C)} = \Delta PR_{g.IM}(\Delta C) \text{ and } \overline{\Delta PR_{g.CSM}(\Delta B)} = \Delta PR_{g.IM}(\Delta B)$$

accurate to the fifth decimal place, and this fact fully confirms the conclusions of paragraph 4 of the "Theoretical Analysis" section.

CONCLUSION

The results of the theoretical analysis in Section 2 and the practical calculations confirming them in Section 3 allow us to make an unambiguous conclusion that the modified method of chain substitutions of deterministic factor analysis of various economic models proposed in the article has fully proven its validity. The results of this technique, obtained using the arithmetic mean sum of the results of the influence of each factor on the indicator in all priority options using the method of chain substitutions, can successfully replace the results using the integral method. The accuracy of the results obtained using the modified technique is practically no different from the results of the integral method, but from a mathematical point of view, the proposed technique is much simpler than the mathematical apparatus of the integral method. This circumstance makes it possible to use the method of chain substitutions modified in this way for widespread use in real practical calculations of economic analysis.

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