Pak. J. Statist.
2022 Vol. 38(1), 77-88

RATIO-CUM-PRODUCT TYPE ESTIMATORS FOR MEAN IN PRESENCE OF NON-RESPONSE

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ABSTRACT

This paper proposed an estimator of population mean in the presence of non-response on study variable. Expression for bias and MSE of this ratio-cum-product type of generalized estimator has been derived up to first order approximation. Bias and MSE of several sub-cases of the proposed estimator has been given in the presence of non-response. Efficiency comparison has been made with Hansen-Hurwitz estimator of population mean in presence of non-response. Non-response has also applied on both study and auxiliary variable. Empirical study has conducted to check the efficiency of the estimator. Comparison with other sub-cases is made on the basis of PRE value with respect to the Hansen-Hurwitz estimator of population mean. The study has showed that the new suggested estimator has the potential of wider applicability over these existing estimators.

KEY WORDS

Generalized estimator; population mean; auxiliary variate.

1. INTRODUCTION

Ratio, product and regression method of estimation use the concept of auxiliary information to make estimators more efficient. The estimators become more efficient when the study variable is highly correlated with the auxiliary variable. While conducting survey where information on study variable as well as on auxiliary variable is necessary, people may feel hesitate to respond. Information on age, income, weight or some other social, economic or medical issue is difficult to obtain. There may arise a situation of non-response. Hence the data remain incomplete or mislead. As a result, biased estimate will be obtained. Here the respondent and non-respondent are two different groups. Hansen and Hurwitz (1946) were the first one who incorporated sub-sampling from non-respondents for estimation of population mean. Several authors paid attention to this technique. Cochran (1977), Khare and Srivastava (1993, 1995, 1997), Okafor and Lee (2000), Ahmad et al. (2009) and Khare and Sinha (2009, 2011) used the auxiliary information in the presence of non-response for the estimation of population mean.

A mailed questionnaire is used to obtain the information. Then a list of non-respondents is prepared. A sub-sample is drawn from the list and direct interview is conducted with the selected non-respondents to obtain the necessary information.

Divide the population into two groups. The respondent class is one who will respond and the nonrespondent class will not respond. Let N_1 and N_2 be the number of units in the population of respondent and non-respondent class such that $N_1 + N_2 = N$. Let n_1 be the sample size from the respondent class and n_2 be the simple random sample from the non-respondent class. Let h_2 be the size of sub-sample from n_2 to be interviewed. Let $\bar{y}_1$ denotes the sample mean based on n_1 units and $\bar{y}_{h2}$ denotes the sub-sample mean based on h_2 units. Then the proposed estimator by Hansen and Hurwitz (1946) is given below.

$$y^* = \frac{n_1\bar{y}_1 + n_2\bar{y}_{h2}}{n} \tag{1}$$

The estimator given above is unbiased and has variance of the form,

$$Var(\bar{y}^*) = \left(\frac{1}{n} - \frac{1}{N}\right)S_y^2 + \bar{Y}^2(f-1)\frac{N_2}{N}\frac{C_{y2}^2}{n} \tag{2}$$

Here $f = \frac{n_2}{h_2}$ and population mean square of y for response class is S_y^2 and population mean square of y for non-response class is $S_{y2}^2 = \bar{Y}^2 C_{y2}^2$.

Singh et al. (2016) proposed a generalized ratio cum product estimator for population mean $\bar{Y}$ under SRSWOR.

$$T = \bar{y}\left[\frac{a\bar{X} + b}{a\bar{x} + b}\right]^{2g-1} \tag{3}$$

where $a \neq 0$ and b is the function of known parameters of auxiliary variable X. The ratio type product estimator has several sub-cases such as the usual unbiased estimator for population mean, usual ratio type estimator, product estimator, Sisodia and Dwivedi (1981), Singh and Tailor (2003), Singh et al. (2004) and Singh and Agnihotri (2008) for several values of a, b and g. The bias and mean square error of the estimator T to first degree of approximations given as,

$$Bias(T) = \left(\frac{1}{n} - \frac{1}{N}\right)\bar{Y}\theta(2g-1)(g\theta - C)C_x^2 \tag{4}$$

$$MSE(T) = \left(\frac{1}{n} - \frac{1}{N}\right)\bar{Y}^2\left[C_y^2 + (2g-1)\theta C_x^2\left\{(2g-1)\theta - 2C\right\}\right] \tag{5}$$

where $\theta = \frac{a\bar{X}}{a\bar{x} + b}, C = \frac{\rho C_y}{C_x}, C_x^2 = \frac{S_x^2}{\bar{X}^2}, C_y^2 = \frac{S_y^2}{\bar{Y}^2}$

By taking the idea of Hansen and Hurwitz and using the generalized ratio cum product estimator by Singh et al. (2016), we proposed generalized ratio cum product estimator for population mean in the presence of non-response.

