Pak. J. Statist.
2019 Vol. 35(3), 187-196

A CLASS OF ESTIMATORS FOR POPULATION MEAN UTILIZING INFORMATION ON AUXILIARY VARIABLES USING TWO PHASE SAMPLING SCHEME IN THE PRESENCE OF NON-RESPONSE WHEN STUDY VARIABLE IS AN ATTRIBUTE

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ABSTRACT

In this paper, we have considered the problem of estimating the population mean using one or two auxiliary variables in the presence of non response under two phase sampling when study variable itself is qualitative in nature. Bias and mean squared error (MSE) expressions of the classes of estimators are derived up to the first order of approximation. The proposed estimators have been compared with the usual estimator. An empirical study has been carried out to show that the proposed class of estimators using auxiliary variables are of great importance in increasing the efficiency of the survey.

KEYWORDS

Non Response, Population Mean, Two Phase Sampling, Auxiliary Information, Simple Random Sampling, Mean Square Error.

1. INTRODUCTION

In sample surveys the utilization of auxiliary information is frequently acknowledged to the higher accuracy of the estimation of population characteristics. Ratio, regression and product methods of estimation are good examples in this context. It is not always require to use quantitative auxiliary information. Auxiliary information can also be used in forms of attributes. Jhajj et al. (2006), Koyuncu (2012), Adichwal et al. (2015a, 2015b, 2015c and 2016), Shabbir and Gupta (2007, 2010), Singh and Solanki (2012), Singh et al. (2010) are few example in this context. They have proposed different type of estimators for estimation of population mean or variance when population proportion $\bar{\varphi}_n$ for attribute φ is known or unknown.

Using Hansen and Hurwitz's (1946) technique, Cochran (1977) suggested the use of the ratio method for estimation for the population mean $\bar{Y}$ of the study variate y with sub-sampling from amongst non-respondents. Khare and Sinha (2011), Singh and Kumar (2008), Chaudhary et al. (2012), Sharma and Singh (2014) and Naik and Gupta (1996) have suggested some estimators of population mean $\bar{Y}$ of the study variable y using the auxiliary information in the presence of non response and studied their properties. Singh et al. (2010), Khare and Srivastava (1995) have suggested an estimator for estimating the population mean $\bar{Y}$ of study variable in the case of non-response under two phase sampling. Shabbir et al. (2013) have suggested an estimator of estimating the population mean $\bar{Y}$ of the study variate y using information on two auxiliary variables in the presence of non response under two-phase sampling.

There may be situations when study variable itself is qualitative in nature. For examples a family either owns a house or it does not, rural-urban, it has disability insurance or it does not, both husband and wife are in the labour force or only one suppose is, etc. (Gujrati, 2007). In this context Sharma and Singh (2015) propose an estimator for estimating for estimating the population mean in the presence of auxiliary information in simple random sampling when study variable itself qualitative in nature. Ahmad et al. (2014) have suggested a general class of estimators for two-phase sampling to estimate the population mean of study variable in the case when non-response occur at second phase on study and/or auxiliary variable(s). Khare et al. (2015) have proposed a class of estimators for population mean using an attribute and an auxiliary variable with unknown population mean using two phase sampling scheme in the presence of non response on the study variable. In this paper we propose estimators in which study variable itself is qualitative in nature.

Let a sample of size n is drawn by simple random sampling without replacement (SRSWOR) from a population of size N. Let ψ_i, x_i and z_i denote the observations on variables ψ, x and z respectively for ith unit $\left(i=1,2,3...N\right)$. Let, $\psi_i=1$, if ith unit of the population possesses attribute ψ and $\psi_i=0$, otherwise. Let $A=\sum_{i=1}^{N}\psi_i$ and $a=\sum_{i=1}^{n}\psi_i$, denotes the total number of units in the population and sample possessing attribute ψ respectively. $P=\frac{A}{N}$ and $p=\frac{a}{n}$, denote the proportion of units in the population and sample, respectively, possessing attribute ψ. From N population units, a first phase sample of n' units is drawn by SRSWOR to estimate $\bar{X}$ and $\bar{Z}$. A second phase a sample of n units (i.e. $n<n'$) is drawn from n' by SRSWOR and the study variate ψ under study is measured on it. Non response occurs on second phase in which n_1 units respond and n_2 do not respond for the study characteristics ψ. From n_2 non respondents, a sample of $r=n_2/h;h>1$ units is selected, where h is the inverse sampling rate at the second phase sample of size n.

