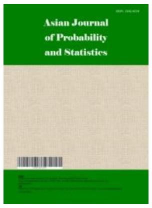

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Logarithmic Ratio-Type Estimator of Population Coefficient of Variation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

The estimation of population coefficient of variation is one of the challenging aspects in sampling survey techniques for the past decades and much effort has been employed to develop estimators to produce its efficient estimate. In this paper, we proposed logarithmic ratio type estimator for the estimating population coefficient of variation using logarithm transformation on the both population and sample variances of the auxiliary character. The expression for the mean squared error (MSE) of the proposed estimator has been derived using Taylor series first order approximation approach. Efficiency conditions of the proposed estimator over other estimators in the study has also been derived. The empirical study was conducted using two-sets of populations and the results showed that the proposed estimator is more efficient. This result implies that, the estimate of proposed estimator will be closer to the true parameter than the estimates of other estimators in the study.

Keywords: Auxiliary variable; MSE; coefficient of variation; study variable, simple random sampling.

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1 Introduction

Coefficient of variation is unit less tool used in statistics to assess variability within the data, for example, In finance, the coefficient of variation allows investors to determine how much volatility, or risk, is assumed in comparison to the amount of return expected from investments, in analytical chemistry, it is used to express the precision and repeatability of an assay and in the fields of engineering or physics when doing quality assurance studies. Coefficient of variation can also be used for comparison between the variabilities of two or more quantities with different units or dimensions, for examples variabilities in weight and height of individuals, are in kilogram (kg) and centimeter (cm). The development of estimators for estimating population coefficient of variation has received wide attention in sampling theory recently and many efforts have been made to improve the precision of the estimate through the use of information on auxiliary character.

For estimating population parameters like population mean, population variance, standard deviation etc. of the study variable using information on auxiliary variable, a considerable amount of work has been already performed by several researchers like Sisodia and Dwivedi [1], Murthy [2], Yadav and Kadilar [3], Singh and Tailor [4], Bahl and Tuteja [5], Singh et al. [6], Singh et al [7], Kadilar and Cingi [8], Singh and Solanki [9], Sahai and Ray [10], Srivastava and Jhajj [11], Ahmed et al. [12], Audu and Adewara [13], Audu et al. [14], Muili et al. [15], Khoshnevisan et al. [16], Singh and Audu [17], Ahmed et al.[18] and Audu and Singh [19], Das and Tripathi [20], Das and Tripathi [21], Patel and Rina [22], Rajyaguru and Gupta [23], Rajyaguru and Gupta [24], Archana and Rao [25], Singh et al. [26], Audu et al. [27-32], Singh et al. [33], Muili et al. [34], Ishaq et al. [35]. Nevertheless, the investigators did not much emphasize for the problem of estimation of coefficient of variation for a long time. However, some authors have worked on this, for instance Das, A.K., & Tripathi, T.P. [36] and Das and Tripathi [37] first proposed the estimator for coefficient of variation when samples were selected using SRSWOR. Other works include that of Patel and Shah [22], Rajyaguru and Gupta [23,24], Audu et al. [38], also, worked on the problem of estimation of coefficient of variation (C.V) under simple random sampling and stratified random sampling.

In this study, logarithmic ratio-type estimator for population coefficient of variation was suggested. The suggested estimator utilized information on logarithm transformation on the both population and sample variances of the auxiliary character.

Assuming a simple random sample size n is drawn from a population of size N units having the values of the study Y and the auxiliary variables X as Y_i and X_i (i=1, 2,3, 4, …, N). Let the i[th] unit in the sample (i=1, 2, 3, …, n) be given as y_i and x_i. Then we have

$\bar{Y} = \frac{1}{N}\sum_{i=1}^{N} Y_i$ and $\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i$ - are the population means of Y and X.

$S_y^2 = \frac{1}{N-1}\sum_{i=1}^{N}(Y_i - \bar{Y})^2$ - is the population mean square of Y

$S_x^2 = \frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})^2$ - is the population mean square of X.

$S_{xy} = \frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})(Y_i - \bar{Y})$ - is the population covariance of Y and X

$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ and $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ - are the sample mean of Y and X.