2. THE ESTIMATOR OF MEAN

We have proposed a generalized estimator for population mean $\bar{Y}$ in the presence of non-response using auxiliary variable in this section. Bias, MSE of the estimator are also discussed here. Optimum value of "g" is derived and hence optimum MSE is obtained. Proposed estimator is compared with HH estimator for efficiency.

2.1 The Suggested Estimator

We proposed the following general class of estimator for population mean $\bar{Y}$ using the information contained in auxiliary variable X. We assume non-response is on study variable.

$$T^* = \bar{y}^* \left[\frac{a\bar{X}+b}{a\bar{x}+b} \right]^{2g-1} \tag{6}$$

To find the bias and MSE of the estimator, we use

$$\bar{y}^* = \bar{Y}\left(1+e_o^*\right) \quad \bar{x} = \bar{X}\left(1+e_1\right)$$

such that

$$E\left(e_o^*\right) = E(e_1) = 0$$

$$E\left(e_o^{2*}\right) = \left(\frac{1}{n}-\frac{1}{N}\right)C_y^2 + \frac{(f-1)}{nN} N_2 C_{y2}^2$$

$$E\left(e_1^2\right) = \left(\frac{1}{n}-\frac{1}{N}\right)C_x^2$$

$$E\left(e_o^* e_1\right) = \left(\frac{1}{n}-\frac{1}{N}\right)\rho C_x C_y$$

Expressing (6) in terms of e's and to the first degree of approximation,

$$T^* = \bar{Y}\left(1+e_o^*\right)\left[\frac{a\bar{X}+b}{a\bar{X}(1+e_1)+b}\right]$$

By using $\theta = \dfrac{a\bar{X}}{a\bar{x}+b}$,

$$T^* = \bar{Y}\left(1+e_o^*\right)\left(1+\theta e_1\right)^{-(2g-1)}$$

Expanding the above Equation and neglecting the higher power of e's, we get

$$T^* - \overline{Y} = \overline{Y}\left[e_o^* - (2g-1)\theta e_1 - (2g-1)\theta e_o^* e_1 + g(2g-1)\theta^2 e_1^2 \right] \quad (7)$$

Applying Expectation on both sides of (7) and using $C = \frac{\rho C_y}{C_x}$, the bias of proposed generalized estimator is given as,

$$Bias(T^*) = \left(\frac{1}{n} - \frac{1}{N}\right)\overline{Y}\theta(2g-1)(g\theta - C)C_x^2 \quad (8)$$

Neglecting higher powers of e's, Squaring and applying expectation on both side of (7) the MSE of the proposed estimator is,

$$MSE(T^*) = \left(\frac{1}{n} - \frac{1}{N}\right)\overline{Y}^2\left[C_y^2 + (2g-1)\theta C_x^2 \{(2g-1)\theta - 2C\} \right] + \overline{Y}^2 \frac{(f-1)}{nN} N_2 C_{y2}^2 \quad (9)$$

The suggested estimator is a generalized estimator which has several sub-cases. The sub-cases in the presence of non-response on study variable are presented below.

Taking $(a,b,g) = (a,b,\frac{1}{2})$, The usual unbiased estimator of population mean given by Hansen and Hurwitz (1946).

Taking $(a,b,g) = (1,0,1)$, the usual ratio estimator

$$T_1^* = \overline{y}^*\left[\frac{\overline{X}}{\overline{x}}\right] \quad (10)$$

Taking $(a,b,g) = (1,0,0)$, the usual product estimator

$$T_2^* = \overline{y}^*\left[\frac{\overline{x}}{\overline{X}}\right] \quad (11)$$

Taking $(a,b,g) = (a,b,1)$, Singh and Agnihotri 2008 estimator

$$T_3^* = \overline{y}^*\left[\frac{a\overline{X} + b}{a\overline{x} + b}\right] \quad (12)$$

Taking $(a,b,g) = (a,b,0)$, Singh and Agnihotri 2008 estimator

$$T_2^* = \overline{y}^*\left[\frac{a\overline{x} + b}{a\overline{X} + b}\right] \quad (13)$$