Following Hansen and Hurwitz (1946), the estimator for estimating unknown population proportion is given by

$$p^{*}=\frac{n_1}{n}p_1+\frac{n_2}{n}p' \tag{1.1}$$

where p_1 and p_2' are sample proportions based on n_1 responding units and sub samples $r\left(\frac{n_2}{h}, h>1\right)$ units from non responding units, respectively.

The variance of $p*$ is given by

$$V(p*) = P^2\left[\lambda C_p^2 + \lambda^* C_{p2}^2\right] \tag{1.2}$$

Similarly,

$$\bar{x}* = \frac{n_1}{n}\bar{x}_1 + \frac{n_2}{n}\bar{x}' \tag{1.3}$$

$$\bar{z}* = \frac{n_1}{n}\bar{z}_1 + \frac{n_2}{n}\bar{z}' \tag{1.4}$$

where $\bar{x}_1$ and $\bar{x}_2'$ are sample means based on corresponding n_1 responding units and r sub sampled units from n_2 non responding units on the auxiliary variable x and $\bar{z}_1$ and $\bar{z}_2'$ are sample mean based on corresponding n_1 responding units and r sub sampled units from n_2 non responding units on the auxiliary variable z .

Let,

$$p* = P(1+e_0),\ \bar{x}* = \bar{X}(1+e_1),\ \bar{x}' = \bar{X}(1+e_1'),\ \bar{x} = \bar{X}(1+e_2),\ \bar{z}* = \bar{Z}(1+e_3),$$
$$\bar{z}' = \bar{Z}(1+e_3') \text{ and } \bar{z} = \bar{Z}(1+e_4)$$

such that $E(e_i) = E(e_i') = 0$, (i=0,1,2,3,4) and

$$E(e_0^2) = \lambda C_p^2 + \lambda^* C_{p2}^2,\ E(e_1^2) = \lambda C_x^2 + \lambda^* C_{x2}^2,\ E(e_3^2) = \lambda C_z^2 + \lambda^* C_{z2}^2,$$

$$E(e_2^2) = \lambda C_x^2,\ E(e_4^2) = \lambda C_z^2,\ E(e_1'^2) = \lambda' C_x^2,\ E(e_3'^2) = \lambda' C_z^2,$$

$$E(e_0 e_1) = \lambda \rho_{px} C_p C_x + \lambda^* \rho_{px2} C_{p2} C_{x2},\ E(e_0 e_3) = \lambda \rho_{pz} C_p C_z + \lambda^* \rho_{pz2} C_{p2} C_{z2},$$

$$E(e_0 e_2) = \lambda \rho_{px} C_p C_x,\ E(e_0 e_4) = \lambda \rho_{pz} C_p C_z,\ E(e_0 e_1') = \lambda' \rho_{px} C_p C_x,$$

$$E(e_0 e_3') = \lambda' \rho_{pz} C_p C_z,\ E(e_1 e_1') = \lambda' C_x^2,\ E(e_3 e_3') = \lambda' C_z^2,\ E(e_2 e_1') = \lambda' C_x^2,$$

$$E(e_4 e_3') = \lambda' C_z^2,\ E(e_1 e_2) = \lambda C_x^2,\ E(e_3 e_4) = \lambda C_z^2$$

where,

$$\lambda = \left(\frac{1-f}{n}\right),\ \lambda' = \left(\frac{1-f'}{n'}\right),\ \lambda^* = W_2\left(\frac{h-1}{n}\right),$$

$$f = \frac{n}{N},\ f' = \frac{n'}{N},\ W_2 = \frac{N_2}{N},\ C_p^2 = \frac{S_p^2}{P^2},\ C_x^2 = \frac{S_x^2}{\bar{X}^2},\ C_y^2 = \frac{S_y^2}{\bar{Y}^2},$$

$$C_{p2}^2 = \frac{S_{p2}^2}{P^2},\ C_{x2}^2 = \frac{S_{x2}^2}{\bar{X}^2} \text{ and } C_{z2}^2 = \frac{S_{z2}^2}{\bar{Z}^2} \text{ respectively.}$$

2. PROPOSED ESTIMATOR

Following Khare et al. (2015), we have suggested an improved class of estimators for estimating unknown population proportion using auxiliary information with unknown population mean in the presence of non response.