$s_y^2 = \frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2$ - is the sample variance Y.

$s_x^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$ - is the sample variance X.

$s_{xy} = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})$ - is the sample covariance of the Y and X.

To obtain the properties (Bias and MSE) of the proposed estimator, the procedure in which the sample statistics in the estimator are defined in terms of errors $e_h,\ h = 0,1,2,3$ given below was used

$$e_0 = \frac{\bar{y} - \bar{Y}}{\bar{Y}}, e_1 = \frac{\bar{x} - \bar{X}}{\bar{X}}, e_2 = \frac{s_y^2 - S_y^2}{S_y^2}, e_3 = \frac{s_x^2 - S_x^2}{S_x^2}$$

such that

$$\bar{y} = \bar{Y}\left(1+e_0\right), \bar{x} = \bar{X}\left(1+e_1\right), s_y = S_y\left(1+e_2\right)^{1/2}, s_x = S_x\left(1+e_3\right)^{1/2}, s_y^2 = S_y^2\left(1+e_2\right), s_x^2 = S_x^2\left(1+e_3\right)$$

The expectations of first and second degrees of $e_h,\ h = 0,1,2,3$ are;

$$E\left(e_0\right) = E\left(e_1\right) = E\left(e_2\right) = E\left(e_3\right) = 0$$

$$E\left(e_0^2\right) = \gamma C_y^2, E\left(e_1^2\right) = \gamma C_x^2, E\left(e_2^2\right) = \gamma\left(\lambda_{40} - 1\right), E\left(e_3^2\right) = \gamma\left(\lambda_{04} - 1\right),$$

$$E\left(e_0 e_1\right) = \gamma\rho C_y C_x, E\left(e_0 e_2\right) = \gamma C_y \lambda_{30}, E\left(e_0 e_3\right) = \gamma C_y \lambda_{12},$$

$$E\left(e_1 e_2\right) = \gamma C_x \lambda_{21}, E\left(e_1 e_2\right) = \gamma C_x \lambda_{03}, E\left(e_2 e_3\right) = \gamma\left(\lambda_{22} - 1\right).$$

Here $\gamma = \frac{\left(1-f\right)}{n}$, $f = \frac{n}{N}$ sampling fraction. $C_y = \frac{S_y}{\bar{Y}}$ and $C_x = \frac{S_x}{\bar{X}}$ are the population coefficient of variation for the study variable Y and auxiliary variable X. Also ρ denotes the correlation coefficient between X and Y.

In general, $\mu_{rs} = \frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^r (x_i - \bar{x})^s$ and $\lambda_{rs} = \frac{\mu_{rs}}{\mu_{20}^{r/2}\mu_{02}^{s/2}}$ respectively.

2 Some Existing Estimators in Literature

The usual unbiased estimator using information on single auxiliary variable to estimate the population coefficient of variation is given by:

$$t_0 = \hat{C}_y = \frac{s_y}{\bar{y}} \tag{2.1}$$

The MSE of t_0 is given in (2.2)

$$MSE\left(t_0\right)=C_y^2\gamma\left(C_y^2+\frac{1}{4}\left(\lambda_{40}-1\right)-C_y\lambda_{30}\right) \tag{2.2}$$

Archana and Rao [39] proposed ratio estimators of population coefficient of variation using information on sample mean, population mean, sample variance and population variance of the auxiliary character as in (2.3) and (2.4.)

$$t_{AR1}=\hat{C}_y\left(\frac{\bar{X}}{\bar{x}}\right) \tag{2.3}$$

$$t_{AR2}=\hat{C}_y\left(\frac{S_x^2}{s_x^2}\right) \tag{2.4}$$

The mean square error (MSE) expression of the estimator t_{AR} is given by:

$$MSE\left(t_{AR1}\right)=C_y^2\gamma\left[C_y^2+\frac{1}{4}\left(\lambda_{40}-1\right)+C_x^2-C_x\lambda_{21}-C_y\lambda_{30}+2\rho C_yC_x\right] \tag{2.5}$$

$$MSE\left(t_{AR2}\right)=C_y^2\gamma\left[C_y^2+\frac{1}{4}\left(\lambda_{40}-1\right)+\left(\lambda_{04}-1\right)-\left(\lambda_{22}-1\right)-C_y\lambda_{30}+2C_y\lambda_{12}\right] \tag{2.6}$$

