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ESTIMATION OF POPULATION MEAN USING RANKED SET SAMPLING

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ABSTRACT

In the present study, a modified ratio cum product type estimate for estimating the population mean in rank set sampling has been suggested. The bias and MSE (mean squared error) of all the discussed estimators are obtained. Comparison of the proposed estimator with the Samawi and Muttalak (1996) estimator is carried out. By comparison, the condition which make the proposed more efficient than the other estimators are found.

KEYWORDS

Auxiliary Variable, Study Variable, Simple Random Sampling, Rank Set Sampling, Ratio Estimators.

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1. INTRODUCTION

In surveys, for estimating population parameters like the mean, total or ratio, product and regression, sample surveys experts sometimes use auxiliary information to improve precision of the estimates. When both the variables i.e. study as well as auxiliary variables are positively correlated, ratio estimators are frequently employed to estimate the population mean of a random variable 'Y'. Let 'Y' and 'X', respectively, are study variable and the auxiliary variable. In simple random sampling (SRS), the usual SRS-ratio estimator of, based on a simple random sample of size is denoted by

$$t_{SRS} = t_R \mu_X \quad \text{with} \quad t_R = \frac{\bar{Y}_{SRS}}{\bar{X}_{SRS}} \quad (1)$$

where $\bar{Y}_{SRS}$ and $\bar{X}_{SRS}$ are the means of single random samples of measurements of 'Y' and 'X', respectively. It is assumed that X_i 's are positive and μ_X is known. The SRS-ratio estimator t_{SRS} is known to be biased with

$$E[t_{SRS}] = \mu_Y + \frac{b_1}{n} + O\left[\frac{1}{n^2}\right]$$

and a suitable choice of b_1 using a first order Taylor series expansion, the approximated mean square error(MSE) and the bias of the SRS-ratio estimator are given by

$$MSE[t_{SRS}] \cong \frac{\mu_Y^2}{n} [C_Y^2 + C_X^2 - 2C_{XY}] \quad (2)$$

$$\text{and } MSE[t_{SRS}] \cong \frac{\mu_Y}{n} [C_X^2 - C_{YX}] \quad (3)$$

where $C_X = \frac{\sigma_Y}{\sigma_X}$; $C_Y = \frac{\sigma_X}{\sigma_Y}$ and $C_{YX} = \rho C_Y C_X$

with $\rho = \text{Corr}(X, Y)$, respectively.

Ranked set sampling (RSS) was first proposed by McIntire (1952). He used this model for estimating the mean of pasture yields. This design appeared as a useful technique for improving the accuracy of the estimation of means. This fact was affirmed by McIntire but a mathematical prove of it was settled by Takahashi-Wakimoto (1968). In many situations the statistician deals with the need of combining some control and the implementation of some flexibility with the use of a random based sample. This is a common problem in the study of environmental and medical studies. In these cases the researcher generally has abundant and accurate information on the population units. It is related with the variable of interest Y and to rank the units using this information is cheap. The RSS procedure is based on the selection of m independent samples, not necessarily of the same size, by using simple random sampling (SRS). The sampled units are ranked and the selection of the units evaluated takes into account the order of them in the combined m samples. The proposal of McIntire (1952) was to use a prediction of Y. After some experiences with its application the lack of a coherent statistical theory appeared as an interesting theme of study to theoretical statisticians. An important role was played by Halls-Dell (1966) who established that RSS was more efficient than SRS for estimating the population mean from a large study of sampling forage yields. The interest for RSS in applications is reflected not only in the initial papers but in the orientation of a series of papers to practice. See for

example Chen (1999), Demir-Singh (2000), Kour et al. (1997) and Hall-Dell (1996) for examples. The interest in the development of a new statistical theory using RSS can be illustrated by the contributions of Abu-Dayyeh and Muttalak (1996), Al-Saleh and Al-Khadari (2000), Barabasi and El-Shamawi (2001), Bouza (2002b) and Chen (2001 a, 2001b), {see Bouza et al. (2005)}.

Let $(X_{11}, Y_{11}), (X_{12}, Y_{12}) \dots (X_{1n}, Y_{1n}), (X_{21}, Y_{21}) \dots (X_{2n}, Y_{2n}), \dots (X_{n1}, Y_{n1}) \dots (X_{nn}, Y_{nn})$ be independent bivariate random vector all with same cumulative distribution function and $(X_{[i1]}, Y_{[i1]}) \dots (X_{[in]}, Y_{[in]})$ be the order statistics of $X_{[i1]}, X_{[i2]} \dots X_{[in]}$ and $Y_{[i1]}, Y_{[i2]} \dots Y_{[in]}$.

Let $(X_{1[1]}, Y_{1[1]}), (X_{2[2]}, Y_{2[2]}) \dots (X_{n[n]}, Y_{n[n]})$ denote the rank set sample where $(X_{[i]}, Y_{[i]})$ be the i^{th} order statistics in the i^{th} sample for auxiliary variable 'X' and study variable 'Y', respectively. However, by Samawi and Muttalak (1996), as well as Kadilar et al (2009), the supplementary information can also be used at the estimator stage by using ratio estimators. To this end, Samawi and Muttak (1996) proposed a ratio based estimator for estimating the population mean μ_Y based on a ranked set sample as follow

$$t_R^* = r_{RSS} \mu_X; \text{ with } r_{RSS} = \frac{\bar{Y}_{RSS}}{\bar{X}_{RSS}} \quad (4)$$

where $\bar{Y}_{RSS} = \frac{1}{mk} \sum_{i=1}^m \sum_{j=1}^k Y_{[ij]}$ and $\bar{X}_{RSS} = \frac{1}{mk} \sum_{i=1}^m \sum_{j=1}^k X_{[ij]}$ respectively.