The estimator of P using auxiliary variable X in the presence of non response is given by

$$t_1 = H\left(p^*, v\right) \tag{2.1}$$

such that $v = \dfrac{\bar{x}^*}{\bar{x}'_n}$

where $H\left(p^*,\ v\right)$ is a function of p^* and v and satisfies the following regularity conditions.

a) Whatever be the sample chosen, the point $\left(p^*,\ v\right)$ assumes the values in a closed convex subset R_2 of two dimensional real space containing the point (P,1).

b) The function $H\left(p^*,\ v\right)$ is continuous and bounded in R_2.

c) $H\left(P,1\right) = P$ and $H_0(P,1) = 1$, where $H_0(P,1)$ denotes the first order partial derivative of H with respect to p^*.

d) The first and second order partial derivatives of $H\left(p^*,\ v\right)$ exist and are continuous, and bounded in R_2.

Expanding $H\left(p^*,\ v\right)$ about the point (P,1) in a second order Taylor series, we have

$$t_1 = H\left(p^*, v\right) = H\left[P + p^* - P, 1 + v - 1\right] \tag{2.2}$$

$$= H\left(P,1\right) + \left(p^* 1\right) \left.\frac{\partial H}{\partial p^*}\right|_{p^*=P, v=1} + (v-1)\left.\frac{\partial H}{\partial v}\right|_{p^*=P, v=1} + (v-1)^2 \frac{1}{2}\left.\frac{\partial^2 H}{\partial v^2}\right|_{p^*=P, v=1}$$

$$+ (p^* - P)^2 \frac{1}{2}\left.\frac{\partial^2 H}{\partial p^{*2}}\right|_{p^*=P, v=1} + (p^* - P)^2 \frac{1}{2}\left.\frac{\partial^2 H}{\partial p^{*2}}\right|_{p^*=P, v=1} + ... \tag{2.3}$$

$$= p^* + (v-1)H_1 + (v-1)^2 H_2 + (p^* - P)^2 H_3 + (p^* - P)(v-1)H_4 + ... \tag{2.4}$$

where,

$$H_1 = \left.\frac{\partial H}{\partial v}\right|_{p^*=P, v=1},\ H_2 = \frac{1}{2}\left.\frac{\partial^2 H}{\partial v^2}\right|_{p^*=P, v=1},\ H_3 = \frac{1}{2}\left.\frac{\partial^2 H}{\partial p^{*2}}\right|_{p^*=P, v=1},$$

$$H_4 = \frac{1}{2}\left.\frac{\partial^2 H}{\partial p^* \partial v}\right|_{p^*=P, v=1}$$ and so on.

$$t_1 = P(1+e_0) + (e_1 - e_1' + e_1'^2 - e_1 e_1')H_1 + (e_1 - e_1' + e_1'^2 - e_1 e_1')^2 H_2$$
$$+Pe_0(e_1 - e_1' + e_1'^2 - e_1 e_1')H_3 + P^2 e_0^2 H_4 + \ldots\ldots\ldots\ldots\ldots \quad (2.5)$$

The MSE expression of the estimator t_1 is given by

$$MSE(t_1)_{\min} = P^2(\lambda C_p^2 + \lambda^* C_{p2}^2) + H_1^{*2}\left\{(\lambda - \lambda')C_x^2 + \lambda^* C_{x2}^2\right\}$$
$$+2PH_1^*\left\{(\lambda - \lambda')\rho_{px} C_p C_x + \lambda^* \rho_{px2} C_{p2} C_{x2}\right\}$$

where H_1^* is given by

$$H_1^* = \frac{-P\left[(\lambda - \lambda')\rho_{px} C_p C_x + \lambda^* \rho_{px2} C_{p2} C_{x2}\right]}{\left[(\lambda - \lambda')C_x^2 + \lambda^* C_{x2}^2\right]} \quad (2.6)$$

Using two auxiliary variables X and Z in the presence of non response, we have proposed an estimator t_2 of population proportion P, which is given by

$$t_2 = F(p^*, v, u) \quad (2.7)$$

where, $v = \frac{\bar{x}^*}{\bar{x}'}$, $u = \frac{\bar{z}^*}{\bar{z}'}$

where $H(p^*, v, u)$ is a function of p^*, v and u and satisfies the following regularity conditions.

a) Whatever be the sample chosen, the point (p^*, u, v) assumes the values in a closed convex subset R_3 of three dimensional real space containing the point $(P, 1, 1)$.

b) The function $H(p^*, v, u)$ is continuous and bounded in R_3.

c) $H(P,1,1) = P$ and $H_0(P,1,1) = 1$, where $H_0(P,1,1)$ denotes the first order partial derivative of H with respect to p^*.

d) The first and second order partial derivatives of $H(p^*, v, u)$ exist and are continuous, and bounded in R_3.

