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EXPONENTIAL TYPE RATIO AND PRODUCT ESTIMATOR FOR RATIO OF TWO POPULATION MEANS

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ABSTRACT

In this paper suggested ratio and product type exponential estimator for ratio of two population mean. Bias and mean squared error of suggested estimator have been obtained suggested estimator have been compared with usual estimator, ratio estimator given by Singh (1965). An empirical study has been carried out to demonstrate the performance of suggested estimator.

KEYWORDS: Ratio and Product Type Estimator, Bias, Mean Square Error

1. INTRODUCTION

This paper deals with the problem of estimation of ratio of two population means. Bahl and Tuteja (1991) suggested exponential type estimator of ratio of two population means. In this p we have proposed modified exponential type estimator for ratio of two population means. Suggested estimators have been compared with usual estimator and ratio type estimator. It has been shown that proposed estimators are more efficient than other considered estimators under certain given conditions.

Let $U = \{U_1, U_2, \ldots, U_N\}$ be a finite population of size N and y_0 and y_1 are two study variates. Let x, is a auxiliary variate taking values $x_i\ (i = 1,2,\ldots, N)$. A sample of size n is drawn from N with simple random sampling without replacement an estimator of ratio of two population means.

$$R = \frac{\overline{Y}_0}{\overline{Y}_1}$$

to estimate ratio of two population mean R usual estimator is

$$\hat{R} = \frac{y_0}{y_1} \tag{1.1}$$

Let

$$\overline{y}_0 = \overline{Y}(1 + e_0),\ \bar{y}_1 = \overline{Y}_1(1 + e_1)\ \ \overline{x} = \overline{X}(1 + e_2)$$

Such that

$$E(e_0) = E(e_1) = E(e_2) = 0,\ E(e_0^2) = \theta C_0^2\ \ E(e_1^2) = \theta C_1^2\ \ E(e_2^2) = \theta C_2^2$$

$E(e_0e_1)=\theta\rho_{01}C_0C_1$, $E(e_0e_2)=\theta\rho_{02}C_0C_2$, $E(e_1e_2)=\theta\rho_{12}C_1C_2$

Now we express R in terms of e_is we have

$$\hat{R}=\frac{y_0}{y_1}$$

$$\hat{R}-R=R(e_0-e_1+e_1^2-e_0e_1) \quad (1.2)$$

Taking expectation of both sides of (1.2) we get

$$\text{Bias}(\hat{R})=R\theta(C_1^2-\rho_{01}C_0C_1) \quad (1.3)$$

Taking square and expectation of both sides of (1.3), upto the first degree of approximation mean squared error of $\hat{R}$ is

$$MSE(\hat{R})=R^2\theta(C_0^2+C_1^2-2\rho_{01}C_0C_1) \quad (1.4)$$

where

$$S_0^2=\frac{1}{N-1}\sum_{i=1}^{N}(y_{0i}-\bar{Y}_0)^2,\ S_1^2=\frac{1}{N-1}\sum_{i=1}^{N}(y_{1i}-\bar{Y}_1)^2,\ S_2^2=\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{X})^2$$

$$C_0^2=\frac{S_0^2}{\bar{Y}_0^2},\ C_1^2=\frac{S_1^2}{\bar{Y}_1^2},\ C_2^2=\frac{S_2^2}{\bar{X}^2}$$

$$S_{01}=\frac{1}{N-1}\sum_{i=1}^{N}(y_{0i}-\bar{Y}_0)(y_{1i}-\bar{Y}_1),\ S_{02}=\frac{1}{N-1}\sum_{i=1}^{N}(y_{0i}-\bar{Y}_0)(x_i-\bar{X}),$$

$$S_{12}=\frac{1}{N-1}\sum_{i=1}^{N}(y_{1i}-\bar{Y}_1)(x_i-\bar{X})$$

$$\rho_{01}=\frac{S_{01}}{S_0S_1}\quad \rho_{02}=\frac{S_{02}}{S_0S_2}\quad \rho_{12}=\frac{S_{12}}{S_1S_2}$$

$$\theta=\left(\frac{1}{n}-\frac{1}{N}\right).$$

Using information of an auxiliary variate x, ratio estimator of ratio of two population mean is defined as

$$\hat{R}_R=\hat{R}\left(\frac{\bar{X}}{\bar{x}}\right) \quad (1.5)$$

$$\hat{R}_R-R=R(e_0-e_1-e_2+e_1^2+e_2^2+e_1e_2-e_0e_1) \quad (1.6)$$

Taking expectation of both sides of (1.6) we get

$$Bias\left(\hat{R}_R\right) = R\theta(C_1^2 + C_2^2 + \rho_{12}C_1C_2 - \rho_{01}C_0C_1) \tag{1.7}$$

