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THE MODIFIED SCALE N.A. PROF. V.A. YADOV USING FOR THE THEORETICAL DISTRIBUTIONS CREATION IN THE TURBULENT ECONOMICS

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Abstract: In the current social and economic conditions, academic and corporative practice the prospects of some variation series alignment methods and the goodness-of-fit tests line using are particularly defined by the available number of elements sets. Usually for the ultra-small sample size which units number doesn't exceed twenty-five the problem of relation estimation becomes complicated with the current ”turbulent economy” features when the stable trends duration of the analyzed sets often doesn't exceed several units. In these conditions even the Romanovsky and Pearson fitting criterion using will be concerned with the cases of discrepancy to its calculated and tabular values. During the pandemic period the data sets could be even smaller than usual, so here we propose to use the modified scale n.a. prof. V.A. Yadov which could estimate the correlation between the nature of sample representativeness in a linguistic scale and its error size in the interval scale in percentage points. In this case we offer to modify a scale with the specification of a linguistic variable terms names: an error size up to three percent could be characterized as a “minimum deviation"; from three percent to ten percent as the "usual deviations"; from ten percent to twenty percent as "tentative estimation deviations"; from twenty percent to forty percent as "evaluative deviations" and in the case of error more than forty percent as the "rough deviations". With such approach the goodness-of-fit tests computed results have the special sense also for the analyzed short statistical series.

Keywords: Turbulent economy, random value, fitting criterion, normal distribution (law)

1. INTRODUCTION

In the modern turbulent economy [1] it is difficult to expect the observed samples and sets with the high statistical power. Most likely the research will be concerned (due to necessity) with the rather stable sites of data [2], [3] consisting the small number of the studied elements with some indicators [4]. As the researchers first of all are interested in the direction and strength of relationship for the studied statistics indicators (SI) the most preferable way usually is the calculation of linear correlation coefficient (LCC, PCC or

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PPMCC) which in turn demands the preliminary analysis of compared statistics indicators (SI) with the normality test as the random values (RV), for example with the names X and Y: X = {xi}, i = 1, n; Y = {yi}, i = 1, m, and the LCC calculation assumes the identical number of the compared elements, i.e. the equality of “n” and “m” (n = m = N) [20].

In the different sources there is a famous gradation recognized in the close scientific researches on the elements number (size) for both statistical sets N [3]:

a) usual sample, when N > 50 (here and below it’s about the studied set units);
b) small sample, when N < 50;
c) very small (mini or micro) sample, when N < 25.

However during the unstable economy era in the observed period the N number is closer to serious change in decrease. Then it’s becomes important to estimate the acceptable border in the Nmin form, which could provide a possibility of standard operations realizing [5] with the such criteria of the main goodness-of-fit tests using as Pearson and Romanovsky tests which we will also consider further as the criteria of normal distribution law (NDL) compliance for the studied sets elements i.e. x_i and y_i.

2. METHODOLOGICAL APPROACH. EXPECTATIONS AND HYPOTHESIS

2.1. AN ASSESSMENT OF MINIMUM BORDER OF THE RANDOM VALUES X AND Y ELEMENTS SET FOR THE CHOSEN GOODNESS-OF-FIT TESTS USING

First of all, before starting calculation of the LCC direction and module ρXУ it is necessary to verify that empirical distribution of the random values X and Y elements as a result of the variation series (VS) preliminary creation for each RV with the fi frequency corresponds to the normal distribution law (NDL) to find on the next steps the theoretical values of frequencies fiтand to use it in Pearson and Romanovsky goodness-of-fit tests calculation. For this purpose we will use the famous assessment technique for the variation series (VS) intervals number [6]: the VS groups number “k” for each random value is calculated by the approximate Sturges formula:

$$k = 1 + 3{,}322 \cdot \lg N \qquad (1)$$

We must remember that when we will calculate Pearson goodness-of-fit test (the same is true for the Romanovsky's criterion, too) for the standard table "Pearson χ2 - criterion value at a significance level 0.10; 0.05; 0.01" using [5] it is necessary to have at least the degree of freedom number like df = 1 (we don't have for df = 0 the Pearson table). Then, due to [4] the required number of the “df” i.e. degree of freedom is.