Expanding $H(p^*, v, u)$ about the point $(P,1,1)$ in a second order Taylor series we have

$$t_2 = F\left[P+(p*-P),1+v-1,1+u-1\right]$$

$$= F\left(P,1,1\right)+\left(p*-P\right)\left.\frac{\partial F}{\partial p*}\right|_{(P,1,1)} + (v-1)\left.\frac{\partial F}{\partial v}\right|_{(P,1,1)} + (u-1)\left.\frac{\partial F}{\partial u}\right|_{(P,1,1)}$$

$$+(p*-P)^2\frac{1}{2}\left.\frac{\partial^2 F}{\partial p*^2}\right|_{(P,1,1)} + (v-1)^2\frac{1}{2}\left.\frac{\partial^2 F}{\partial v^2}\right|_{(P,1,1)} + (u-1)^2\frac{1}{2}\left.\frac{\partial^2 F}{\partial u^2}\right|_{(P,1,1)}$$

$$+(p*-P)(v-1)\frac{1}{2}\left.\frac{\partial^2 F}{\partial p*\partial v}\right|_{(P,1,1)} + (v-1)(u-1)\frac{1}{2}\left.\frac{\partial^2 F}{\partial v\partial u}\right|_{(P,1,1)}$$

$$+(p*-P)(u-1)\frac{1}{2}\left.\frac{\partial^2 F}{\partial u\partial p*}\right|_{(P,1,1)} + ... \quad (2.8)$$

$$= p* + (v-1)F_1 + (u-1)F_2 + (p*-P)^2F_3 + (v-1)^2F_4 + (u-1)^2F_5$$
$$+(p*-P)(v-1)F_6 + (v-1)(u-1)F_7 + (p*-P)(u-1)F_8 + ... \quad (2.9)$$

where,

$$F_1 = \left.\frac{\partial F}{\partial v}\right|_{(P,1,1)},\ F_2 = \left.\frac{\partial F}{\partial u}\right|_{(P,1,1)},\ F_3 = \frac{1}{2}\left.\frac{\partial^2 F}{\partial p*^2}\right|_{(P,1,1)},\ F_4 = \frac{1}{2}\left.\frac{\partial^2 F}{\partial v^2}\right|_{(P,1,1)},$$

$$F_5 = \frac{1}{2}\left.\frac{\partial^2 F}{\partial u^2}\right|_{(P,1,1)}\ F_6 = \frac{1}{2}\left.\frac{\partial^2 F}{\partial p*\partial v}\right|_{(P,1,1)},\ F_7 = \frac{1}{2}\left.\frac{\partial^2 F}{\partial v\partial u}\right|_{(P,1,1)},\ F_8 = \frac{1}{2}\left.\frac{\partial^2 F}{\partial u\partial p*}\right|_{(P,1,1)}$$

and so on.

The MSE expression of the estimator t_2 is given by

$$MSE(t_2)_{\min} = P^2(\lambda C_p^2 + \lambda^* C_{p2}^2) + F_1^{*2}\left\{(\lambda-\lambda')C_x^2 + \lambda^* C_{x2}^2\right\}$$
$$+F_2^{*2}\left\{(\lambda-\lambda')C_z^2 + \lambda^* C_{z2}^2\right\}$$
$$+2P\left\{(\lambda-\lambda')\rho_{px}C_pC_x + \lambda^*\rho_{px2}C_{p2}C_{x2}\right\}F_1^*$$
$$+2P\left\{(\lambda-\lambda')\rho_{pz}C_pC_z + \lambda^*\rho_{pz2}C_{p2}C_{z2}\right\}F_2^*$$
$$+2\left\{(\lambda-\lambda')\rho_{xz}C_xC_z + \lambda^*\rho_{xz2}C_{x2}C_{z2}\right\}F_1^*F_2^* \quad (2.10)$$

To find the optimum values of F_1^* and F_2^* let us define

$$A = \left\{(\lambda-\lambda')\rho_{xz}C_xC_z + \lambda^*\rho_{xz2}C_{x2}C_{z2}\right\}$$
$$B = P\left\{(\lambda-\lambda')\rho_{px}C_pC_x + \lambda^*\rho_{px2}C_{p2}C_{x2}\right\}$$
$$C = P\left\{(\lambda-\lambda')\rho_{pz}C_pC_z + \lambda^*\rho_{pz2}C_{p2}C_{z2}\right\}$$

$$D = \left\{(\lambda - \lambda')C_x^2 + \lambda^* C_{x2}^2\right\}$$

$$E = \left\{(\lambda - \lambda')C_z^2 + \lambda^* C_{z2}^2\right\}$$

$$F = \left[\lambda C_p^2 + \lambda^* C_{p2}^2\right]$$

Then the value of F_1^* and F_2^* is given by

$$F_1^* = \frac{BE - AC}{A^2 - DE} \tag{2.11}$$

$$F_2^* = \frac{CD - AB}{A^2 - DE} \tag{2.12}$$

3. EFFICIENCY COMPARISON

In this section we are comparing the minimum MSE of the proposed estimators t_1 and t_2 with usual estimator p*.