The approximated bias and MSE of t_R^* as follows

$$\begin{aligned} Bias(t_R^*) &\cong \frac{\mu_Y}{n} [(C_X^2 - C_{XY}) - (W_X^2 - W_{XY})] + O\left(\frac{1}{n^2}\right) \\ &= Bias(t_{RSS}) - \frac{\mu_Y}{n} (W_X^2 - W_{XY}) \end{aligned} \quad (5)$$

$$\begin{aligned} MSE(t_R^*) &\cong \frac{\mu_Y^2}{n} [C_X^2 + C_Y^2 - 2C_{YX}] - \frac{1}{nk} \sum_{j=1}^k \{R\tau_{X[j]} - \tau_{Y[j]}\}^2 \\ &= MSE(t_{RSS}) - \frac{1}{nk} \sum_{j=1}^k \{R\tau_{X[j]} - \tau_{Y[j]}\}^2 \end{aligned} \quad (6)$$

where $\tau_{X[j]} = \mu_{X[j]} - \mu_X$ with $\mu_{X[j]} = E[X_{(j)}]$, $\tau_{Y[j]}$ and $\mu_{Y[j]}$ are defined similarly, and $W_X^2 = \frac{1}{k\mu_X^2} \sum_{j=1}^k \tau_{X(j)}^2$, $W_{XY} = \frac{1}{k\mu_X\mu_Y} \sum_{j=1}^k \tau_{X[j]} \tau_{Y[j]}$.

2. THE PROPOSED ESTIMATOR

In the section, we suggest a modified ratio cum product type estimator for estimating population mean of the study variable based on a ranked set sample as follows

$$t_{RSS}^* = \bar{Y}_{RSS} \left[\alpha \frac{\mu_X}{\bar{X}_{RSS}} + (1 - \alpha) \frac{\bar{X}_{RSS}}{\mu_X} \right] \quad (7)$$

where α is any suitably chosen constant.

For $\alpha = 1$; the proposed estimator reduces to the ratio type estimator by Samawi Muttak (1996) as

$$t_R^* = \frac{\bar{Y}_{RSS}}{\bar{X}_{RSS}} \mu_X \quad \text{defined at (4)}$$

For $\alpha = 0$; the proposed estimator reduces to the product type estimator as

$$t_R^* = \frac{\bar{Y}_{RSS}}{\mu_X} \bar{X}_{RSS} \quad (8)$$

The bias and MSE of (8) is as follow:-

$$Bias(t_R^*) \cong \frac{\mu_Y}{n} [(C_X^2 + C_{XY}) - (W_X^2 + W_{XY})] + O\left(\frac{1}{n^2}\right) \quad (9)$$

$$MSE(t_R^*) \cong \frac{\mu_Y^2}{n} [C_X^2 + C_Y^2 + 2C_{YX}] - \frac{1}{nk} \sum_{j=1}^k \{\tau_{Y[j]} + R\tau_{X[j]}\}^2 \quad (10)$$

The bias and MSE of the product estimator t_{RSS}^* to the first degree of approximation respectively as follows:-

$$Bias(t_{RSS}^*) \cong \frac{\mu_Y}{n} \{[C_X^2 + (1 - 2\alpha)C_{XY}] - [W_X^2 + (1 - 2\alpha)W_{XY}]\} + O\left(\frac{1}{n^2}\right) \quad (11)$$

$$MSE(t_{RSS}^*) \cong \frac{\mu_Y^2}{n} \{C_Y^2 + (1 - 2\alpha)(1 - 2\alpha + 2K_{YX})C_X^2\} - \frac{1}{nk} \sum_{j=1}^k \{\tau_{Y[j]} + R(1 - 2\alpha)\tau_{X[j]}\}^2 \quad (12)$$

which is minimum, when

$$\alpha = \frac{1}{2} \left[1 - \frac{C_{YX} - W_{XY}}{C_X^2 - W_X^2} \right] = \alpha_{10}(\text{say})$$

Thus the resulting minimum mean squared error of t_{RSS}^* is given by

$$MSE(t_{RSS}^*) \cong \frac{\mu_Y^2}{n} \{C_Y^2 + A_0(2K_{YX} - A_0)C_X^2\} - \frac{1}{nk} \sum_{j=1}^k \{\tau_{Y[j]} + RA_0\tau_{X[j]}\}^2 \quad (13)$$

where $A_0 = \left[\frac{C_{YX} - W_{XY}}{C_X^2 - W_X^2} \right]$.

3. EFFICIENCY COMPARISONS

In this section, we compare $\min MSE(t_{RSS}^*)$ with $MSE(t_R^*)$ using equation (13) and (6), as follows

$$MSE(t_R^*) - \min MSE(t_{RSS}^*) > 0$$

$$\text{If } K_{YX} > \frac{1+A_X^2}{2(1+A_X)} \text{ and } > \frac{2\tau_{Y[j]}}{R\tau_{X[j]}(1+A_X)}. \quad (14)$$

When the condition (14) holds, the proposed estimator at its optimum condition is more efficient than rank set ratio estimator by Samawi and Muttalak (1996).

4. CONCLUSION

In estimating the population parameters like mean, total or ratio, product and regression, sample survey experts sometimes use auxiliary information to improve efficiency of the estimates. The method of ranked set sampling (RSS) is a cost efficient alternative to simple random sampling (SRS) for those situations where measurements are difficult or expensive to obtain but (judgement) ranking of units according to the variable of interest is relatively easy and cheap. In this paper, we have suggested a modified ratio cum product type estimator for estimating population mean of the study variable based on a ranked set sample. By comparing the proposed estimator with the ranked set ratio estimator, we showed that the proposed estimator at its optimum condition is more efficient one. So, it is recommended to use the proposed estimator in further research in this field.

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