3 Proposed Estimator

In this paper, we have proposed logarithmic ratio type estimator for the estimation of population coefficient of variation of the study variable when the natural logarithm of the population variance of the auxiliary variable is known and it is defined as:

$$T_y=\hat{C}_y\left(\frac{Ln(S_x^2)}{Ln(s_x^2)}\right) \tag{3.1}$$

The above estimator is defined under the assumptions that $Ln(S_x^2)\neq 0$ and $Ln(s_x^2)\neq 0$,

3.1 Mean squared error of the T_y

Using the error terms of e_0, e_1, e_2, e_3, defined in section 1, the proposed estimator T_y can be expressed as in (3.2).

$$T_y=\frac{s_y}{\bar{y}}\left(\frac{Ln(S_x^2)}{Ln(S_x^2\left(1+e_3\right))}\right) \tag{3.2}$$

Expand (3.2) using law of logarithm, we obtained (3.3).

$$T_y=\frac{S_y\left(1+e_2\right)^{1/2}}{\bar{Y}\left(1+e_0\right)}\left(\frac{Ln(S_x^2)}{Ln(S_x^2)+Ln\left(1+e_3\right)}\right) \tag{3.3}$$

$$T_y = C_y \left(1+e_2\right)^{1/2} \left(1+e_0\right)^{-1} \left(\frac{Ln(S_x^2)}{Ln(S_x^2) + Ln\left(1+e_3\right)} \right) \tag{3.4}$$

Simplify (3.4) by factorizing $Ln(S_x^2)$ from the numerator and denominator of the expression in the last bracket of (3.4), we obtained (3.5).

$$T_y = C_y \left(1+e_2\right)^{1/2} \left(1+e_0\right)^{-1} \left(\frac{1}{1+kLn\left(1+e_3\right)} \right) \tag{3.5}$$

where $k = 1/Ln(S_x^2)$

$$T_y = C_y \left(1+e_2\right)^{1/2} \left(1+e_0\right)^{-1} \left(1+kLn\left(1+e_3\right)\right)^{-1} \tag{3.6}$$

By expanding $Ln\left(1+e_3\right), \left(1+e_2\right)^{1/2}$ and $\left(1+e_0\right)^{-1}$ up to first order of approximation we have,

$$T_y = C_y \left(1+\frac{e_2}{2}-\frac{e_2^2}{8}\right)\left(1-e_0+e_0^2\right)\left(1-k\left(e_3-\frac{e_3^2}{2}\right)+k^2\frac{e_3^2}{2}\right) \tag{3.7}$$

$$T_y = C_y \left(1-e_0+e_0^2+\frac{e_2}{2}-\frac{e_0 e}{2}-\frac{e_2^2}{8}\right)\left(1-k\left(e_3-\frac{e_3^2}{2}\right)+k^2\frac{e_3^2}{2}\right) \tag{3.8}$$

By simplifying (3.8) and subtract C_y from both sides, we obtained (3.9).

$$T_y - C_y = C_y\left(-ke_3+\frac{1}{2}\left(k+k^2\right)e_3^2-e_0+ke_0e_3+e_0^2+\frac{e_2}{2}-\frac{ke_2e_3}{2}+\frac{e_0e}{2}-\frac{e_2^2}{8}\right) \tag{3.9}$$

Square and take expectation of both sides of (3.9) up to first order of approximation, we have,

$$MSE\left(T_y\right) = C_y{}^2\gamma\left(C_y{}^2+\frac{\left(\lambda_{40}-1\right)}{4}+\frac{\left(\lambda_{04}-1\right)}{\left(L_n\left(S_x^2\right)\right)^2}-\frac{\left(\lambda_{22}-1\right)}{L_n\left(S_x^2\right)}-C_y\lambda_{30}+\frac{2C_y\lambda_{12}}{L_n\left(S_x^2\right)}\right) \tag{3.10}$$