$$df = k – 3 \qquad (2)$$

This means that for the simultaneous realization conditions (1) and (2) it is necessary to have the number of intervals not less than $k_{min} = 4$, then the equality (2) will take a form: $df_{min} = 4 – 3 = 1 \neq 0$, as it is required as the minimum for entry into the table "Pearson χ2-criterion values" with the given α significance level (the usual level α = 0.05 as it is noted in the same source). Then the minimum initial elements number of the studied RV X and Y in the N_{min} form could be easily found from the equation (1):

$$lgN_{min} = \frac{k - 1}{3,322} \quad (3)$$

The minimum intervals number for the future variation series is already defined like k = 4 intervals, then expression (3) will take the next form:

$$lg\ N\ min = \frac{4 - 1}{3,322} = \frac{3}{3,322} = 0,90307,$$

from which after the potentiation we receive Nmin = 7.9996 ≈ 8 of random values elements X and Y. Now it is only necessary to check our propositions and this approach on a model data example.

2.2. THE MODEL EXAMPLE

Let's analyze the results of the grade rating system (GRS) using as the result of random sampling from the students group of one course (RV X) and the results of midterm exam (RV Y):

Table 1. The observations (input data) results

No. in num. order, i	Failed attendances in semester $X = \{x_i\}$, pcs.	Final academic progress $Y = \{y_i\}$, points / grades
1	2	3
1	1	75 / 4
2	3	48 / 2
3	0	80 / 4
4	2	60 / 3
5	2	60 / 3
6	1	90 / 5
7	2	56 / 3
$8 = N_{min}$	2	85 / 4

Note. The current grade rating system at the Kazan (Volga region) Federal University works with the next details: if the student gathered less than 56 scores in the current semestrial term work and on the tests (year exams) the assessment will be "unsatisfactorily" or “failed”, if he/she reached 56 – 70 points it will be marked as “satisfactory” or “passed” (at lower grade) in a high school five-point grade system; with the 71 – 85 points it will be the “good”’ mark, and with more than 86 points an assessment will be "excellent". We also must note that in the current unstable economic conditions some of the students are the time-part workers etc., which lead to failed attendances.

2.3. THE VARIATION SERIES CREATION FOR THE X RANDOM SAMPLE

For the random sample X distribution creation it is necessary to construct the variation series for which it is necessary to calculate the step size:

$$h_X = R_X / k \quad (4)$$

where $R_X = x^{max} - x^{min} = 3 – 0 = 3$ is the selection range; $k = k_{min} = 4$ is the already concrete intervals number. And with the formula (4) $h_X = R_X/k = 3/4 = 0.75$ (failed attendances).

On the basis of Table 1 (column 2) now it is possible to construct a variation series for an X random sample set of failed attendances for which the Rx sample range looks like: $R_x = x^{max} - x^{min} = 3 – 0 = 3$ (failed attendances). Step «h» according to a formula (4) with the accepted minimum k =4 of variation series: $h = R_x/n = 3/4 = 0.75$ (pieces). Then demanded variation series for the variable X will look like presented in tab. 2 (columns 1-4). The plus sign (+) in the first interval table 2 indicates that the sign value coinciding with an interval upper bound is included to the same interval [6]. For the goodness-of-fit tests calculation it is also necessary so-called "theoretical frequencies of f_i^T distribution".

For the f_i^T values finding it is necessary to estimate firstly the value of a weighted average (mean) x_{av}^{wh} and its standard deviation σ_x basing on the famous formulas (5) – (8).

$$x_{av}^{wh} = \frac{\sum x^{av}{}_i \cdot f_i}{\sum f_i} = 1{,}5938 \approx 1{,}59 \text{ (failed attendances - pcs.)} \quad (5)$$

The variance (dispersion) for fluidized average will be calculated as:

$$D_x = [\sum (x_i^{av} - x_{av}^{wh})\ 2 \cdot f_i] / \sum f_i = 0.4096 \text{ (pcs.}^2\text{)} \quad (6)$$

The standard deviation on the basis of (6) expression will look like:

$$\sigma_x = (D_x)\ ½ = 0.6427 \approx 0.64 \text{ (pcs.)} \quad (7)$$

Then on the basis of (5) and (7) it is possible to write the next (in general case):

$$x_{av}^{wh} \pm \sigma_x = 1.59 \pm 0.64 = \text{failed attendances} \quad (8)$$

With the found values x_{av}^{wh} and σ_x and also the initial observations number N = 8 we could find the constant value for the f_i^T:

$$const_x = Nh / \sigma_x = 9{,}34 \quad (9)$$

Noted formula (8) gives the possibility to analyze the studied set in the form of some closed (off-state) interval which represent the studied variable X = "Failed attendances, pcs." for a concrete course with the empirical indicators which are ranging from 0.95 up to 2.33 failed attendances in the semester that covers (by the standard deviation definition) about 68.3% of all distribution cases [12], [13].