Taking square and expectation of both sides of (1.7), upto the first degree of approximation is mean squared error of $\hat{R}_R$ is

$$MSE\left(\hat{R}_R\right) = R^2\theta(C_0^2 + C_1^2 + C_2^2 - 2\rho_{01}C_0C_1 - 2\rho_{02}C_0C_2 + 2\rho_{12}C_1C_2) \tag{1.8}$$

where $C_2 = \frac{S_x}{\bar{X}}$

C_0 = coefficient of variation y_0

C_1 = coefficient of variation y_1

C_2 = coefficient of variation x

Bahl and Tuteja (1991) suggested exponential type ratio and product type estimator for population mean as

$$\hat{\bar{Y}}_{Re} = \bar{y}\ \exp\left[\frac{\bar{X}_1 - \bar{x}_1}{\bar{X}_1 + \bar{x}_1}\right] \tag{1.9}$$

$$\hat{\bar{Y}}_{Pe} = \bar{y}\ \exp\left[\frac{\bar{X}_2 - \bar{x}_2}{\bar{X}_2 + \bar{x}_2}\right] \tag{1.10}$$

2.2 SUGGESTED ESTIMATOR

In the line of Bahl and Tuteja (1991), proposed ratio and product type estimator for ratio of two population means are

$$\hat{R}_{Re}^{R} = \hat{R}\ \exp\left[\frac{\bar{X}_1 - \bar{x}_1}{\bar{X}_1 + \bar{x}_1}\right] \tag{2.1}$$

$$\hat{Y}_{Pe}^{R} = \bar{y}\ \exp\left[\frac{\bar{X}_2 - \bar{x}_2}{\bar{X}_2 + \bar{x}_2}\right] \tag{2.2}$$

When x_1 and x_2 are positively and negatively correlated auxiliary variate with (y_0, y_1) respectively.

$$\hat{R}_{Re}^{R} - R = R\left[e_0 - e_1 - \frac{e_2}{2} + e_1^2 + \frac{3e_2^2}{8} - e_0e_1 + \frac{e_1e_2}{2} - \frac{e_0e_2}{2}\right] \tag{2.3}$$

Taking expectation of both sides of (1.6) we get

$$Bias\left(\hat{R}_{Re}^{R}\right) = R\left(\frac{1}{n} - \frac{1}{N}\right)\left[C_1^2 + \frac{3C_2^2}{8} - \rho_{01}C_0C_1 + \frac{\rho_{12}C_1C_2}{2} - \frac{\rho_{02}C_0C_2}{2}\right] \tag{2.4}$$

Taking square and expectation of both sides of (1.7), upto the first degree of approximation is mean squared error of $\hat{R}^R_{\text{Re}}$ is

$$MSE\left(\hat{R}^R_{\text{Re}}\right)=R^2\theta\left(C_0^2+C_1^2+\frac{C_2^2}{4}-2\rho_{01}C_0C_1-\rho_{02}C_0C_2+\rho_{12}C_1C_2\right) \quad (2.5)$$

Similarly bias and mean squared error of suggested estimator is obtained are

$$Bias\left(\hat{R}^R_{Pe}\right)=R\theta\left[C_1^2+\frac{3C_3^2}{8}-\rho_{01}C_0C_1+\frac{\rho_{12}C_1C_3}{2}-\frac{\rho_{02}C_0C_3}{2}\right] \quad (2.6)$$

$$MSE\left(\hat{R}^R_{Pe}\right)=R^2\theta\left(C_0^2+C_1^2+\frac{C_2^2}{4}-2\rho_{01}C_0C_1-\rho_{02}C_0C_2+\rho_{12}C_1C_2\right) \quad (2.7)$$

2.3 BIAS COMPARISION

Some times bias of an estimator is considered as disadvantageous. So in this section we compare the bias of proposed estimators with the biases of other considered estimators.