The Bias and MSE of the above estimators in the presence of non-response are obtained by substituting different values of a, b and g in (8) and (9).

$$Bias\left(T_1^*\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}(1-C)C_x^2 \tag{14}$$

$$Bias\left(T_2^*\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}CC_x^2 \tag{15}$$

$$Bias\left(T_3^*\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}\theta(\theta-C)C_x^2 \tag{16}$$

$$Bias\left(T_4^*\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}\theta CC_x^2 \tag{17}$$

$$MSE\left(T_1^*\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+C_x^2(1-2C)\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2 \tag{18}$$

$$MSE\left(T_2^*\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+C_x^2(1+2C)\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2 \tag{19}$$

$$MSE\left(T_3^*\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+\theta C_x^2(\theta-2C)\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2 \tag{20}$$

$$MSE\left(T_4^*\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+\theta C_x^2(\theta+2C\}\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2. \tag{21}$$

2.2 Efficiency Comparison

MSE of the proposed estimator is compared with the variance of the estimator given by Hansen and Hurwitz for population mean in the presence of non-response. Comparing (2) and (9),

$$Var(\bar{y}^*)\geq MSE(T^*)$$

$$\left(\frac{1}{n}-\frac{1}{N}\right)\overline{Y^2}C_y^2+\frac{(f-1)}{nN}N_2S_{y2}^2\geq\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2$$

$$\left[C_y^2+(2g-1)\theta C_x^2\left\{(2g-1)\theta-2C\right\}\right]+\frac{(f-1)}{nN}N_2S_{y2}^2$$

$$\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2C_y^2\geq\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+(2g-1)\theta C_x^2\left\{(2g-1)\theta-2C\right\}\right]$$

$$C_y^2\geq C_y^2+(2g-1)\theta C_x^2\left\{(2g-1)\theta-2C\right\}$$

$$0\geq(2g-1)\theta C_x^2\left\{(2g-1)\theta-2C\right\}$$

$$g\leq\min\left(\frac{1}{2},\frac{1}{2}\left(1+\frac{2c}{\theta}\right)\right)$$

When this condition is satisfied, the proposed estimator is more reliable.

2.3 Optimum Value of “ g ”

Differentiating (9) with respect to” g” and equating to zero, we get

$$\frac{\partial MSE(T^*)}{\partial g}=\frac{\partial}{\partial g}\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+(2g-1)\theta C_x^2\{(2g-1)\theta-2C\}\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2$$

$$\frac{\partial MSE(T^*)}{\partial g}=0$$

$$g=\frac{1}{2}\left(1+\frac{C}{\theta}\right)$$

By substituting the optimum value of g , the optimum $MSE(T^*)$ will be obtain.

$$Optimum\ MSE(T^*)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2-C^2C_x^2\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2$$

Using the value of C and $\bar{Y}^2C_y^2=S_y^2$, the optimum MSE is given as,

$$Optimum\ MSE(T^*)=\left(\frac{1}{n}-\frac{1}{N}\right)S_y^2\left(1+\rho^2\right)+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2\,. \tag{22}$$

3. NON-RESPONSE ON STUDY AND AUXILIARY VARIABLE

In this section, we consider the presence of non-response on both study and auxiliary variable. The proposed estimator under non-response is given as,

$$T^{**}=\bar{y}^*\left[\frac{a\bar{X}+b}{a\bar{x}^*+b}\right]^{2g-1} \tag{23}$$

We use the following conditions to find the bias and MSE of the estimator.

$$\bar{y}^*=\bar{Y}\left(1+e_o^*\right)$$

$$\bar{x}^*=\bar{X}\left(1+e_1^*\right)$$

such that

$$E\left(e_o^*\right)=E\left(e_1^*\right)=0$$

$$E\left(e_o^{2*}\right)=\left(\frac{1}{n}-\frac{1}{N}\right)C_y^2+\frac{(f-1)}{nN}N_2C_{y2}^2$$

$$E\left(e_1^{2*}\right)=\left(\frac{1}{n}-\frac{1}{N}\right)C_x^2+\frac{(f-1)}{nN}N_2C_{x2}^2$$

$$E\left(e_o^*e_1\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\rho C_xC_y$$

Hence the estimator by expressing in e's and value of θ become

$$T^{**}=\bar{Y}\left(1+e_o^*\right)\left(1+\theta e_1^*\right)^{-(2g-1)}$$

$$T^{**}-\bar{Y}=\bar{Y}\left[e_o^*-(2g-1)\theta e_1^*-(2g-1)\theta e_o^* e_1^*+g(2g-1)\theta^2 e_1^{*2}\right] \quad (24)$$