Next we could realize an entrance to the Appendix with the tabulated values φ(t) (column 7 table 2) from the column 6 contents of the same table. Further we will make calculations on the table 2 and then we round upward the theoretical frequencies values to the whole values (column 8).

Table 2. The working table for the variable X theoretical frequencies calculation

№№	Failed attendances, pcs. x_i^{beg} - x_i^{end}	Statistical frequency, pcs. f_i	Class midpoint, x_i^{av}	x_i^{av} - x_{av}^{wh}	$(x_i^{av} - x_{av}^{wh}) / \sigma_x = t$	φ(t), from the Append. 1 [4]	$f_i^T = [(Nh) / \sigma] \cdot \varphi(t)$
1	0,00 – 0,75	1	0,38	- 1,21	- 1,90	0,0656	0,612≈ 1
2	0,75 – 1,50	2	1,13	- 0,46	- 0,73	0,3056	2,853≈ 3
3	1,50 – 2,25	4	1,88	0,29	0,44	0,3621	3,380 ≈ 3
4	2,25 – 3,00	1	2,63	1,04	1,60	0,1109	1,035≈ 1
…							
Total:		∑= 8	-	-	-	-	Total: ∑ = 8

We have found the f_i^T theoretical frequencies; now it's possible to apply the goodness-of-fit tests.

2.4. THE GOODNESS-OF-FIT TESTS CALCULATION FOR THE VARIABLE X ELEMENTS DISTRIBUTION

As goodness-of-fit tests we will use the Pearson and Romanovsky's criteria (for Kolmogorov's criterion it is required strictly N>50). The Pearson goodness-of-fit test χ2 ("chi-square") calculation is realized on formula (10):

$$\chi^2_{calc} = \sum \frac{(f_i - f_i^T)^2}{f_i^T} \tag{10}$$

Now it is necessary to compare the calculated value of Pearson goodness-of-fit test $\chi^2_{calc} = 0.66$ with the tabular value for its χ^2_{tabl}. With the degrees of freedom number on a formula (2) at chosen for the researches $k_{min} = k =$ the 4 the degree of freedoms will be df = k – 3 = 4 – 3 = 1, and taking the most often used significance level α = 0.05 it is necessary to use the Appendix 4 materials [5]. According to the Pearson criterion values table χ^2_{tabl} (df = 1; α = 0.05) =3.84. As the $\chi^2_{calc} = 0.66 < \chi^{2t}_{abl} = 3.84$ therefore the divergences between the empirical frequencies (f_i) and theoretical frequencies (f_i^t) could be considered as the accidental and the null hypothesis about an empirical distribution proximity on the normal law could be formally accepted.

For the control check we will use the one additional goodness-of-fit test. As this goodness-of-fit test it is expedient to try out the Romanovsky's criterion [14] possibilities from [15]:

$$\mathrm{Rom}_x = \frac{|\chi^2_p - df|}{(2 \cdot df)^{1/2}} = \frac{|0{,}66 - 1|}{(2 \cdot 1)^{1/2}} = \frac{0{,}34}{1{,}414} = 0{,}24<3 \qquad (11)$$

$\mathrm{Rom}_x = 0{,}24<\mathrm{Rom}^{border} = 3$: the null hypothesis about the normal law distribution here is accepted. Thus, the X random sample elements checked on Pearson and Romanovsky goodness-of-fit tests are convincingly distributed under the normal law. Now it is necessary to make the similar calculations on formulas (1) – (11) also for the random sample elements Y = "The total progress" on the same technique.