Bias of usual estimator $\hat{\text{R}}$ and ratio of estimator $\hat{\text{R}}_{\text{R}}$ are

$$Bias\left(\hat{R}\right)=R\theta(C_1^2-\rho_{01}C_0C_1) \quad (3.1)$$

$$Bias\left(\hat{R}_R\right)=R\theta(C_1^2+C_2^2+\rho_{12}C_1C_2-\rho_{01}C_0C_1) \quad (3.2)$$

Comparing (2.4) and (3.1) it is observed that the bias of the proposed estimator $\hat{R}^R_{\text{Re}}$ is less then the bias of usual estimator $\hat{R}$,

i.e.

$$\left|B(\hat{R}^R_{\text{Re}})\right| \langle \left|B(\hat{R})\right|$$

$$\Rightarrow\left(\frac{3C_2^2}{8}+\frac{\rho_{12}C_1C_2}{2}-\frac{\rho_{02}C_0C_2}{2}\right)\left(2C_1^2+\frac{3C_2^2}{8}-2\rho_{01}C_0C_1+\frac{\rho_{12}C_1C_2}{2}-\frac{\rho_{02}C_0C_2}{2}\right)\langle\ 0$$

Comparing (2.4) and (3.1) it is observed that bias of the proposed estimator $\hat{R}^R_{\text{Re}}$ is less then $\hat{R}_R$

i.e.

$$\left|B(\hat{R}^R_{\text{Re}})\right| \langle \left|B(\hat{R}_R)\right|$$

$$\Rightarrow\left(\frac{5}{8}C_2^2-\frac{\rho_{02}C_0C_2}{2}-\frac{\rho_{12}C_1C_2}{2}\right)$$
$$\left(2C_1^2+\frac{11}{8}C_2^2-2\rho_{01}C_0C_1+\frac{3}{2}\rho_{12}C_1C_2-\frac{\rho_{02}C_0C_2}{2}\right)\langle\ 0$$

- Similarly condition under the bias estimator of $\hat{R}_{Pe}^{R}$ is less then $\hat{R}$ is

$$\left|B(\hat{R}_{\mathrm{Re}}^{R})\right|\langle\ \left|B(\hat{R})\right|$$

$$\Rightarrow\left(\frac{3C_3^2}{8}+\frac{\rho_{13}C_1C_3}{2}-\frac{\rho_{03}C_0C_3}{2}\right)$$
$$\left(2C_1^2+\frac{3C_3^2}{8}-2\rho_{01}C_0C_1+\frac{\rho_{13}C_1C_3}{2}-\frac{\rho_{03}C_0C_3}{2}\right)\langle\ 0$$

Comparing (2.6) and (3.1) it is observed that bias of the proposed estimator $\hat{R}_{\mathrm{Re}}$ is less then $\hat{R}_R$

i.e.

$$\left|B(\hat{R}_{Pe}^{R})\right|\langle\ \left|B(\hat{R}_R)\right|$$

$$\Rightarrow\left(\frac{5}{8}C_3^2-\frac{\rho_{03}C_0C_3}{2}-\frac{\rho_{13}C_1C_3}{2}\right)$$
$$\left(2C_1^2+\frac{11}{8}C_3^2-2\rho_{01}C_0C_1+\frac{3}{2}\rho_{13}C_1C_3-\frac{\rho_{03}C_0C_3}{2}\right)\langle\ 0$$

2.4 EFFICIENCY COMPARISION

Mean squared error of usual estimator $\hat{R}$ an ratio type estimator $\hat{R}_R$

$$MSE\left(\hat{R}\right)=R^2\theta(C_0^2+C_1^2-2\rho_{01}C_0C_1) \tag{4.1}$$

$$MSE\left(\hat{R}_R\right)=R^2\theta(C_0^2+C_1^2+C_2^2-2\rho_{01}C_0C_1-2\rho_{02}C_0C_2+2\rho_{12}C_1C_2) \tag{4.2}$$