The bias and MSE of the estimator under non-response are given below.

$$Bias\left(T^{**}\right)=\bar{Y}\left[(2g-1)\theta\left(\frac{1}{n}-\frac{1}{N}\right)(g\theta-C)C_x^2\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2\left(C_2-1\right)C_{x2}^2 \quad (25)$$

where N_2 non-response unit of character x contains mean square error S_{x2}^2 and hence $C_{x2}^2=\frac{S_x^2}{X^2}$ and $C_2=\frac{\rho_2 C_{y2}}{C_{x2}}$.

$$MSE\left(T^{**}\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+\left(2g-1\right)\theta C_x^2\left\{(2g-1)\theta-2C\right\}\right]$$
$$+\bar{Y}^2\frac{(f-1)}{nN}N_2\left[C_{y2}^2+\left(2g-1\right)\theta C_{x2}^2\left\{\left(2g-1\right)\theta-2C_2\right\}\right]. \quad (26)$$

4. EMPIRICAL STUDY

In this section we used different data sets to access the efficiency of the proposed estimator of population mean in the presence of non-response. The proposed generalized estimator and other sub-cases are compared with the HH estimator of population mean. The results thus obtained will be presented in the form of Percentage Relative Efficiency (PRE). We used the optimum MSE of the proposed estimator.

$$PRE\left(T^*\right)=\frac{Var\left(\bar{y}^*\right)}{MSE\left(T^*\right)}\times 100$$

$$PRE\left(T^*\right)=\frac{\left(\frac{1}{n}-\frac{1}{N}\right)S_y^2+\bar{Y}^2(f-1)\frac{N_2}{N}\frac{C_{y2}^2}{n}}{\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+(2g-1)\theta C_x^2\left\{(2g-1)\theta-2C\right\}\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2}\times 100$$

$$PRE\left(T_1^*\right)=\frac{Var\left(\bar{y}^*\right)}{MSE\left(T_1^*\right)}\times 100$$

$$PRE\left(T_1^*\right)=\frac{\left(\frac{1}{n}-\frac{1}{N}\right)S_y^2+\bar{Y}^2(f-1)\frac{N_2}{N}\frac{C_{y2}^2}{n}}{\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+C_x^2(1-2C)\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2}\times 100$$

$$PRE\left(T_2^*\right)=\frac{Var\left(\bar{y}^*\right)}{MSE\left(T_2^*\right)}\times 100$$

$$PRE\left(T_2^*\right)=\frac{\left(\frac{1}{n}-\frac{1}{N}\right)S_y^2+\bar{Y}^2(f-1)\frac{N_2}{N}\frac{C_{y2}^2}{n}}{MSE\left(T_2^*\right)=\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+C_x^2(1+2C)\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2}\times 100$$

$$PRE\left(T_3^*\right)=\frac{Var\left(\bar{y}^*\right)}{MSE\left(T_3^*\right)}\times 100$$

$$PRE\left(T_3^*\right)=\frac{\left(\frac{1}{n}-\frac{1}{N}\right)S_y^2+\bar{Y}^2(f-1)\frac{N_2}{N}\frac{C_{y2}^2}{n}}{\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+\theta C_x^2(\theta-2C)\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2}\times 100$$

$$PRE\left(T_4^*\right)=\frac{Var\left(\bar{y}^*\right)}{MSE\left(T_4^*\right)}\times 100$$

$$PRE\left(T_4^*\right)=\frac{\left(\frac{1}{n}-\frac{1}{N}\right)S_y^2+\bar{Y}^2(f-1)\frac{N_2}{N}\frac{C_{y2}^2}{n}}{\left(\frac{1}{n}-\frac{1}{N}\right)\bar{Y}^2\left[C_y^2+\theta C_x^2(\theta+2C\}\right]+\bar{Y}^2\frac{(f-1)}{nN}N_2C_{y2}^2}\times 100 .$$

4.1 Population 1

The first population consist of 96 villages whose area is greater than 160 hectares, Hooghly, West Bengal. Study variable is number of agriculture labors whereas the area in hectares of the village is considered as auxiliary as auxiliary information. The noon-response group contains 25% (i.e. 24 villages) of the data.