2.5. THE VARIATION SERIES CREATION FOR A RANDOM SAMPLE Y IN THE FOUR-POINT SCALE ESTIMATION

We make it similar to the operations realized for the X random sample elements on formulas (2) – (11) and to tables like tab. 2 type. So we have the following results: the variation series empirical frequencies for the random sample Y elements: $f_1 = 1$; $f_2 = 3$; $f_3 = 3$; $f_4 = 1$; $y_{av}^{wh} = 3.5$ points; $\sigma_y = 0.65$ points; $const_y= 9.231$; the theoretical frequencies of $f_1^T = 1$; $f_2^T = 3$; $f_3^T = 3$; $f_4^T = 1$; $\chi^2_{calc} = 0 < \chi^2_{tab} = 3.84$ with the significance level $\alpha = 0.05$; $\mathrm{Rom}_y = 0.71 <\mathrm{Rom}^{border} = 3$. This means that the random sample Y elements are also distributed under the normal law. Therefore, it is possible to estimate very correctly the correlation direction and ratio between the X and Y variables with the linear correlation coefficient (LCC) method calculation [7].

2.6. THE LINEAR CORRELATION COEFFICIENT CALCULATION BETWEEN THE X AND Y RANDOM SAMPLES

The necessary calculation will be made on a formula (12) [7], [16]:

$$\rho_{XY} = \frac{N \sum x_i y_i - \sum x_i \sum y_i}{\{[N \sum x_i^2 - (\Sigma x_i)^2] [N \sum y_i^2 - (\Sigma y_i)^2]\}^{1/2}} \qquad (12)$$

For our model example the required sums will be calculated on the tab. 2 basis:

$$\rho_{XY} = \frac{8 \bullet 41 - 13 \bullet 28}{([8 \bullet 27 - (13)^2] [8 \bullet 104 - (28^2)]\}^{1/2}} = \frac{-36}{(2256)^{1/2}} = \frac{-36}{47{,}497} = -0{,}758.$$

Thus, the relation between the lectures attendance and total progress in LCC $\rho_{XY} = -0.758$. On the R. E. Chaddock's scale [6] the relation is estimated as the "high" (from 0.70 to 0.90) and is negative on the X and Y interaction direction. Said another way, the bigger number of student's failed attendances concerned with the lower total progress and vice versa. Next we will estimate the importance of the received LCC on a Student's t-test [4] with the number of degree of freedoms df = N – 2 = 8 – 2 = 6 on formula (13):

$$t_{calc} = \frac{|\rho|(N-2)^{1/2}}{(1-\rho^2)^{1/2}} \tag{13}$$

$$T_{calc} = \frac{|\rho|(N-2)^{1/2}}{(1-\rho^2)^{1/2}} = \frac{0{,}758 \bullet (8-2)^{1/2}}{(1-0{,}758^2)^{1/2}} = \frac{1{,}8567}{(0{,}4254)^{1/2}} = \frac{1{,}8567}{0{,}6522} = 2{,}8468.$$

The tabular t_{tabl} (df, α) are the following: t_{tabl} (6; α = 0.10) = 1.9432; t_{tabl} (6; α = 0.05) = 2.4469; t_{tabl} (6; α = 0.01) = 3.7074. Thus

$$t_{tabl}(6;\alpha = 0.10) = 1.9432 < t_{calc} = 2.8468 < t_{tabl}(6;\alpha = 0.01) = 3.7074, \tag{14}$$

This means that the LCC equal to (-0.758) is calculated with the reliability not less than 95%. However we could propose the Y results in a four-point scale are too "rough" and then we will realize the same algorithm for the estimation in GRS points from the table 1.

3. MODEL DEVELOPMENT

3.1. THE VARIATION SERIES (VS) CREATION FOR THE Y RANDOM SAMPLE IN THE GRADE RATING SYSTEM SCALE ESTIMATION

Similar to the operations realized for the X random sample elements on formulas (2) – (11) and tab.1 we will receive the following results: the empirical frequencies for the new variation series of random sample Y elements will be f_1 = 2; f_2 = 2; f_3 = 1; f_4 = 3 (8); y_w^a = 3.5 points; σ_y = 0.65 points; $const_y$= 9.231; the theoretical frequencies of f_1^T = 1; f_2^T = 2; f_3^T = 2; f_4^T = 1 (only 6 in total); χ^2_{calc} = 5.50> χ^{2t}_{able} = 3.84 with the α = 0.05 significance level; Rom_y = 3.18>Rom^{border} = 3. Therefore, the YGRS random sample elements are distributed not normally on Pearson and Romanovsky goodness-of-fit tests i.e. that "null hypothesis" about the normal law distribution isn't confirmed. At the same time the results are also close to the tabulated points (conventional true values):

- on the Pearson goodness-of-fit test χ^2_{calc}= 5.50 which exceeds the tabular value size χ^2_{tabl} = 3.84 approximately on 30%;
- on a Romanovsky goodness-of-fit test Rom_y = 3.18 which also exceeds the threshold value Rom^{border}= 3 only for 6%.