$$V(p^*) - MSE(t_1)_{\min} = \frac{B^2}{D} \geq 0 \tag{3.1}$$

$$V(p^*) - MSE(t_2)_{\min} = \frac{(AB - CD)^2}{D(DE - A^2)} - \frac{B^2}{D} \geq 0 \tag{3.2}$$

$$MSE(t_1)_{\min} - MSE(t_2)_{\min} = \frac{(AB - CD)^2}{D(DE - A^2)} \geq 0 \tag{3.3}$$

4. EMPIRICAL STUDY

To illustrate the performance of various estimators of P we consider the following data sets.

Population I: [Source: Sarjinder Singh (2003), p. 1116].

ψ : More than 1000 Fishes caught in year 1995, *x*: Fish caught in year 1993, *z*: Fish caught in year 1994,

N=69, n'=40, n=30, W_2=0.20,

$\bar{X}$=4591.073, P=0.710, $\bar{Z}$=4954.435, $\bar{X}_2$=4785, P_2=0.5, $\bar{Z}_2$=4958,

$C_x = 1.376$, C_p=0.644, C_z=1.425, C_{x2}=1.995, C_{p2}=0.757, C_{z2}=2.064,

$\rho_{px} = 0.4036$, $\rho_{pz} = 0.3973$, $\rho_{xz} = 0.9729$, $\rho_{px2} = 0.4423$, $\rho_{pz2} = 0.4101$, $\rho_{xz2} = 0.9934$.

Population II: [Source: Murthy (1967), p. 266].

ψ : proportion of output more than 4500, x: Number of workers more than 400, z: Fixed capital,

N=80, n'=50, n=32, W_2 =0.25,

$\bar{X}$ =285.13, P=0.59, $\bar{Z}$ =1126.46, $\bar{X}_2$=418.65, P_2=0.65, $\bar{Z}_2$ =1544.65,

$C_x = 0.948$, C_p =0.843, C_z =0.751, C_{x2} =1.231, C_{p2} =0.829, C_{z2} =0.933,

$\rho_{px} = 0.634$, $\rho_{pz} = 0.664$, $\rho_{xz} = 0.988$, $\rho_{px2} = 0.664$, $\rho_{pz2} = 0.686$, $\rho_{xz2} = 0.992$.

Table 4.1
PRE's and MSE's of Various Estimators w.r.t. P*

h		Population I			Population II		
		p*	t_1	t_2	p*	t_1	t_2
2	PRE	100.00	112.65	113.29	100.00	141.83	150.43
	MSE	0.0059	0.0052	0.0051	0.0065	0.0046	0.0043
3	PRE	100.00	115.32	117.10	100.00	148.50	158.41
	MSE	0.0078	0.0068	0.0067	0.0084	0.0056	0.0053
4	PRE	100.00	116.99	119.81	100.00	153.17	163.96
	MSE	0.0097	0.0083	0.0081	0.0103	0.0067	0.0063
5	PRE	100.00	118.15	121.15	100.00	156.61	168.06
	MSE	0.0116	0.0099	0.0096	0.0121	0.0077	0.0072

Increasing value of h decreases the sub sample size which results in increase of MSE of the estimators. From Table 4.1 it is clear that the estimators t_1 and t_2 are more efficient than $p*$ for different values of h. MSE of t_1 and t_2 increases with increase in h. Further, it is observed that PRE's of the estimator t_1 and t_2 increases as h increases. It is also observed that there is highly increases in PRE of the estimator t_2 compared to the estimator t_1 as h increases, which shows that the addition of an auxiliary information in t_2 has greater role among the estimators in increasing the efficiency as compared to t_1.

5. CONCLUSION

In this paper, we have proposed an estimator for estimating the population mean using one/two auxiliary variables in the presence of non response under two phase sampling when the study variable itself is qualitative in nature. The performance of the proposed estimator was assessed using two population data sets. From Table 4.1 it is clear that the proposed estimator t_2 has greater role among the estimators in increasing the efficiency as compared to t_1. Hence it is recommended for use in practice.

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