3.2 Efficiency comparison

In this subsection, efficiency conditions of T_y over sample coefficient of variation t_0 , t_{AR1} estimator (2014) and t_{AR2} estimator (2014) were established.

i. T_y is more efficient than t_0 if:

$MSE\left(T_y\right) < MSE\left(t_0\right)$ (3.11)

$$k\left(\lambda_{04}-1\right)+2C_y\lambda_{12}<\left(\lambda_{22}-1\right) \tag{3.12}$$

ii. T_y is more efficient than t_{AR1} if:

$$MSE\left(T_y\right)<MSE\left(t_{AR1}\right) \tag{3.13}$$

$$k\left\{k\left(\lambda_{04}-1\right)-\left(\lambda_{22}-1\right)\right\}<C_x\left(C_x-\lambda_{21}\right)-2C_y\left(k\lambda_{21}-\rho C_x\right) \tag{3.14}$$

iii. T_y is more efficient than t_{AR2} if:

$$MSE\left(T_y\right)<MSE\left(t_{AR2}\right) \tag{3.15}$$

$$\left(k+1\right)\left(\lambda_{04}-1\right)<\left(\lambda_{22}-1\right)-2C_y\lambda_{12} \tag{3.16}$$

where

$$k=1/Ln(S_x^2)$$

4 Results and Discussion

In this section, numerical analyses to elucidate the performance of T_y t_0 , t_{AR1} and t_{AR2} were illustrated.

Population 1: [Source: Murthy [40], p.399]

X: Area under wheat in 1963, Y: Area under wheat in 1964

$$N=34, n=15, \bar{X}=208.88, \bar{Y}=199.44, C_x=0.72, C_y=0.75, \rho=0.98, \lambda_{21}=1.0045, \lambda_{12}=0.9406,$$
$$\lambda_{40}=3.6161, \lambda_{04}=2.8266, \lambda_{30}=1.1128, \lambda_{03}=0.9206, \lambda_{22}=3.0133$$

Population 1: [Source: Singh [41], p.1116]

X: Number of fish caught in year 1993, Y: Number of fish caught in year 1995

$$N=69, n=40, \bar{X}=4591.07, \bar{Y}=4514.89, C_x=1.38, C_y=1.38, \rho=0.96, \lambda_{21}=2.19, \lambda_{12}=2.30,$$
$$\lambda_{40}=7.66, \lambda_{04}=9.84, \lambda_{30}=1.11, \lambda_{03}=2.52, \lambda_{22}=8.19$$

Table 1. MSE and PRE of proposed estimator and the existing estimators

ESTIMATORS	POPULATION 1		POPULATION 2	
	MSE	PRE	MSE	PRE
t_0	0.0080036	100.00	0.038088	100.00
t_{AR1}	0.0258907	30.91	0.0851798	44.71
t_{AR2}	0.0336578	23.78	0.18860299	20.19
T_y	0.0071255	112.32	0.0375686	101.38

Table 1 shows MSEs and PREs of the proposed estimator T_y and existing estimators t_0 , t_{AR1} t_{AR2} . The results showed that T_y has minimum MSE and highest PREs among other estimators for the two data-sets considered in the study. These results imply that the proposed estimator T_y is more efficient than the sample coefficient of variation t_0 , t_{AR1} estimator [25] and t_{AR2} estimator [25].

5 Conclusion

In this study, logarithm ratio-type estimator of coefficient of variation has been suggested. The estimator utilized information on natural logarithm of the population variance of the auxiliary character. The empirical results revealed that the new proposed estimator outperformed its counterparts considered in the study. Therefore, the new estimator is recommended for use in real practical scenarios.

Competing Interests

Authors have declared that no competing interests exist.

References

[1] Sisodia BSV, Dwivedi VK. A modified ratio estimator using coefficient of variation of auxiliary variable. Jour. Ind. Soc. Agr. Statistics. 1981a;33(2):13-18.

[2] Murthy MN. Product method of estimation. Sankhya. 1964;26:294-307.

[3] Yadav SK, Kadilar C. Improved exponential type ratio estimator of population Variance. Revista Colombiana de Estadística. 2013;36(1):145–152.

[4] Singh HP, Tailor R. Estimation of finite population mean using known correlation coefficient between auxiliary characters. Statistica. 2005;65: 07-418.