- Comparison of (2.5) and (4.1) shows that suggested estimator $\hat{R}_{\mathrm{Re}}^{R}$ is more efficient than usual estimator $\hat{R}$ if

$$MSE\left(\hat{R}_{\mathrm{Re}}^{R}\right)\langle\ MSE\left(\hat{R}\right)$$

$$R^2\theta\left(C_0^2+C_1^2+\frac{C_2^2}{4}-2\rho_{01}C_0C_1-\rho_{02}C_0C_2+\rho_{12}C_1C_2\right)\langle\ R^2\theta(C_0^2+C_1^2-2\rho_{01}C_0C_1)$$

$$C_2\left(\frac{C_2}{4}-\rho_{02}C_0+\rho_{12}C_1\right)\langle\ 0$$

$C_2 \ \langle\ 0$ and $\frac{C_2}{4} - \rho_{02}C_0 + \rho_{12}C_1 \ \rangle\ 0$

either $C_2 \ \langle\ 0$ and $C_2 \ \rangle\ 4(\rho_{02}C_0 - \rho_{12}C_1)$

or $C_2 \ \rangle\ 0$ and $\frac{C_2}{4} - \rho_{02}C_0 + \rho_{12}C_1 \ \langle\ 0$

$\Rightarrow C_2 \ \rangle\ 0$ and $C_2 \ \langle\ 4(\rho_{02}C_0 - \rho_{12}C_1)$

Thus conditions under which proposed estimator $\hat{R}^{R}_{\text{Re}}$ would be more efficient then $\hat{R}$ is

either $0 \ \langle\ C_2 \ \langle\ 4(\rho_{02}C_0 - \rho_{12}C_1)$ or $4(\rho_{02}C_0 - \rho_{12}C_1) \ \langle\ C_2 \ \langle\ 0$

- Comparison of (2.5) and (4.2) shows that suggested estimator $\hat{R}^{R}_{\text{Re}}$ is more efficient than usual estimator $\hat{R}$ if

$$MSE\left(\hat{Y}^{R}_{\text{Re}}\right) \langle\ MSE\left(\hat{R}_{R}\right)$$

$$R^2\theta\left(C_0^2 + C_1^2 + \frac{C_2^2}{4} - 2\rho_{01}C_0C_1 - \rho_{02}C_0C_2 + \rho_{12}C_1C_2\right) \langle$$
$$R^2\theta\left(C_0^2 + C_1^2 + C_2^2 - 2\rho_{01}C_0C_1 - 2\rho_{02}C_0C_2 + 2\rho_{12}C_1C_2\right)$$

$$C_2\left(\frac{-3}{4}C_2 + \rho_{02}C_0 - \rho_{12}C_1\right) \langle\ 0$$

$C_2 \ \langle\ 0$ and $\frac{-3}{4}C_2 + \rho_{02}C_0 - \rho_{12}C_1 \ \rangle\ 0$

either $C_2 \ \langle\ 0$ and $C_2 \ \rangle\ \frac{4}{3}(\rho_{02}C_0 - \rho_{12}C_1)$

or $C_2 \ \rangle\ 0$ and $\frac{C_2}{4} - \rho_{02}C_0 + \rho_{12}C_1 \ \langle\ 0$

$\Rightarrow C_2 \ \rangle\ 0$ and $C_2 \ \langle\ \frac{4}{3}(\rho_{02}C_0 - \rho_{12}C_1)$

Thus conditions under which proposed estimator $\hat{R}^{R}_{\text{Re}}$ would be more efficient then $\hat{R}_{R}$ is either

$0 \ \langle\ C_2 \ \langle\ 4(\rho_{02}C_0 - \rho_{12}C_1)$

or $\frac{4}{3}(\rho_{02}C_0 - \rho_{12}C_1) \ \langle\ C_2 \ \langle\ 0$

- Comparison of (2.7) and (4.1) shows that suggested estimator $\hat{R}^{R}_{Pe}$ is more efficient than usual estimator $\hat{R}$ if

$$MSE\left(\hat{R}^{R}_{Pe}\right) \langle \; MSE\left(\hat{R}\right)$$

$$R^2\theta\left(C_0^2 + C_1^2 + \frac{C_2^2}{4} - 2\rho_{01}C_0C_1 - \rho_{02}C_0C_2 + \rho_{12}C_1C_2 \right) \langle \; R^2\theta(C_0^2 + C_1^2 - 2\rho_{01}C_0C_1)$$