For the answer on a question is that a lot or not is necessary to use the scale like the Chaddock's scale [8]. For this purpose we suggest to use the famous scale named after prof. V.A. Yadov [9], [18]. The table was created for the results of a sample survey reliability assessment; however it could be practically useful for our goals, too.

Table 3. Usual (current) Yadov scale and offered scale

Usual (current) Yadov scale		Offered (modified) scale	
Reliability degree	Possible sampling error, %	The admissibility levels of fitting criterion acceptance	Admissible excess of the boundary (threshold) values, %
Increased Usual Tentative estimation Evaluative Rapid calculation (the “napkin math”)	Up to 3 3 - 10 10 - 20 20 - 40 >40	Minimum Usual Tentative estimation Evaluative More (than) evaluative	Up to 3 3 - 10 10 - 20 20 - 40 > 40

4. FINDINGS AND DISCUSSION

The excess of the Pearson criterion calculated value over the table is about 30% with the significance level 0.05. Therefore, the excess here on this goodness-of-fit test is qualified as the “evaluative”. At the same time an excess for 6% on Romanovsky's criterion means an excess within the "usual" borders. In this case it is important that excesses differ from boundary (threshold) values with the set α not in many times but only on some units or tens of percent. Thus, basing on the table 3 we could lead to the following conclusions: the studied distribution of the YGRS random sample elements by Pearson's criterion approximately on the 30% exceeds the threshold value (at set α = 0.05) and the hypothesis accessory degree to a normal distribution looks like an “evaluative” (according to tab. above); but by Romanovsky’s criterion could be qualified with the mistake level as "usual". The distribution here is close to the “quasinormal” law.

Now it is necessary to show the proposed scale in practice. Let's make it on the same LCC calculation, but now is in the case of progress Y expression in GRS, and then we will compare this with the earlier received element when Y were the elements represented in a high school four-point scale (ρXУ = - 0.758). For this purpose we will repeat the similar calculations according to table 2 and a formula (12), but for the X and YGRS and we will receive the new LCC: ρXУ = - 0.709 that on Chaddock’s scale is the also negative, and the degree of relation is still “high”. Result: tcalc. = 2.4627>ttabl (df = 6; α – 0.05) = 2.4469. Therefore, the reliability of a new linear correlation coefficient is also from 95% to 99%.

After the LCC calculation when Y is in a four-point scale we received ρXУ = - 0,758 with reliability not less than 95%. On the same coefficient calculation (with Y in BRS scale) we received ρXУ = - 0.709 also with the reliability not less than 95%. Both coefficients demonstrate the negative "high" relation (from 0.70 to 0.90). However the pair rank correlation coefficients (PRCC) i.e. Spearman’s coefficient with the bound ranks [11], [17] groups in the first case is equal to -0.819, and in the second case -0.706 that also verify its belonging to the Chaddock’s scale term "high relation" (from 0.70 to 0.90).

5. SHORT RESULTS AND SUGGESTIONS FOR FUTURE RESEARCH

If in the research concerned with the two random samples X and Y interrelation the null hypotheses about the normal distribution of its elements is unconditionally accepted, then this circumstance gives the base for using the linear correlation coefficient calculation tool (as in this case) between the studied random samples with the determination of relation direction (positive or negative) and its narrowness's with the linguistic variable term "strength of relationship" indication in Chaddock's scale. If the null hypotheses about the normal distribution of the analyzed random samples elements aren't confirmed (or aren't fully confirmed) then it's necessary to point in the modified n.a. prof. Yadov scale the percent of increase in border (threshold) values of the considered goodness-of-fit tests and the decision to use the same tool.

For the inclusion and analysis of the influence of the requirements excess measure to normal law distribution with the random samples which are distributed like the "quasinormal" to the final results it's necessary to make the additional theoretical researches. In this paper we analyzed only a model example, which could have the special meaning for the current conditions with the problem of the initial samples with the adequate volume [19] receiving in the unstable economy even for the separate firms [11], [21].

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