[5] Bahl S, PK Tuteja. Ratio and product type exponential estimator. Journal of Information and Optimization Science. 1991;12(1):159-163.
DOI: 1080/02522667.1991. 10699058

[6] Singh R, Chauhan P, Sawan N, Smarandache F. Ratio estimators in simple random sampling using information on auxiliary attribute. Pak. J. Stat. Oper. Res. 2008;4(1):47-53.

[7] Singh HP, Tailor R, Kakran MS. An improved estimation of population mean using power transformation. Journal of the Indian Society of Agricultural Statistics. 2004;58(2):223–230.

[8] Kadilar C, Cingi H. Ratio estimators for population variance in simple and stratified sampling. Applied Mathematics and Computation. 2006;173:1047–1059.

[9] Singh HP, Solanki RS. An efficient class of estimators for the population mean using auxiliary information in systematic sampling. Journal of Statistical Theory and Practice. 2012;6(2):274-285.

[10] Sahai A, Ray SK. And efficient estimator using auxiliary information. Metrika. 1980;27(4):271-275.

[11] Srivastava SK, Jhajj HA. A class of estimators of the population mean in survey sampling using auxiliary information. Biometrika. 1981;68(1):341-343.

[12] Ahmed A, Adewara AA, Singh RVK. Class of ratio estimators with known functions of auxiliary variable for estimating finite population variance. Asian Journal of Mathematics and Computer Research. 2016;12(1):63-70.

[13] Audu A, Adewara AA. Modified factor-type estimators under two-phase sampling. Punjab Journal of Mathematics. 2017;49(2):59 -73.

[14] A. Audu, Singh R, Khare S, Dauran NS. Almost unbiased estimators for population mean in the presence of non-response and measurement error. Journal of Statistics & Management Systems. 2020;24(3):573-589.
DOI: 10.1080/09720510.2020.1759209

[15] Muili JO, Agwamba EN, Erinola YA, Yunusa MA, Audu A, Hamzat MA. Modified ratio-cum-product estimators of finite population variance. International Journal of Advances in Engineering and Management. 2020;2(4):309-319.
DOI: 10.35629/5252-0204309319

[16] Khoshnevisan M, Singh R, Chauhan P, Sawan N, Smarandache F. A general family of estimators for estimating population means using known value of some population parameter(s). Far East Journal of Theoretical Statistics. 2007;22(2):181-191.

[17] Singh RVK, Audu A. Efficiency of ratio estimators in stratified random sampling using information on auxiliary attribute. International Journal of Engineering Science and Innovative Technology. 2013;2(1):166-172.

[18] Ahmed A, Singh RVK, Adewara AA. Ratio and product type exponential estimators of population variance under transformed sample information of study and supplementary variables. Asian Journal of Mathematics and Computer Research. 2016;11(3):175-183.

[19] Audu A, Singh RVK. Exponential-type regression compromised imputation class of estimators. Journal of Statistics and Management Systems. 2020;1-15.
DOI: 10.1080/09720510.2020.1814501

[20] Das AK, Tripathi TP. A class of estimators for co-efficient of variation using knowledge on co-efficient of variation of an auxiliary character. In annual conference of Ind. Soc. Agricultural Statistics. Held at New Delhi, India; 1981.

[21] Das AK, Tripathi TP. Use of auxiliary information in estimating the coefficient of variation. Alig. J. of Statist. 1992;12:51-58.

[22] Patel PA, Rina S. A Monte Carlo comparison of some suggested estimators of coefficient of variation in finite population. Journal of Statistics Science. 2009;1(2):137-147.

[23] Rajyaguru A, Gupta P. On the estimation of the coefficient of variation from finite population-I, Model Assisted Statistics and Application. 2002;36(2):145-156.

[24] Rajyaguru A, Gupta P. On the estimation of the coefficient of variation from finite population –II, Model Assisted Statistics and Application. 2006;1(1):57-66.

[25] Archana V, Rao A. Same improved estimators of co-efficient of variation from bivariate normal distribution. a monte carlo comparison. Pakistan Journal of Statistics and Operation Research. 2014;10(1).