$$C_2\left(\frac{C_2}{4} - \rho_{02}C_0 + \rho_{12}C_1 \right) \langle \; 0$$

$$C_2 \; \langle \; 0 \text{ and } \frac{C_2}{4} - \rho_{02}C_0 + \rho_{12}C_1 \; \rangle \; 0$$

either $C_2 \; \langle \; 0$ and $C_2 \; \rangle \; 4\left(\rho_{02}C_0 - \rho_{12}C_1\right)$

or $C_2 \; \rangle \; 0$ and $\frac{C_2}{4} - \rho_{02}C_0 + \rho_{12}C_1 \; \langle \; 0$

$\Rightarrow C_2 \; \rangle \; 0$ and $C_2 \; \langle \; 4\left(\rho_{02}C_0 - \rho_{12}C_1\right)$

Thus conditions under which proposed estimator $\hat{R}^{R}_{Re}$ would be more efficient then $\hat{R}$ is either

$0 \; \langle \; C_2 \; \langle \; 4\left(\rho_{02}C_0 - \rho_{12}C_1\right)$

or $4\left(\rho_{02}C_0 - \rho_{12}C_1\right) \langle \; C_2 \; \langle \; 0$

- Comparison of (2.7) and (4.2) shows that suggested estimator $\hat{R}^{R}_{Pe}$ is more efficient than usual estimator $\hat{R}_R$ if

$$MSE\left(\hat{R}^{R}_{Pe}\right) \langle \; MSE\left(\hat{R}_R\right)$$

$$R^2\theta\left(C_0^2 + C_1^2 + \frac{C_3^2}{4} - 2\rho_{01}C_0C_1 - \rho_{03}C_0C_3 + \rho_{13}C_1C_3 \right) \langle \; 0$$

$$R^2\theta\left(C_0^2 + C_1^2 + C_3^2 - 2\rho_{01}C_0C_1 - 2\rho_{03}C_0C_3 + 2\rho_{13}C_1C_3\right)$$

$$C_3\left(\frac{-3}{4}C_3 + \rho_{03}C_0 - \rho_{13}C_1 \right) \langle \; 0$$

$$C_3 \; \langle \; 0 \text{ and } \frac{-3}{4}C_3 + \rho_{03}C_0 - \rho_{13}C_1 \; \rangle \; 0$$

either $C_3 \; \langle \; 0$ and $C_3 \; \rangle \; \frac{4}{3}\left(\rho_{03}C_0 - \rho_{13}C_1\right)$

or $C_3 \; \rangle \; 0$ and $\frac{C_3}{4} - \rho_{03}C_0 + \rho_{13}C_1 \; \langle \; 0$

$$\Rightarrow C_3 \ \rangle\ 0 \text{ and } C_3 \ \langle\ \frac{4}{3}\left(\rho_{03}C_0 - \rho_{12}C_1\right)$$

Thus conditions under which proposed estimator $\hat{R}_{Pe}^{R}$ would be more efficient then $\hat{R}$ is either

$$0 \ \langle\ C_3 \ \langle\ \frac{4}{3}\left(\rho_{03}C_0 - \rho_{12}C_1\right)$$

or $\frac{4}{3}\left(\rho_{03}C_0 - \rho_{12}C_1\right) \ \langle\ C_3 \ \langle\ 0$

Thus the condition under which suggested estimator $\hat{R}_{\text{Re}}^{R}$ would be more efficient then ratio estimator $\hat{R}_R$ given by Singh (1965) if

either $0 \ \langle\ C_2 \ \langle\ 4\left(\rho_{02}C_0 - \rho_{12}C_1\right)$

or $\frac{4}{3}\left(\rho_{02}C_0 - \rho_{12}C_1\right) \ \langle\ C_2 \ \langle\ 0$

Similarly the condition under which suggested estimator $\hat{R}_{Pe}^{R}$ would be more efficient then ratio estimator $\hat{R}_R$ given by Singh (1965) if

either $0 \ \langle\ C_2 \ \langle\ 4\left(\rho_{02}C_0 - \rho_{12}C_1\right)$

or $\frac{4}{3}\left(\rho_{02}C_0 - \rho_{12}C_1\right) \ \langle\ C_2 \ \langle\ 0$