$N=96$ $\quad N_1=72$ $\quad N_2=24$

$\bar{Y}=137.92$ $\quad \bar{X}=144.87$ $\quad f=0.25$

$C_y=1.32$ $\quad C_x=0.81$

$C_{y2}=2.08$ $\quad C_{x2}=0.094$

$\rho=0.77$ $\quad \rho_2=0.72$

4.2 Population 2

The second data that we consider in our study contains the information on weights as study variable and chest circumference as auxiliary variable of 95 school children, Department of Pediatrics, BHU during 1983-1984. The data contains 25% of non-response units.

$N = 95$ $\quad N_1 = 71$ $\quad N_2 = 24$

$\bar{Y} = 19.49$ $\quad \bar{X} = 51.17$ $\quad f = 0.25$

$C_y = 0.15$ $\quad C_x = 0.03$

$C_{y2} = 0.12$ $\quad C_{x2} = 0.02$

$\rho = 0.32$ $\quad \rho_2 = 0.47$

4.3 Population 3

The data consider here contains 109 village/town/ward wise population of urban area under Police Station Orissa, India. The non-response group was again comprises of 25% of the population. The data used number of literate people in the village as the study variable while the auxiliary variable is number of main workers.

$N = 109$ $\quad N_1 = 81$ $\quad N_2 = 28$

$\bar{Y} = 145.3$ $\quad \bar{X} = 165.26$ $\quad f = 0.25$

$C_y = 0.76$ $\quad C_x = 0.68$

$C_{y2} = 0.68$ $\quad C_{x2} = 0.057$

$\rho = 0.81$ $\quad \rho_2 = 0.78$

4.4 Population 4

The data used here consist of 100 consecutive trips after omitting 20 outliers gathered by two fuel meters for a small family car. The non-response group consist of 25% of the population. The data used measure of tribune meter in milliliter is taken as study variable and measure of displacement meter in cm^3 as auxiliary variable.

$N = 80$ $\quad N_1 = 60$ $\quad N_2 = 20$

$\bar{Y} = 3500.12$ $\quad \bar{X} = 260.84$ $\quad f = 0.25$

$C_y = 0.5941$ $\quad C_x = 0.5996$

$C_{y2} = 0.5075$ $\quad C_{x2} = 0.5168$

$\rho = 0.985$ $\quad \rho_2 = 0.995$

Table 1
PRE of Proposed Estimator and other Sub-Cases with respect to HH Estimator of Population Mean

Population I

Estimator	T^*	T_1^*	T_2^*	T_3^*	T_4^*
n=10	153.8984	150.5522	56.1600	150.3739	56.3774
n=20	149.7730	146.7607	57.4470	146.6000	57.6629
n=30	145.2591	142.5977	59.0149	142.4554	59.2284
n=50	134.8235	132.9148	63.4632	132.8123	63.6678

Population II

Estimator	T^*	T_1^*	T_2^*	T_3^*	T_4^*
n=10	109.4964	108.0534	87.5436	107.9610	87.8022
n=20	109.2888	107.8797	87.7622	107.8494	88.0169
n=30	109.0307	107.6635	88.0368	107.5759	88.2864
n=50	108.7010	107.3871	88.3920	107.3029	88.6352

Population III

Estimator	T^*	T_1^*	T_2^*	T_3^*	T_4^*
n=10	215.0408	212.3671	35.2780	212.6923	35.4648
n=20	210.1283	207.6259	35.7481	207.9304	35.9361
n=30	204.5343	202.2209	36.3278	202.5026	36.5171
n=50	109.6436	188.7710	38.0149	188.9993	38.2078

Population IV

Estimator	T^*	T_1^*	T_2^*	T_3^*	T_4^*
n=10	507.2044	505.9549	28.6689	500.3198	28.7738
n=20	455.3766	454.3972	29.2521	454.6833	29.3582
n=30	401.6298	400.8965	30.0528	407.1107	30.1605
n=50	287.9366	287.6087	33.0820	287.7046	33.1954

5. CONCLUSION

The generalized ratio cum product estimator in the presence of non-response on study variable using the information on auxiliary variable for population mean is proposed. The proposed estimator has several sub-cases in the presence of non-response. The PREs of the suggested estimator and its different sub-cases that already exist in literature with respect to the usual estimator of population mean in the presence of non-response are given for different populations in Table (1). The proposed estimator has the highest PRE indicating the effectiveness as compared to other existing estimators. It is observed that as the sample size increases the estimator become less effective. This is may be due to the fact that for small sample size the proportion of non-response is small in sample and is far away from the proportion of non-response in population while for the large sample size the proportion of non-response became much closer to the proportion of non-response in population.

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