[26] Singh R, Mishra M, Singh BP, Singh P, Adichwal NK. Improved estimators for population coefficient of variation using auxiliary variables. Journal of Statistics & Management Systems. 2018;21(7):1335-1335.

[27] Audu A, Singh R, Khare S. Developing calibration estimators for population mean using robust measures of dispersion under stratified random. Statistics in Transition New Series. 2021;22(2):125–142.
DOI: 10.21307/stattrans-2021-019

[28] Audu A, Ishaq OO, Abubakar A, Akintola KA, Isah U, Rashida A, Muhammad S. Regression-type Imputation Class of Estimators using Auxiliary Attribute. Asian Research Journal of Mathematics. 2021;17(5):1-13.
DOI: 10.9734/ARJOM/2021/v17i530296

[29] Audu A, Ishaq OO, Isah U, Muhammed S, Akintola KA, Rashida A, Abubakar A. On the Class of Exponential-Type Imputation Estimators of Population Mean with Known Population Mean of Auxiliary Variable. NIPES Journal of Science and Technology Research. 2020;2(4):1–11.
Available:https://doi.org/10.37933/nipes/2.4.2020.1

[30] Audu A, Ishaq OO, Muili JO, Abubakar A, Rashida A, Akintola KA, Isah U. Modified estimators of population mean using robust multiple regression methods. NIPES Journal of Science and Technology Research. 2020;2(4):12–20.
Available:https://doi.org/10.37933/nipes/2.4.2020.2

[31] Audu A, Ishaq OO, Muili JO, Zakari Y, Ndatsu AM, Muhammed S. On the Efficiency of Imputation Estimators using Auxiliary Attribute. Continental J. Applied Sciences. 2020;15(1):1-13.
DOI: 10.5281/zenodo.3721046

[32] Audu A, Ishaq OO, Zakari Y, Wisdom DD, Muili J, Ndatsu AM. Regression-cum-exponential ratio imputation class of estimators of population mean in the presence of non-response. Science Forum Journal of Pure and Applied Science. 2020;20:58-63.
DOI: http://dx.doi.org/10.5455/sf.71109

[33] Singh R, Mishra P, Audu A, Khare S. Exponential Type Estimator for Estimating Finite Population Mean. Int. J. Comp. Theo. Stat. 2020;7(1):37-41.

[34] Muili JO, Agwamba EN, Erinola YA, Yunusa MA, Audu A, Hamzat MA. A Family of Ratio-Type Estimators of Population Mean using Two Auxiliary Variables. Asian Journal of Research in Computer Science; 2020.
DOI: 10.9734/AJRCOS/2020/v6i130152

[35] Ishaq OO, Audu A, Ibrahim A, Abdulkadir HS, Tukur K. On the linear combination of sample variance, ratio, and product estimators of finite population variance under two-stage sampling. Science Forum Journal of Pure and Applied Science. 2020;20:307-315.
DOI: http://dx.doi.org/10.5455/sf.90563

[36] Das AK, Tripathi TP. A class of Estimators for co-efficient of Variation using knowledge on co-efficient of variation of an auxiliary character. In annual conference of Ind. Soc. Agricultural Sdtatistics. Held at New Delhi, India; 1981.

[37] Das AK, Tripathi TP. Use of auxiliary information in estimating the coefficient of variation. Alig. J. of Statist. 1992;12:51-58.

[38] Audu A, Yunusa MA, Ishaq OO, Lawal MK, Rashida A, Muhammad AH, et al. Difference-Cum-Ratio Estimators for Estimating Finite Population Coefficient of Variation in Simple Random Sampling. Asian Journal of Probability and Statistics. 2021;13(3):13-29.

DOI: 10.9734/AJPAS/2021/v13i330308

[39] Archana V, Rao A. Some improved Estimators of co-efficient of variation from Bivariate normal distribution. A Monte Carlo comparison. Pakistan Journal of Statistics and Operation Research. 2014;10(1).

[40] Murthy MN. Sampling theory and methods. Sampling Theory and Methods; 1967.

[41] Singh S. Advanced Sampling Theory with Applications. How Michael Selected Amy. Springer Science and Media. 2003;2.

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