2.5 EMPERICAL STUDY

To show the performance of the suggested estimator $\hat{R}_{\text{Re}}$ and $\hat{R}_{\text{Re}}^{R}$ we are considering two natural data sets. Descriptions of the problem is given below

Population I

y_0 **:** Wing length

y_1 **:** Fourth palp length

x **:** Third palp length

Population I [Source: Johnson & Wichern (2003)]

Table 1

N=10 n=3	θ=0.23333	R=1.328767	R^2 =1.765622
	$\overline{Y}_0$ =102	$\overline{Y}_1$ =35.6	$\overline{X}$ =26.5
	S_{01} =-0.55556	S_{02} =12.66667	S_{12} =-0.33333
	C_0 =0.055073	C_1 =0.0.040164	C_2 =0.127348784
	ρ_{01} =-0.11513	ρ_{02} = 0.668165	ρ_{12} = -0.06908
	C_0^2 =0.003033	C_1^2 =0.001613	C_2^2 =0.016218
	S_0^2 =31.55556	S_1^2 =2.044444	S_2^2 =11.38889
	S_0 =5.617433	S_1 =1.429841	S_2 =3.374743

Population II [Source: Johnson & Wichern (2003)]

(a) For $\hat{R}^R_{\text{Re}}$

$\overline{Y}_0$ **:** Male length

$\overline{Y}_1$ **:** Male width

$\overline{X}$ **:** Male height

Table 2

N=24 N=4	θ=0.208333	R=1.284096	R^2 =1.648903
	$\overline{Y}_0$ =113.375	$\overline{Y}_1$ =74	$\overline{X}$ =37
	S_{01} =79.14674	S_{02} =37.375	S_{12} =21.65399
	C_0 =0.103902	C_1 =0.080121	C_2 =0.082427
	ρ_{01} =0.949785	ρ_{02} =0.945558	ρ_{12} =0.912265
	C_0^2 =0.010796	C_1^2 =0.006419	C_2^2 =0.006794
	S_0^2 =138.7663	S_1^2 =50.04166	S_2^2 =11.25906
	S_0 =11.77991	S_1 =7.074013	S_2 =3.355452

(b) For $\hat{R}^R_{Pe}$

$\overline{Y}_0$ **:** Male length

$\overline{Y}_1$ **:** Male width

$\overline{X}$ **:** Male height

Table 3

N=24 N=4	θ=0.208333	R=1.284096	R^2=1.648903
	$\bar{Y}_0$=113.375	$\bar{Y}_1$=37	$\bar{X}$=74
	S_{01}=79.14674	S_{03}=21.65399	S_{13}=37.375
	C_0=0.103902	C_1=0.082427	C_3=0.080121
	ρ_{01}=0.949785	ρ_{03}=0.912265	ρ_{13}=0.945558
	C_0^2=0.010796	C_1^2=0.006794	C_3^2=0.006419
	S_0^2=138.7663	S_1^2=11.25906	S_2^2=50.04166
	S_0=11.77991	S_1=3.355452	S_2=7.074013

Percent Relative Efficiencies

Table 4

Estimator	Population I	Population II
$\hat{R}$	100.00	100.00
$\hat{R}_R$	45.64718	166.0676
$\hat{R}_{\text{Re}}^R$	219.0716	654.3909
$\hat{R}_{Pe}^R$	107.1302	601.5625

Table 1 shows that suggested estimators $\hat{R}_{\text{Re}}^R$ and $\hat{R}_{Pe}^R$ have higher percentage relative efficiency in comparison to $\hat{R}$ and $\hat{R}_R$. Thus suggested estimator recommended for use in practice.

Section 2.4 provides the conditions under which suggested exponential type estimator are more efficient than usual estimator $\hat{R}$ and ratio estimator $\hat{R}_R$ for ratio of two population means.

7. CONCLUSIONS

Estimation is a common problem in various field if agriculture, economics, population etc. where some parameters like population total, population mean population variance ratio of two population means etc need to be estimates.

In this article we have considered the problem of estimating the population mean of the study variable when the population mean of an auxiliary variable is known in simple random sampling without replacement (SRSWOR). The class of estimators has been proposed and the bias and mean square error expressions of the proposed class of estimators have been obtained up to first degree of approximation.

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